Determining the Primary Drivers of Liking to Predict Consumers' Acceptance of Fresh Nectarines and Peaches

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Abstract: A generic descriptive analysis using 11 judges provided 16 sensory attributes that described the aroma, flavor, and texture characteristics of 7 nectarine and peach cultivars selected for their predominant sensory attributes. Simultaneously, the "in-store" acceptability of these cultivars was evaluated by 120 consumers from northern California. The relationships among instrumental measurements (flesh firmness, ripe soluble solids concentration (RSSC), and ripe titratable acidity (RTA), sensory panel descriptors, and consumer hedonic responses were studied. In these cultivars, RSSC was the only instrumental measurement significantly related to overall liking. Cultivars with medium acidity and/or flavor/aroma were liked "very much," and consumer willingness to pay more was correlated with overall liking without regard to cultivar. Cluster analysis revealed 3 segments that were associated with ethnicity and consumer preferences within each segment. Sweetness was the main driver of liking for 2 consumer clusters; however, for the 3rd cluster, the perception of fruit aromas described as grassy/green fruit and pit aromas were the main drivers of liking. There was a high correlation between instrumental measurements and their sensory perception; however, the sensory attribute measurements explained cultivar characteristics better than instrumental measurements alone. Sweetness correlated positively with overall liking and consumer acceptance.

Keywords: consumer studies, descriptive analysis, drivers of liking, fruit sensory attributes, instrumental quality

Practical Application: The main objective of this study was to identify drivers of liking for fresh peaches and nectarines in order to understand consumer preferences for these fruits. This information can be used by postharvest researchers to evaluate the potential of new postharvest technologies and consumer acceptance and for plant breeders to develop new cultivars with desirable sensory attributes driven by the consumer.

Introduction

Despite increasing knowledge of the health benefits of eating fruits and vegetables, consumption of some tree fruit commodities in the United States, such as peaches, nectarines, and plums, has been static. Since 1980, consumption has averaged 5.5 pounds per capita per year (USDA Economic Research Data 2009). A recent consumer quality survey of 1552 consumers (Sterling-Rice Group 2006) corroborates previous survey results (Bruhn 1995), concluding that lack of flavor and chilling injury symptoms are still the main barriers restricting California peach, nectarine, and plum purchasing in the U.S. market. Some researchers have tried to predict tree fruit consumer acceptance and/or preference using fruit physicochemical quality measurements at harvest, such as soluble solids concentration (SSC) for overall sweetness, penetration force for firmness-texture, and titratable acidy (TA) for sourness (Crisosto and others 2003). A similar approach was used in Italy (Esti and others 1997) and Slovenia (Colaric and others 2005) to predict consumer quality. However, most of these studies did not attempt to relate these measurements to consumer responses. Other groups have attempted to evaluate the efficacy of such physicochemical measurements to explain consumer responses to apples (Hoehn and others 2003), pears (Predieri and Gatti 2009), pineapples (Schulback and others 2007), mangos (Malundo and others 2001), blueberries (Saftner and others 2008), and oranges (Obenland and others 2009). In some instances, fruit physicochemical measurements were related to consumers' hedonic ratings or acceptance percentages (Crisosto and Crisosto 2001; Crisosto and others 2003, 2004, 2005; Guerra and others 2009; Gunness and others 2009). Despite general agreement that measured soluble sugars and/or organic acid concentrations are key components in predicting consumer acceptability of fresh fruits, other fruit quality characteristics also affect liking. In peaches, fruit firmness, color, and aroma were important characteristics consumers used to evaluate fruit quality when selecting fruit to purchase (Bruhn and others 1991; Bruhn 1995). These physicochemical measurements and sensory techniques can be used by the industry to evaluate the potential effect of new postharvest technologies on consumer acceptance; by shippers to evaluate current postharvest practices; by retail managers to validate their handling practices; and by plant breeders to develop new cultivars with desirable sensory attributes. Although significant correlations have been reported between physicochemical parameters measured instrumentally and sensory properties/hedonic scores

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(Rossiter and others 2000; Colaric and others 2005; Crisosto and Crisosto 2005), these correlations usually do not predict consumer behavior well. Despite the expense of consumer tests, they are more effective in predicting consumer behavior (Bett 2002; Harker and others 2008; Saftner and others 2008). In an ideal situation, researchers should simultaneously use physical instrumental fruit quality measurements and sensory methodology to evaluate consumer responses; however, because of budget constraints, fast rotation, intensive preparation, and/or limited quantities of fruit available, it is not always possible to conduct sensory evaluations. Information regarding the sensory characteristics of selected fruit cultivars (product information/characteristics) is usually obtained through descriptive analysis, while consumer tests indicate how much those fruit cultivars are liked. Preference mapping techniques are well known for their use in the sensory field to relate sensory and consumer data with the purpose of identifying the drivers of liking (Lawless and Heymann 2010; Yenket and others 2011). Both internal and external preference mappings provide a relationship between consumer preference data and sensory properties; van Kleef and others (2006) indicated that external preference mapping is more useful in understanding the differences in preferences from the product point of view, while internal preference mapping is more appropriate to understand consumers' preferences.

L-PLS analysis is a relatively new technique based on partial least square regression (PLS) used to characterize 3 different datasets: the sensory attributes [X], consumers' liking [Y], and consumers' information [Z] to identify demographic differences among consumers (Lengard and Kermit 2006).

Several researchers have explored the relationship between instrumental measurements, sensory properties, and consumer perception in other fruit commodities, for example: apples (Daillant-Spinnler and others 1996; Kühn and Thybo 2001; Harker and others 2002, 2003, 2008; Oraguzie and others 2009), tomatoes (Lee and others 1999; Causse and others 2010; Sinesio and others 2010), and strawberries (Ares and others 2009). We believe that the recent release and marketing of tree fruit cultivars with different flavors and the establishment of ripening protocols (Crisosto 1999) justify the expense of developing drivers of liking for tree fruit. Thus, the main goal of this study was to identify drivers of liking for fresh nectarines and peaches that predict consumer acceptance and/or preferences for these fruits during postharvest handling.

Materials and Methods

Cultivar selection and fruit preparation

Seven peach and nectarine cultivars were selected for this study for their commercial importance, differences in titratable acidity, flavor, and aroma, and similar melting flesh texture after ripening (Table 1). "August Pearl" is a low acid, white flesh nectarine; "Fire Sweet," a medium acid, flavorful, yellow flesh nectarine; "August Bright," a high acid, yellow flesh nectarine; "Autumn Snow," a low acid, white flesh peach; "Ryan Sun," a medium acid, yellow flesh peach with balanced sensory attributes; "O'Henry," a medium acid, flavorful, yellow flesh peach; and "Summer Lady," a medium acid, sweet, yellow flesh peach. The cultivars were selected based on their previously determined sensory attributes (Crisosto and others 1998, 2006; Crisosto and Crisosto 2005). For each cultivar, fruits were harvested at peak size and California Well-mature for that cultivar from commercial orchards in Fresno Co., Reedley, Calif., U.S.A., then held at 0 °C (85% RH) for up to 10 d, except for "Summer Lady," which was held at 5 °C (85% RH) prior to ripening to induce onset of chilling injury (Crisosto and Labavitch 2002). The same fruit from each cultivar was used for both descriptive analysis and the consumer study.

