Mapping the Preferences of Adult and Child Consumers for California-grown Mandarins

Tyler Simons1, Hanne Sivertsen, and Jean-Xavier Guinand
Department of Food Science and Technology, University of California, Davis, One Shields Avenue, Davis, CA 95616

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Abstract. Citrus consumers from Northern California—231 adults (ages 18–77 years) and 98 children (ages 8–12 years)—rated their overall liking (OL) and liking for appearance, flavor, and texture, as well as adequacy of sweetness, sourness, firmness, and juiciness for eight commercially available California mandarins and a tangelo. Descriptive analysis was performed on fruit from the same batch. Three adult and two child preference clusters were identified. Most of the adult and child consumers preferred samples that were high in sweetness, peelability, mandarin aroma, and firmness of fruit flesh. Sour fruit was substantially preferred by 23% of the adult consumers. Liking of appearance showed the lowest correlations with liking of flavor, texture, and OL. This work confirms past research on the necessity of sweet, sour, and peelable fruit for consumers. The findings presented here also suggest that consumer clustering can help to demystify research into preferences for mandarins and their hybrids.

Production of fresh citrus fruit begets a tremendous economic impact on the State of California, accounting for a total market value of more than $2.2 billion per year [National Agricultural Statistics Service (NASS), 2017]. Fresh market mandarins in the United States are a $570 million crop with California as the majority producer among the states, at 94% of production [National Agricultural Statistics Service (NASS), 2017]. Because of their desirability, ease of peeling, and favorable flavor, the market for mandarins is growing. There was a 10% increase in production volume since 2015 [National Agricultural Statistics Service (NASS), 2017].

Numerous sensory evaluation studies have been conducted on mandarins, mainly through the use of semi-expert or expert judges who evaluated sensory attributes, quality, and hedonic liking (Goldenberg et al., 2015; Hagenmaier, 2002; Obenland et al., 2009, 2011; Tietel et al., 2010). These studies have investigated flavor changes from fruit diversity (Goldenberg et al., 2014, 2015), preharvest effects (Mourão Filho et al., 2007), and postharvest treatments such as waxing (Hagenmaier, 2002; Tietel et al., 2010), storage time, and temperature (Obenland et al., 2011; Tietel et al., 2012). Although valuable, many studies fail to address perceptions of consumers with fruit that they are able to purchase. More studies are needed involving fruit that have been washed, waxed, and packed; a key detail which substantially modulates the flavor of the fruit (Davis and Hofmann, 1973; Hagenmaier, 2002; Obenland et al., 2011; Tietel et al., 2010).

Current regulations in California for Navel oranges and mandarins differ. Mandarins are required to have a soluble solids content (SSC) to titratable acid (TA) ratio of at least 6:1, whereas Navel oranges are regulated by the California Standard (Ferguson and Grafton-Cardwell, 2014). The California Standard is derivative of the BrimA measurement which subtracts weighted TA from SSC (Ferguson and Grafton-Cardwell, 2014; Jordan et al., 2001). Both of these values are known to affect consumer liking (Goldenberg et al., 2015; Obenland et al., 2009; Tietel et al., 2012), but the concept of mandarin and citrus flavor is more complicated than that of SSC and TA (Miyazaki et al., 2012; Obenland et al., 2009; Tietel et al., 2011; Yu et al., 2017).

Appearance, flavor, taste, and texture work together to create the sensory experience of a mandarin, which suggests that proper evaluation should use sensory panelists when possible.

Past work with consumer preference mapping has helped to elucidate the important sensory attributes that drive liking for many foods and beverages (Campbell et al., 2004; Carbonell et al., 2008; Daillant-Spinnler et al., 1996; Delgado and Guinand, 2011), often investigating consumer segmentation in tandem. Successful preference mapping requires targeting the correct group of users of the product (Lawless and Heymann, 2010). Today, mandarins are marketed strongly toward children and families. Halos® and Cuties® focus their advertising on families; the former promoting the tagline “Good Choice, Kid,” whereas the latter notes their product is for “little hands,” “kid-sized,” and “kid-friendly.” Despite these slogans, no consumer studies have been published on children’s liking of mandarins in California.

This study set out to characterize the sensory preferences of adult and child consumers living in the Davis and Sacramento area of Northern California with fruit that they might encounter in a typical purchasing situation. We hypothesized that consumer preferences for mandarins would be heterogeneous, with unique cluster preferences for specific sensory attributes. We also hypothesized that sweeter fruit, as opposed to more sour fruit, would be preferred based on past work (Goldenberg et al., 2015; Tietel et al., 2011).