Instrumental fruit quality measurements

Fruits were ripened in a temperature-controlled room at 20 °C (85% RH) until a subsample reached a flesh firmness of $\leq$ 17.8 N as described (Crisosto 1999). On the day of the descriptive analysis session or "in-store" consumer study, a 2-cm-diameter piece of skin was removed from 1 cheek of each ripened fruit of the cultivar to be tested and the flesh firmness (penetration force) was measured with a UC firmness tester (Western Industrial Supply, San Francisco, Calif.) equipped with an 8 mm tip. If the fruit was ripe ($\leq$ 17.8 N flesh firmness), a numerical code was written on the tip of the fruit and the flesh firmness recorded. A sample consisted of 1 longitudinal slice cut from the stem end to the blossom end on the cheek opposite that on which flesh firmness was measured (Crisosto and Crisosto 2005). In addition, a longitudinal wedge was removed from the same area as the flesh firmness measurement, placed between 2 layers of cheesecloth, and the juice expressed for subsequent SSC and titratable acidity (TA) measurements. The SSC of the juice was measured with a digital temperature-compensated refractometer (model PR-32α, Atago Co., Tokyo, Japan). TA was measured with an automatic titrator (TitraLab®850, Radiometer Analytical, Copenhagen, Denmark) and expressed as percent malic acid.

Generic descriptive analysis

A generic descriptive analysis (Lawless and Heymann 2010) was used to identify sensory descriptors for fresh nectarines and peaches. The panel consisted of 11 judges (6 women and 5 men) with an average age of 32 y. Each judge completed 8 training sessions. The first 2 sessions covered the development of the language; 4 sessions were intended to achieve concept alignment, provide references, eliminate similar terms or ambiguities, and perfect use of the scale; and the last 2 sessions evaluated the judges' agreement and understanding of the attributes. FIZZ software (Biosystèmes, Counternon, Dijon, France) was used to build an automated session. Sixteen attributes were defined by the panel using standards (Table 2) and evaluated using a continuous, unstructured 10-cm line scale anchored at the ends by low and high intensity, except for firmness, which was anchored by soft and hard, and crunchy, which was anchored by not and very. Samples were evaluated in triplicate with one single fruit used for each judge. The order of presentation of the samples was randomized using a Latin square design provided by the FIZZ software.

"In-Store" consumer study

One hundred twenty consumers who reported eating fresh nectarines/peaches participated in the study. The experiment was conducted at a major supermarket in Davis, California. Each consumer evaluated 7 samples; the experimental design was a Williams Latin square design provided by the FIZZ software. One fruit sample per cultivar was evaluated by each consumer using a written questionnaire. For each nectarine or peach sample, consumers expressed their overall liking using the 9-point hedonic scale (Peryam and Pilgrim 1957). Consumer acceptance was calculated as a percentage of the number of consumers who liked the sample (score $>$ 5) divided by the total number of consumers within that sample. In a similar manner, the percentage of consumers who disliked the sample (score $<$ 5) and neither liked nor disliked (score $=$ 5)

Table 1–Codes, means (X), and standard deviations (S.D.) of flesh firmness, RSSC, and RTA for nectarine and peach cultivars evaluated in the descriptive analysis and consumer study.

					Firmness (*N*)		RSSC (%)		RTA (%)	
Fruit	Cultivar	Type[A]	Cultivar code	Flesh color	X	S.D.	X	S.D.	X	S.D.
Nectarine	Fire Sweet	N-F	FS	Yellow	14.6	0.8	13.4	1.2	0.31	0.04
	August Bright	N-HA	AB	Yellow	12.8	0.7	11.8	1.2	0.77	0.08
	August Pearl	N-LA	AP	White	18.0	1.0	13.1	1.2	0.24	0.04
Peach	O'Henry	P-F	OH	Yellow	15.0	0.8	10.0	1.1	0.49	0.07
	Ryan Sun	P-MA	RS	Yellow	17.7	1.2	10.8	1.4	0.48	0.07
	Autumn Snow	P-LA	AS	White	17.5	1.5	12.6	1.2	0.21	0.04
	Summer Lady	P-SM	SL	Yellow	6.3	0.5	12.0	1.1	0.51	0.07

[A]N-F = nectarine flavorful, N-HA = nectarine high acidity, N-LA = nectarine low acidity, P-F = peach flavorful, P-MA = peach medium acidity, P-LA = peach low acidity, P-SM = peach slightly mealy.

Table 2–Sensory attribute definitions and standards used for training the descriptive analysis panel to evaluate nectarine and peach cultivars.

Attributes	Description	Standard
Overall aroma	Intensity of aroma (whole aroma)	Verbal description
Floral	Smell of flowers	Nectarine cultivars
Almond	Smell of almonds	1% Artificial flavor (McCormick) over 50 g of peach/nectarine paste[A]
Grassy/green fruit	Smell of grass associated with unripe fruit	0.01 g over 50 g of peach/nectarine paste[A]
Pit	Woody aroma associated with fruit with traces of pit	10 pits were removed from the fruit and used as a standard
Overall flavor	Intensity of flavor (whole flavor)	Verbal description
Sweet	Sweet taste, example sucrose solution	Sucrose solutions 0 to 50 g/L in spring water Fruit with different soluble solids concentrations ranging from 8% to 16%
Sour	Sour taste, example citric acid solution	Citric acid solutions 0 to 1.5 g/L in spring water Fruit with different titratable acidities ranging from 0.2% to 0.8%
Bitter	Bitter taste, example like coffee	Caffeine solutions 0.7 to 2.5 g/L
Firmness	Flesh only: measured at the first bite ranging from soft to hard	Fruit with different firmness, ranging from 4.4 to 44.4 N
Crunchy	Flesh only: making a crunching sound when chewed or pressed	Verbal description
Juicy	Flesh only: amount of liquid	Verbal description
Mealy	Gritty, sandy texture, dry not juicy	Verbal description Fruit with different degrees of mealiness
Melting	How easy to fracture into mouth (high melting examples ice cream and chocolate)	Verbal description and use of ice cream and chocolate to explain concept
Smooth	Texture of the fruit related to having a continuous even surface	Verbal description
Fibrous	After first 2 bites, amount of fibers in the sample	Verbal description

[A]A paste (50/50) peach/nectarine was prepared as base.

that sample was calculated. Consumers were asked to rate their willingness to purchase the sample tested if available at the market using a 5-point scale (1 = definitely would not buy it; 3 = neither would not buy it, nor would buy it; 5 = definitely would buy it), and the likeliness that they would consume the sample for a second time using a 5-point scale (1 = certainly will not consume this peach/nectarine again; 3 = not sure or undecided; 5 = certainly will consume this peach/nectarine again). Finally, consumers were asked, as an open-ended question, to provide a price for a pound of the fruit they had just tasted they would be willing to pay. To understand how the overall liking was related to purchase intent, a 2nd consumption, and the price willingness to pay, the data were filtered according to overall liking to examine how these variables changed when consumers disliked the product (score < 5), neither liked nor disliked the product (score $= 5$), or liked the product (score > 5). At the supermarket, the samples were prepared in the produce room out of sight of the testing area as described in Crisosto and Crisosto (2005).

Statistical analysis

The majority of the statistical analyses were executed using SAS version 9.1 (SAS Institute, Cary, N.C., U.S.A.). To understand the relationships between physicochemical measurements, sensory attributes, and consumer hedonic ratings, univariate analysis (correlation, analysis of variance, and Fisher's LSD multiple mean comparisons) and multivariate analysis (canonical variate analysis (CVA), MANOVA, and preference mapping) were performed. Principal component analysis (PCA) was conducted using SensomineR module on R-software (open-source software). Consumer segments were determined using cluster analysis on overall liking. Cluster analysis was performed with XL-Stat Version 2009.3.02. The Unscrambler version 9.8 was used to perform block partial least square regression (L-PLS) analysis.

Results and Discussion

Instrumental fruit quality measurements

RSSC varied from 10% to 13.4% and RTA ranged between 0.21% and 0.77% in the ripe fruit (Table 1). In general, peaches had lower RSSC than nectarines and RTA varied among cultivars. Among the nectarines, white-fleshed "August Pearl" and yellow-fleshed "Fire Sweet" had low RTAs (approximately 0.30%), while yellow-fleshed "August Bright" had a high RTA (0.77%). "Autumn Snow," a white-fleshed peach, had the lowest RTA (0.21%) and the yellow-fleshed peaches "O'Henry," "Summer Lady," and "Ryan Sun" had medium RTAs (0.50%). Our previous 10 y of surveys indicated that RSSC is more variable than RTA for a given cultivar over years or locations. Orchard management and environmental conditions have a strong effect on RSSC but less on RTA. We observed larger changes in fruit TA than in SSC during ripening on and off the tree. RTA measurements reported here are similar to those measured in previous surveys. RTA values reported here for "August Bright" nectarine (0.77%) and "Summer Lady," "O'Henry," and "Ryan Sun" (approximately 0.50%) peaches were somewhat lower than previously reported for mature fruit (approximately 0.60% to 0.80%). These differences in RTA are explained by loss of fruit acidity during ripening.

Generic descriptive analysis

Sixteen attributes were defined by the judges to describe the sensory characteristics of the 7 nectarine and peach cultivars (Table 2). These attributes were evaluated through a 3-way ANOVA (judges, cultivars, replications, and all 2-way interactions). The ANOVA F-ratios confirmed that the panel performance was satisfactory (data not shown). The replication effects were not significant ($P > 0.05$) for the majority of attributes evaluated, except for firmness, crunchy, juicy, and melting. Given the complexity of fresh nectarines and peaches, this difference may be more due to variation in the fruit than to variation among judges. This explanation was confirmed because the replication per cultivar interaction was significant, indicating that there was some variation in the fruit that is reflected in the replication effect. Chilling injury symptoms such as mealy-woolly texture develop in specific areas in the fruit. Despite "Summer Lady" peaches having the highest mealy texture score, "Summer Lady" also had the highest overall, grassy/green fruit, and pit aromas; bitter taste; and melting and fibrous textures. This cultivar also had moderate sweetness and sourness, and the least floral aroma, firmness, and crunchy attributes among the cultivars. "August Pearl" nectarine had the highest floral aroma (Table 3). There were no significant differences in the sweetness of "Autumn Snow" peach and "August Pearl" and "Fire Sweet" nectarines, which had the highest sweetness scores. The sourest cultivar was "August Bright" nectarine, followed by "Ryan Sun" and "O'Henry" peaches; the descriptive panel was able to detect some minimal bitterness in these cultivars, highest for "Ryan Sun," "Summer Lady," and "O'Henry" peaches. "August Bright" and "Fire Sweet" nectarines had the firmest flesh. Even though care was taken to follow recommended postharvest ripening practices for stone fruit, these cultivars still may behave differently during ripening and exhibit slight differences in texture. Differences in texture perception have also been observed in blueberries at different ripeness (Saftner and others 2008). The 3 nectarine cultivars exhibited no significant differences in crunchy texture, which is

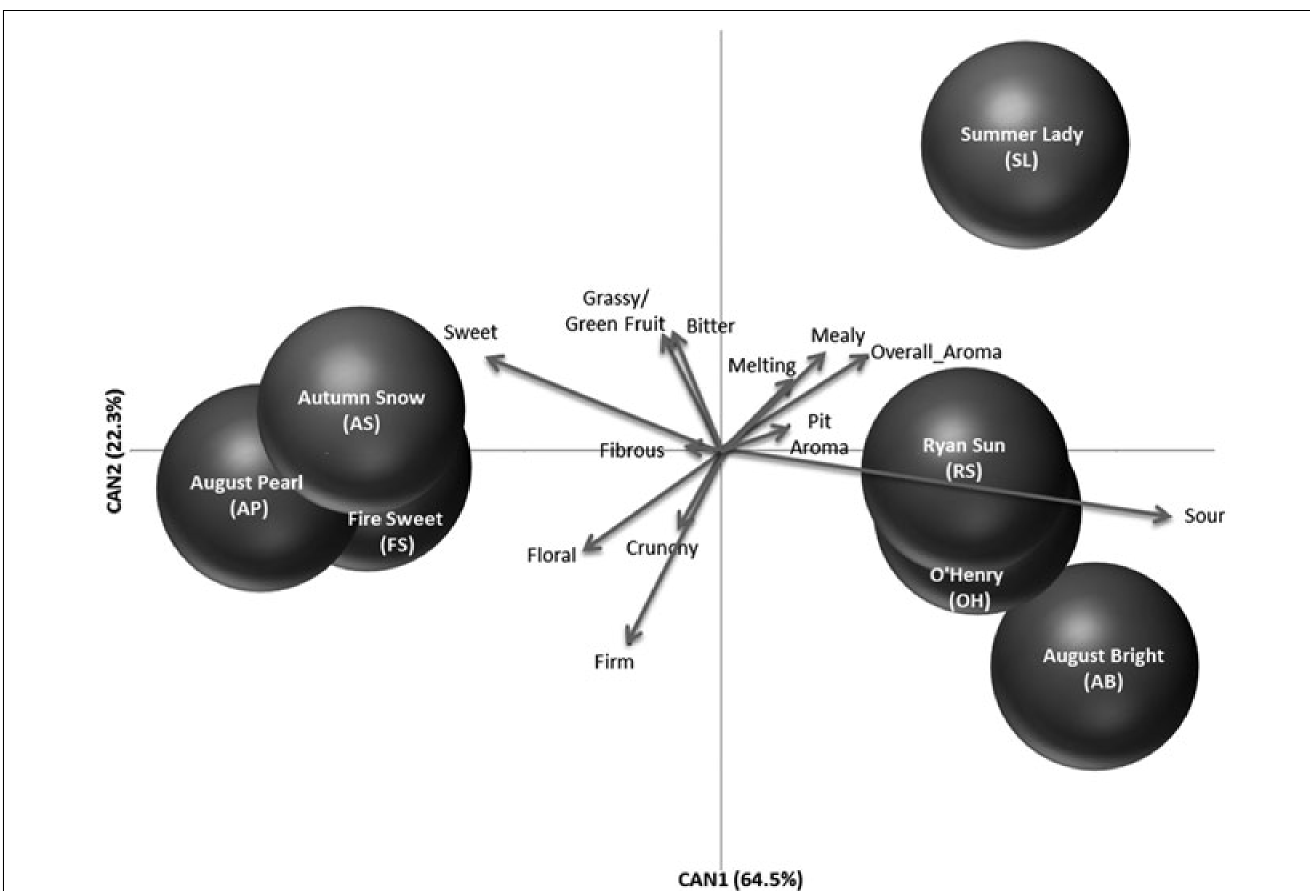

Figure 1–CVA for 7 fresh nectarine and peach cultivars.
Each sphere represents a cultivar * (refer to Table 1 for cultivar descriptions). There is no significant difference between cultivars ($P < 0.05$) when 2 spheres overlap. Attributes are represented by vectors.
*Cultivar type (cultivar): N-F = nectarine flavorful ("Fire Sweet"), N-HA = nectarine high acidity ("August Bright"), N-LA = nectarine low acidity ("August Pearl"), P-F = peach flavorful ("O'Henry"), P-MA = peach medium acidity ("Ryan Sun"), P-LA = peach low acidity ("Autumn Snow"), P-SM = peach slightly mealy ("Summer Lady").

Table 3–Overall means for the significant sensory attributes of aroma, taste, and texture for 7 nectarine and peach cultivars.

Aroma attributes

Overall		Floral		Grassy/green fruit		Pit	
Cultivar type[A]	Mean	Cultivar type	Mean	Cultivar type	Mean	Cultivar type	Mean
P-SM	5.4 a[B]	N-LA	4.2 a	P-SM	2.5 a	P-SM	2.9 a
P-F	4.6 ab	N-HA	3.1 b	P-F	2.1 ab	P-F	1.9 b
N-LA	4.5 b	P-MA	2.9 b	N-F	1.7 cb	N-HA	1.7 b
N-HA	4.4 cb	P-LA	2.7 b	N-HA	1.4 cbd	N-F	1.5 bcd
P-MA	4.4 cb	N-F	2.5 b	P-MA	1.3 cd	P-MA	1.3 cd
N-F	3.7 cd	P-F	2.4 b	N-LA	1.0 cd	P-LA	0.9 cd
P-LA	3.3 d	P-SM	2.4 b	P-LA	0.9 d	N-LA	0.8 d
LSD	0.78	LSD	0.83	LSD	0.68	LSD	0.61

Taste attributes

Sweet		Sour		Bitter	
Cultivar type	Mean	Cultivar type	Mean	Cultivar type	Mean
P-LA	5.3 a	N-HA	6.0 a	P-MA	1.3 a
N-LA	5.1 a	P-MA	4.6 b	P-SM	1.2 ab
N-F	4.9 a	P-F	4.6 b	P-F	1.0 abc
P-SM	3.6 b	P-SM	3.7 c	P-LA	0.8 bc
P-MA	3.0 bc	P-LA	1.3 d	N-F	0.7 bc
N-HA	2.7 c	N-F	1.3 d	N-LA	0.6 c
P-F	2.4 c	N-LA	0.8 d	N-HA	0.5 c
LSD	0.69	LSD	0.68	LSD	0.51

Texture attributes

Firmness		Crunchy		Mealy		Melting		Fibrous	
Cultivar type	Mean	Cultivar type	Mean	Cultivar type	Mean	Cultivar type	Mean	Cultivar type	Mean
N-HA	4.6 a	N-HA	3.6 a	P-SM	2.2 a	P-SM	6.8 a	P-SM	4.8 a
N-F	4.1 ab	N-LA	3.3 a	N-LA	1.3 b	P-LA	4.7 b	N-LA	4.6 ab
N-LA	3.8 cb	N-F	3.0 a	N-HA	1.1 bc	P-MA	4.4 b	P-F	4.4 ab
P-F	3.6 cbd	P-F	2.3 b	N-F	1.1 bc	N-LA	3.8 bc	P-LA	4.4 ab
P-LA	3.2 cd	P-LA	1.9 b	P-LA	0.8 bc	N-F	3.8 bc	N-HA	4.3 abc
P-MA	3.0 d	P-MA	1.9 b	P-MA	0.8 bc	P-F	3.8 bc	P-MA	3.8 bc
P-SM	1.2 e	P-SM	1.0 c	P-F	0.5	N-HA	3.4 c	N-F	3.4 c
LSD	0.63	LSD	0.68	LSD	0.68	LSD	0.97	LSD	0.95

[A]Cultivar type: N-F = nectarine flavorful, N-HA = nectarine high acidity, N-LA = nectarine low acidity, P-F = peach flavorful, P-MA = peach medium acidity, P-LA = peach low acidity, P-SM = peach slightly mealy.
[B]Same letters within the same column indicate no significant difference between means $P < 0.05$.

somewhat expected because the nectarine cultivars were also the firmest cultivars. Other authors have found an association between firmness and crunchiness in processed tomatoes (Lee and others 1999) and kiwifruit (Stec and others 1989). The highest means for mealy, melting, and fibrous textures were found in "Summer Lady" peach, which makes sense because this cultivar was held at a different temperature than the rest (5 °C) to induce mealy texture. We believe that the low floral and high grassy/green fruit and pit aromas, combined with high mealiness and low firmness and crunchy textures detected in "Summer Lady," were the onset of chilling injury symptoms detected by the judges.

A CVA was conducted to understand sensory similarities and differences among the 7 cultivars and characterize their significant sensory attributes (Figure 1). The variance explained corresponds to 64.5% on the x-axis and 22.3% on the y-axis. There was a significant simultaneous effect among all attributes and cultivars (MANOVA, Wilks' Lambda, $F = 9.06$; df 72, $P < 0.05$). Sour, sweet, floral aroma, overall aroma, and mealy were the main attributes associated with the first dimension (CV1), while firmness, grassy/green fruit aroma, and bitterness were the attributes related to the 2nd dimension (CV2). Pit aroma, fibrous, and melting have short vectors, an indication of low discrimination for these attributes. "Autumn Snow" peach was defined as sweet and fibrous, with some grassy/green fruit aroma, and not sour or mealy. "August Pearl" and "Fire Sweet" nectarines were sweet, firm, crunchy, and not sour, with a floral aroma. "Ryan Sun" and "O'Henry" peaches and "August Bright" nectarine were defined mainly by their sour taste; the main difference among them was in firmness. "August Bright" was firmer, crunchier, and also had some floral aroma lacking in "Ryan Sun" and "O'Henry." "Summer Lady" did not cluster with any other cultivar and was characterized as melting and mealy, with the highest overall, grassy/green fruit, and pit aromas.

The relationship among sweetness, sourness, and firmness, measured both instrumentally and by a descriptive analysis panel, was studied using PCA. A correlation matrix was used to explain the relationship between the instrumental quality measurements and the descriptive panel sensory attributes measurements (Figure 2). The total variance explained was 46.4% on the x-axis and 28.4% on the y-axis. The PCA analysis demonstrated that the sensory attributes sourness, firmness, and sweetness were highly correlated with the instrumental measurements (RTA, firmness, and RSSC). The length of the vector indicates the discrimination among samples provided by a particular attribute; for example, firmness as rated by the descriptive panel and firmness as measured instrumentally have exactly the same length vector, indicating that both methods provide similar discrimination among samples. However, sweetness and sourness as rated by the descriptive panel had slightly longer vectors than those generated by RSSC and RTA; this may be an indication that sensory methods provide better discrimination and characterization among samples for these attributes.

"In-Store" consumer study

For this consumer population, there were no significant differences in the distribution of female and male ages ($P > 0.05$, chi-square test): 58% were female and 42% male. The average age was 33 y with a standard deviation of 17.5 y. Of the total population, 41% identified themselves as White-Caucasian, 36% as Asian-Asian American, 18% as Hispanic or Latino, 2% American Indian or Alaska Native, 1% Black-African American, 12% Mixed or other, and 9% preferred not to report their ethnicity. The consumption rate of nectarines and peaches for this consumer population was approximately equally distributed among once a month (23% nectarines, 24% peaches); 2 to 3 times a month (28% nectarines, 23% peaches); once a week (21% nectarines, 21% peaches), and 2 to 4 times a week (12% nectarines, 18% peaches). These consumption rates were low for when nectarines and peaches are in season; this supports reports that indicate a static consumption for nectarines and peaches since 1980 (USDA Economic Research Data 2009).

The 120 consumers differed in their preferences for the 7 cultivars (ANOVA $P < 0.05$). Pearson's correlations ($P \leq 0.05$) between overall liking for each cultivar and instrumental quality measurements of ripe SSC (RSSC), ripe titratable acidity (0.20% to 0.80% RTA), and flesh firmness (6.5 to 20.2 N) were not significant ($P > 0.05$), except for RSSC ($R^2 = 90.2$). Overall liking increased significantly from like slightly to like moderately (positive slope) as RSSC increased from 10.0% to 14.0%. Even though the relationship between RTA and overall liking was not significant, it had a negative slope, suggesting that cultivars with high acidity might be less preferred. The significant negative effect of high RTA on overall liking has been reported previously on fruit with RTA higher than 0.80% to 1.00% and RSSC lower than 12.0% (Crisosto and Crisosto 2001, 2005). The RTA for the tested cultivars ranged from 0.21% to 0.77%, which may explain the lack of significant correlation between hedonic scores and RTA measurements. The relationship between overall liking and flesh firmness had a flat slope and was not significant in any cultivar. This lack of relationship differs from other fruit commodities such as apples, where texture change is one of the most important drivers of liking (Harker and others 2008). However, all fruits tested here were ripened to a firmness penetration force of 6.3 to 17.8 N, considered "ready to eat" with maximum sensory potential based on our previous work (Crisosto and Crisosto 2005).

Since acceptance of these cultivars measured as a degree of liking was not affected by changes in RTA, and RSSC was the only significant instrumental measurement that may affect overall liking of nectarines and peaches, a detailed statistical analysis between RSSC and degree of liking was pursued. In general, degree of liking increased as RSSC increased and then reached a plateau (Table 4). Among the nectarine cultivars, RSSC did not affect degree of liking in this consumer population within each cultivar and consumer acceptance ranged from 65% to 91% (Table 4). Nectarines with predominant sensory characteristics of low acidity and/or flavor/aroma had high consumer acceptance percentages (72% to 91%) and were liked "moderately" to "very much" (6.6 to 7.7). Nectarines with high acidity were liked less (5.7 to 6.7) and less accepted (65% to 82%). In the nectarine cultivar with high acidity (approximately 0.80%), acceptance increased and rejection decreased for fruit with RSSC $\geq$ 12.0%. In the peach with low acidity, RSSC from 10.4% to 14.5% did not significantly affect degree of liking or acceptance. Rejection was around 17% and acceptance ranged from 67% to 84%. In peaches with predominant sensory characteristics of flavor or medium acidity, fruit with RSSC $<$ 9.0% had a low degree of liking (approximately 4.5) and acceptance (25% to 36%). For fruit with RSSC $\geq$ 9.0%, degree of liking increased for peaches with high flavor and for peaches with medium acidity reached a plateau above 9.0% RSSC. In this small population of consumers that tasted nectarines and peaches with predominant flavor and high RSSC, degree of liking and acceptance was very high (91%). This data also suggest that nectarines or peaches with very low acidity may have a low-potential consumer acceptance; however, this is affected by ethnicity (Crisosto and Crisosto 2002). It is important to point out that perception of flavor in peaches decreased and "off flavor" increased during cold storage as a consequence of chilling injury (Crisosto and Labavitch 2002; Infante and others 2009). In most cultivars, this flavor loss is faster when fruit is stored at 5 °C than at 0 °C. In this study, all cultivars were handled rapidly to avoid any onset of chilling injury except for "Summer Lady," in which onset of loss of flavor or "off flavor" development may have occurred.

A further detailed analysis of nectarine and peach cultivars by hedonic scale categories for purchase intent, price expectation, 2nd consumption, and RSSC was conducted (Table 5 and 6). In general, consumers were willing to pay more for fruit with a higher hedonic score; this trend was independent of the nectarine (Table 4) or peach (Table 5) cultivar. The same trends occurred for purchase intent and willingness to consume the fruit for a second time. Other researchers have found a correlation between over-

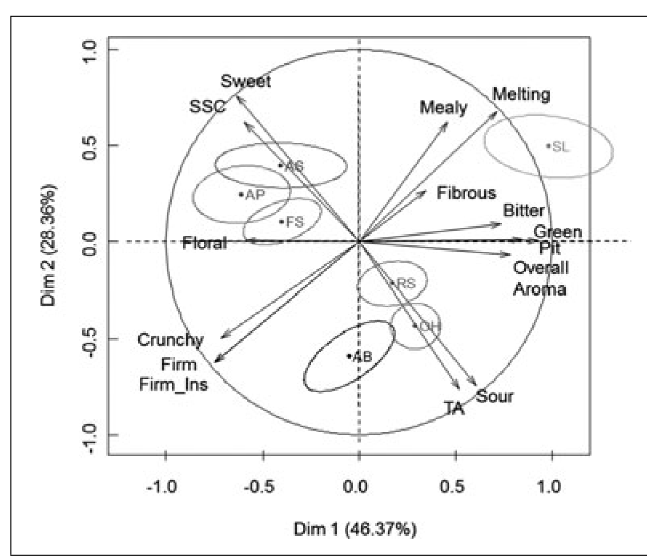

Figure 2–PCA by correlation of instrumental compared with descriptive variables.
Cultivars are represented by ellipses and attributes by vectors. Please refer to Table 1 for a full description of the samples. Cultivar type (cultivar): N-F = nectarine flavorful ("Fire Sweet"), N-HA = nectarine high acidity ("August Bright"), N-LA = nectarine low acidity ("August Pearl"), P-F = peach flavorful ("O'Henry"), P-MA = peach medium acidity ("Ryan Sun"), P-LA = peach low acidity ("Autumn Snow"), P-SM = peach slightly mealy ("Summer Lady").

Table 4–Degree of liking and consumer acceptance according to RSSC classes for different nectarine and peach cultivars and their corresponding instrumental measurements.

Cultivar type[A]	RSSC class (%)	*n*	Liking (1 to 9)[B]	Acceptance (%)	Neutral (%)	Rejection (%)	RSSC (%)	RTA (%)
N-LA	11 to 11.9	19	7.2 a[C]	84	5	11	11.6	0.26
	12 to 12.9	41	7.0 a	83	7	10	12.5	0.24
	13 to 13.9	39	7.1 a	82	15	3	13.4	0.24
	14 to >15	19	7.3 a	89	11	0	14.6	0.23
N-F	9.8 to 11.9	12	6.6 a	75	17	8	11.3	0.31
	12 to 12.9	25	6.6 a	72	16	12	12.5	0.31
	13 to 13.9	48	6.7 a	83	6	10	13.5	0.31
	14 to 14.9	24	7.0 a	88	4	8	14.2	0.31
	15 to >16	11	7.7 a	91	0	9	15.7	0.29
N-HA	10 to 10.9	31	5.7 a	65	3	32	10.4	0.75
	11 to 11.9	43	6.0 a	74	0	26	11.4	0.78
	12 to 12.9	28	6.7 a	82	0	18	12.3	0.80
	13 to >16	18	6.5 a	78	6	17	13.6	0.80
P-LA	<10 to 10.9	9	5.6 a	67	11	22	10.4	0.20
	11 to 11.9	34	6.4 a	71	12	18	11.6	0.20
	12 to 12.9	34	6.5 a	68	12	21	12.5	0.20
	13 to 13.9	31	6.7 a	84	6	10	13.4	0.20
	14 to <16	12	6.7 a	75	8	17	14.5	0.20
P-F	<9	22	4.8 a	36	23	41	8.5	0.47
	9 to 9.9	41	5.4 ab	59	7	34	9.3	0.47
	10 to 10.9	33	6.2 bc	76	6	18	10.4	0.49
	11 to 11.9	13	5.7 abc	62	8	31	11.4	0.54
	12 to <13	11	7.2 c	91	0	9	12.4	0.54
P-MA	<9	12	4.2 a	25	8	67	8.4	0.483
	9 to 9.9	25	6.0 bc	72	4	24	9.5	0.455
	10 to 10.9	34	5.4 ab	62	12	26	10.4	0.452
	11 to 11.9	28	6.3 bc	71	4	25	11.3	0.487
	12 to <15	21	6.6 c	71	19	10	12.7	0.472
P-SM	9 to 9.9	5	5.6a	60	20	20	9.5	0.5
	10 to 10.9	14	6.6a	71	7	21	10.5	0.5
	11 to 11.9	30	6.7a	80	3	17	11.5	0.5
	12 to <15	71	6.5a	78	4	18	12.8	0.5

[A]Cultivar type: N-F = nectarine flavorful, N-HA = nectarine high acidity, N-LA = nectarine low acidity, P-F = peach flavorful, P-MA = peach medium acidity, P-LA = peach low acidity, P-SM = peach slightly mealy.
[B]Degree of liking: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely.
[C]Same letters within the same column indicate no significant difference between means $P < 0.05$.

all liking and the price consumers would be willing to pay for specialty food such as extra virgin olive oil (Stefani and others 2006; Delgado and Guinard 2011) and consumers agreed to pay more when they liked cheeses (Napolitano and others 2010). These "in-store" consumer test results agreed with previous studies (Crisosto and others 2006), in which peaches and/or nectarines with predominant sensory attributes such as flavor and/or aroma had a slightly higher consumer acceptance (approximately 10%) than the standard ones. These results confirmed our previous sensory study and demonstrate that tree fruit degree of liking is associated with buying habits and even willingness to pay more. These results justify changes in orchard management to produce more

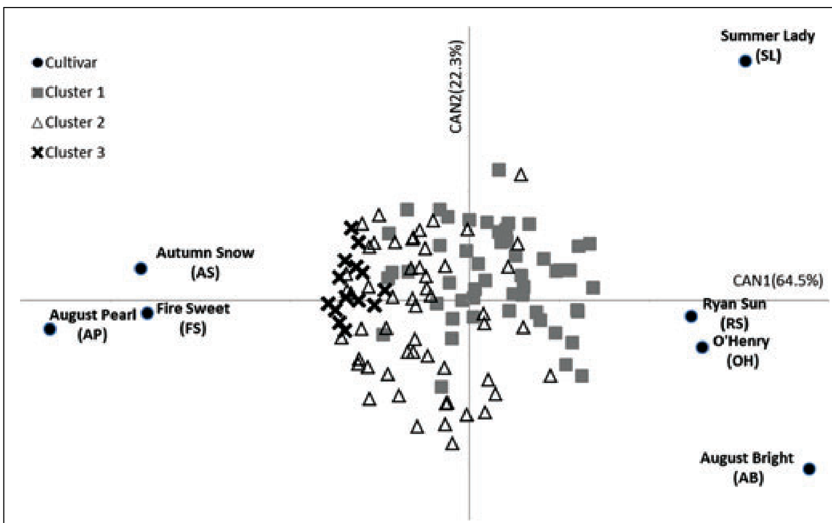

Figure 3–External preference mapping including consumer segments.
Cultivars are represented by solid circles. Please refer to Table 1 for a full description of the samples. Cultivar type (cultivar): N-F = nectarine flavorful ("Fire Sweet"), N-HA = nectarine high acidity ("August Bright"), N-LA = nectarine low acidity ("August Pearl"), P-F = peach flavorful ("O'Henry"), P-MA = peach medium acidity ("Ryan Sun"), P-LA = peach low acidity ("Autumn Snow"), P-SM = peach slightly mealy ("Summer Lady").
Solid squares indicate consumers in cluster 1 (n = 52). Consumers in cluster 2 (n = 54) are indicated by triangles, and in cluster 3 (n = 14) by crosses.

Table 5–Average of purchase intent, price expectation, 2nd consumption, and RSSC by degree of liking category (1 to 9) for nectarine cultivars by northern California consumers.

Cultivar type[A]	Degree of liking[B] (score)	Purchase Intent[C]	Price[D] ($)	Second consumption[E]	RSSC (%)
N-F	1.0	1.0 a[F]	0.00 a	1.0 a	12.7
	2.0	–	–	–	–
	3.0	2.0 a	0.40 a	2.0 a	13.1
	4.0	2.2 a	0.70 a	2.3 a	13.8
	5.0	3.1 b	0.60 a	3.0 b	12.6
	6.0	3.4 b	1.30 b	3.1 b	13.4
	7.0	3.9 c	1.30 b	3.9 c	13.3
	8.0	4.5 d	1.60 b	4.5 d	13.5
	9.0	4.8 d	1.60 b	4.9 d	14.3
	P-value	<0.0001	<0.0001	<0.0001	0.09
N-HA	1.0	1.0 a	0.00 a	1.0 a	11.5
	2.0	1.1 a	0.30 a	1.3 ab	11.8
	3.0	1.7 b	0.40 a	1.9 bc	11.6
	4.0	2.4 c	0.40 a	2.2 cd	10.8
	5.0	4.0 de	0.70 ab	3.0 de	11.8
	6.0	3.6 d	1.30 b	3.5 e	11.5
	7.0	3.8 d	1.40 b	3.9 e	11.8
	8.0	4.3 e	1.50 b	4.3 f	11.8
	9.0	4.9 f	2.50 c	4.8 g	12.5
	P-value	<0.0001	<0.0001	<0.0001	0.10
N-LA	1.0	–	–	-	–
	2.0	–	–	–	–
	3.0	2.3 ab	0.80 ab	1.9 a	11.8
	4.0	1.8 a	0.40 a	2.2 ab	12.6
	5.0	2.8 b	0.70 ab	3.0 bc	13.3
	6.0	3.1 b	1.10 b	3.5 c	13.1
	7.0	3.8 c	1.10 b	3.9 d	13.0
	8.0	4.5 d	1.70 c	4.3 e	13.1
	9.0	5.0 e	1.90 c	4.8 f	13.1
	P-value	<0.0001	<0.0001	<0.0001	0.49

[A]Cultivar type: N-F = nectarine flavorful, N-HA = nectarine high acidity, N-LA = nectarine low acidity, P-F = peach flavorful, P-MA = peach medium acidity, P-LA = peach low acidity, P-SM = peach slightly mealy.
[B]Degree of liking score: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely.
[C]Purchase intent: 1 = definitely would not buy, 2 = probably would not buy, 3 = neither would not buy, nor would buy, 4 = probably would buy, 5 = definitely would buy.
[D]Price willing to pay per pound of the sample tasted at retail.
[E]Second consumption: 1 = certainly will not consume this nectarine again, 2 = probably will not consume this nectarine again, 3 = not sure or undecided, 4 = probably will consume this nectarine again, 5 = certainly will consume this nectarine again.
[F]Same letters within the same column indicate no significant difference between means. *P*-value from 1 factor ANOVA.

Table 6–Average of purchase intent, price expectation, 2nd consumption, and RSSC by degree of liking category (1 to 9) for peach cultivars by northern California consumers.

Cultivar Type[A]	Degree of liking[B] (score)	Purchase Intent[C]	Price[D] ($)	Second consumption[E]	RSSC (%)
P-F	1.0	1.0 a[F]	0.00 a	1.0 a	9.9 ab
	2.0	1.4 a	0.10 a	1.4 a	9.9 ab
	3.0	2.0 b	0.40 a	1.7 ab	9.6 ab
	4.0	2.2 b	0.50 a	2.1 b	9.5 ab
	5.0	2.9 c	0.70 ab	3.0 c	9.3 a
	6.0	3.1 c	1.00 bc	3.0 c	9.8 ab
	7.0	3.9 d	1.40 cd	3.9 d	10.1 bc
	8.0	4.3 e	1.60 d	4.2 de	10.6 cd
	9.0	5.0 f	1.5cd	4.8 e	11.8 d
	P-value	<0.0001	<0.0001	<0.0001	0.001
P-MA	1.0	1.0 a	0.10 a	1.0 a	10.5 ab
	2.0	1.1 a	0.40 ab	1.6 a	9.4 a
	3.0	1.8 b	0.30 a	1.5 a	10.3 ab
	4.0	2.3 b	0.80 abc	2.4 b	10.3 ab
	5.0	2.8 c	0.80 abc	2.6 b	11.3 b
	6.0	3.3 d	0.90 bc	3.4 c	10.3 ab
	7.0	3.6 d	1.20 c	3.7 c	10.8 b
	8.0	4.6 e	1.70 d	4.4 d	11.2 b
	9.0	5.0 e	2.00 d	5.0 d	10.6 ab
	P-value	<0.0001	<0.0001	<0.0001	0.03
P-LA	1.0	1.0 a	–	3.0 cd	13.1
	2.0	2.0 ab	0.30 ac	1.5 ab	12.7
	3.0	1.2 a	0.20 ab	1.3 a	11.8
	4.0	1.9 a	0.60 bc	2.2 bc	12.5
	5.0	2.7 bc	0.80 bc	2.6 c	12.4
	6.0	3.0 c	0.90 c	3.2 d	12.3
	7.0	3.6 d	1.50 d	3.9 d	12.6
	8.0	4.5 e	1.30 d	4.7 e	12.5
	9.0	4.8 e	2.0 e	4.9 e	12.9
	P-value	<0.0001	<0.0001	<0.0001	0.74
P-SM	1.0	1.0 a	0.0 a	1.0 a	10.9
	2.0	1.0 a	0.1 ab	1.0 a	12.2
	3.0	1.8 b	0.1 ab	1.8 b	12.1
	4.0	2.4 c	0.7 bcd	2.7 c	11.7
	5.0	2.5 c	0.8 cde	3.0 cd	11.4
	6.0	3.2 d	1.0 de	3.5 d	11.9
	7.0	3.9 e	1.4 e	3.9 e	12.2
	8.0	4.4 f	1.7 f	4.5 f	12.2
	9.0	4.8 g	2.0 f	4.7 f	11.8
	P-value	<0.0001	<0.0001	<0.0001	0.42

[A]Cultivar type: N-F = nectarine flavorful, N-HA = nectarine high acidity, N-LA = nectarine low acidity, P-F = peach flavorful, P-MA = peach medium acidity, P-LA = peach low acidity, P-SM = peach slightly mealy.
[B]Degree of liking score: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely.
[C]Purchase intent: 1 = definitely would not buy, 2 = probably would not buy, 3 = neither would not buy, nor would buy, 4 = probably would buy, 5 = definitely would buy.
[D]Price willing to pay per pound of the sample tasted at retail.
[E]Second consumption: 1 = certainly will not consume this nectarine again, 2 = probably will not consume this nectarine again, 3 = not sure or undecided, 4 = probably will consume this nectarine again, 5 = certainly will consume this nectarine again.
[F]Same letters within the same column indicate no significant difference between means. *P*-value from 1 factor ANOVA.

fruit with high RSSC and selection of cultivars with predominant sensory attributes by plant breeders during cultivar development and growers for future plantings (Crisosto and others 1997).

Preference mapping techniques were selected to study the relationship between the sensory properties and the hedonic responses. The descriptive analysis ratings were analyzed through a CVA; a detailed explanation is given in the "Generic Descriptive Analysis" section. Then, consumer's hedonic scores were regressed into the CVA space to understand how the consumer data are related to the fruit cultivar's sensory properties (external preference mapping). To further understand the preferences for this consumer population, cluster analysis (Wards Method, Euclidean distance) revealed 3 segments among the consumer population (Figure 3). Each consumer is represented by a square (cluster 1), triangle (cluster 2), or cross (cluster 3). Fruit cultivars are indicated as solid circles. More consumers (square, triangle, or cross depending on the cluster) associated with a fruit cultivar indicate a higher preference for the fruit cultivar. Consumers in cluster 1 (n = 52) preferred "O'Henry" peaches and "August Bright" nectarines. Cluster 2 (n = 54) and cluster 3 (n = 14) were similar: consumers in both clusters liked "August Pearl" and "Fire Sweet" nectarines and "Autumn Snow" peaches. However, while consumers in cluster 2 accepted cultivars that were mainly characterized by sourness, consumers in cluster 3 did not like these sour cultivars at all. Verification of the differences among clusters was accomplished by 1-way ANOVA applied to overall liking on each cluster per cultivar with the exception of "Fire Sweet" nectarine, which had no difference in liking among the 3 clusters. Overall liking was significantly different for each cluster for the

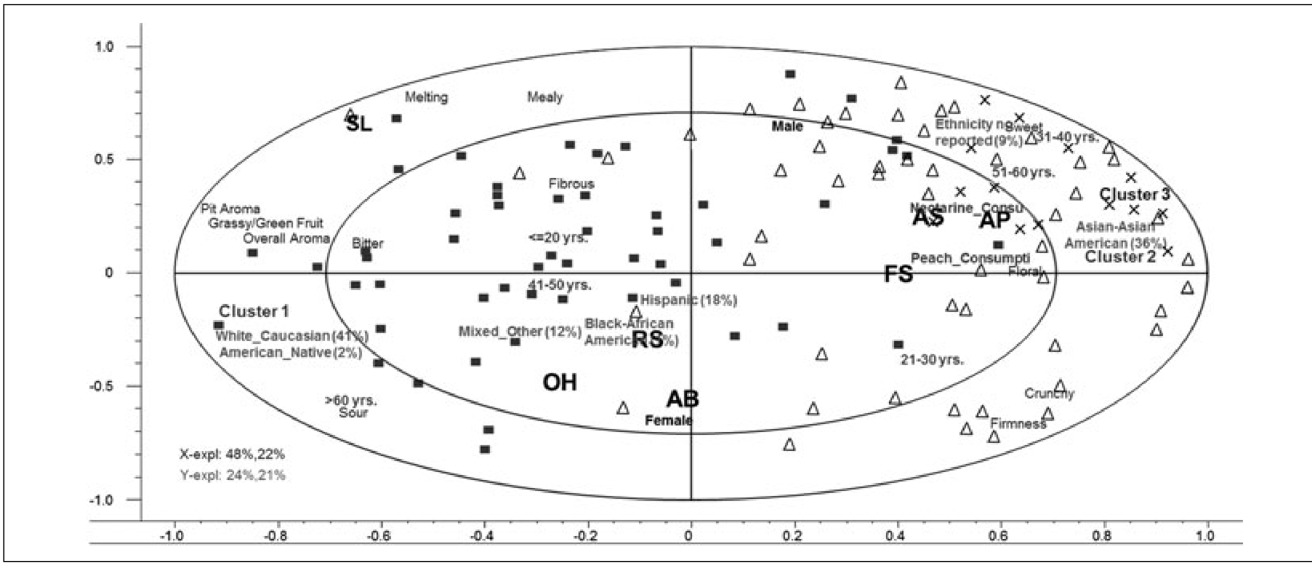

Figure 4–Block partial least square regression (L-PLS).
Descriptive analysis data: sensory attributes per cultivar [X] compared with overall liking by 120 consumers [Y]. Solid squares indicate consumers in cluster 1 ($n = 52$). Consumers in cluster 2 ($n = 54$) are indicated by triangles, and in cluster 3 ($n = 14$) by crosses, and consumers' demographics [Z]. Variables in the outer circle are more important than variables in the inner circle. Cultivar type (cultivar): N-F = nectarine flavorful ("Fire Sweet"), N-HA = nectarine high acidity ("August Bright"), N-LA = nectarine low acidity ("August Pearl"), P-F = peach flavorful ("O'Henry"), P-MA = peach medium acidity ("Ryan Sun"), P-LA = peach low acidity ("Autumn Snow"), P-SM = peach slightly mealy ("Summer Lady").

rest of the cultivars, so even though the number of consumers in cluster 3 is small, it is important to keep this cluster. "August Bright" nectarines were liked equally by clusters 1 and 2, but were disliked by cluster 3. "August Pearl" nectarines received the lowest average hedonic score from cluster 1, but fared better with clusters 2 and 3. "O'Henry" peaches were preferred by consumers in cluster 1 only, while "Ryan Sun" was liked only by consumers in cluster 2. Consumers in cluster 3 provided the highest hedonic score for "Autumn Snow" peaches, while cluster 1 provided the highest hedonic score for "Summer Lady" peaches (Figure 3).

Preference mapping provided the main drivers of liking and which cultivars were preferred most by consumers. Sweetness was the main driver of liking for clusters 2 and 3, while cluster 1 preferences were mainly driven by the aroma composition (overall, grassy/green fruit and pit aromas). Future research should include the new developments to obtain consumer's drivers of liking given the multicollinearity of sensory variables that preference mapping does not take into account (Bi and Chung 2011; Bi 2012). The fact that sweetness was a key driver of liking agrees with other fruit commodities such as apples (Daillant-Spinnler and others 1996; Thybo and others 2004), strawberries (Lado and others 2010), pineapples (Schulback and others 2007), tomatoes (Causse and others 2010), and fruit-based products such as apple juice (Rødbotten and others 2009) or pear fruit leathers (Huang and Hsieh 2005). The perception of grassy/green fruit and pit aromas that were detected in "Summer Lady" stored at 5 °C to induce chilling injury could be the first signs of chill injury development; it has been suggested that specific volatiles can be used to detect onset of mealiness (Crisosto and Labavitch 2002). Block partial least square regression (L-PLS) was used to study the relationship between the sensory descriptors given by the panel and the hedonic responses of consumers. L-PLS demonstrated differences in demographics for the clusters (Figure 4). There were some differences in preferences according to gender; male consumers preferred more firm, crunchy cultivars and females tended to like the nectarine "August Bright" more. Ethnicity had a strong influence on preferences within each cluster; for example, preferences in cluster 1 were mainly associated with White-Caucasian ethnicity that assigned more importance to overall aroma. Consumers in clusters 2 and 3 were mainly Asian-Asian Americans who preferred sweet nectarines and peaches.

Conclusions

There were strong correlations between the instrumental measurements of penetration firmness, RSSC, and RTA, and their respective sensory panel descriptors of firmness-texture, sweet, and sour. The sensory descriptors explained cultivar differences better than instrumental measurements alone.

RSSC (sweetness predictor) was the only instrumental measurement that might have an effect on overall liking by consumers. The expected price that consumers were willing to pay and purchase intent increased with the overall degree of liking and was not affected by cultivar.

Sweetness perception was the main driver of liking for 2 consumer clusters; however, for the 3rd cluster, the sensory attributes of grassy/green fruit and pit aromas were the main drivers of liking.

Future research should include new developments in the sensory field regarding consumer drivers of liking to further understand the importance of attributes taking into consideration the multicollinearity of sensory variables.

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