Materials and Methods

Fruit samples. Eight samples of commercial mandarins and one tangelo (500+ pieces each) were obtained from a local wholesale grocery store and produce wholesalers. The fruit obtained came from the same pallet with all boxes bearing the same run number to ensure consistency. The fruit consisted of specified varieties, as seen in Table 1. On receipt, all samples were stored in a cold room at 5°C and 85% humidity. To minimize sensory changes, all experiments were conducted within 10 d of acquiring the fruit. The fruit were removed from cold storage less than 1 d before testing to equilibrate them to room temperature.

The tangelo sample was included in all analyses as naive consumers may not be aware that they are distinct from true mandarins. These fruits are also consumed in a similar manner to mandarins, i.e., peeled whole and eaten. In addition, this lineage presented an intriguing difference in sensory attributes in comparison with the other samples.

Descriptive analysis. A generic descriptive analysis that combined elements of the quantitative descriptive analysis and spectrum methods was used with six judges (four females, two males; ages 27–50 years) who had prior descriptive analysis experience. All panelists completed 10 training sessions before evaluation. The first two sessions involved term generation based on the sensory properties of mandarins purchased at local retail outlets. The following sessions focused on concept alignment of terms that were generated by the panelists, aided by the use of reference standards, to create a list of terms, as seen in Table 2. Many of the terms generated by the panelists reflect past work that has been performed on citrus fruit (Goldenberg et al., 2015; Kim et al., 2013; Miyazaki et al., 2012; Plotto et al., 2010). During training, judges used a sample ballot, which listed each of the terms adjacent to a 10-cm line scale anchored at 1 cm indentations to limit end effects (Lawless and Heymann, 2010). For data collection, an

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1Corresponding author. E-mail: tsimons@ucdavis.edu.
Table 1. Commercial mandarin and tangelo samples tested. The fruit were stored at 5 °C and 85% relative humidity on reception. Once received, all samples were evaluated by consumer and descriptive analysis within 10 d.

| Products                  | Date received | Dates tested by consumers |
|---------------------------|---------------|---------------------------|
| Clementine (Clem 1)       | 6 Jan. 2016   | 9–13 Jan. 2016            |
| Clementine (Clem 2)       | 8 Jan. 2016   | 9–13 Jan. 2016            |
| Dancy Tangerine (Dancy)   | 8 Jan. 2016   | 9–13 Jan. 2016            |
| Owari Satsuma (Satsuma)   | 8 Jan. 2016   | 9–13 Jan. 2016            |
| Minneola Tangelo (Minneola) | 3 Mar. 2016   | 6–13 Mar. 2016            |
| W. Murcott (Murcott 1)*   | 3 Mar. 2016   | 6–13 Mar. 2016            |
| W. Murcott (Murcott 2)*   | 3 Mar. 2016   | 6–13 Mar. 2016            |
| W. Murcott (Murcott 3)*   | 3 Mar. 2016   | 6–13 Mar. 2016            |
| W. Murcott (Murcott 4)*   | 3 Mar. 2016   | 6–13 Mar. 2016            |

*Indicates tested for sugar and acid content.

electronic ballot was designed using FIZZ (BioSystèmes, Coutersun, France). Under white light, the judges were presented with fruit in whole form and instructed to evaluate the exterior attributes. Following this, the panelists peeled the fruit to evaluate the aroma and peel characteristics. They continued by rating the taste, flavor, and texture of the fruit. Unsalted crackers (Mondelez, East Hanover, NJ) and water were provided to cleanse their palates between samples. The samples, coded using randomized three digit codes, were evaluated in triplicate. Presentation order of the samples was randomized using a William’s Latin square (Williams, 1949) design provided by the FIZZ software. Performance of the panel, including discrimination ability, reproducibility, and concept alignment, was checked before evaluation to ensure panel readiness.

Sugar and acid measurements. Eight mandarins of each sample from the March tasting (W. Murcott and Minneola samples) were separately juiced into replications. Fifty milliliters of the juice from each of the eight replications was then placed into a 60 mL plastic cup, capped, and refrigerated at 3 °C for up to 1 d. Samples of juice were analyzed for SSC using a LTD Refractometer 110 (Bellingham + Stanley, Kent, UK). The pH was measured with an Orion 5-Star Plus pH meter (Thermo Fisher Scientific, Waltham, MA). Samples of the juice were also used to measure TA by the titration of 0.1 M NaOH to the end point of pH 8.2 using a Mettler Toledo DL50 titrator (Mettler Toledo, Columbus, OH). The SSC/TA ratio was calculated by dividing the SSC concentration by the TA concentration. The BrimA value was also calculated for each of the eight replication samples using the equation:

\[
\text{BrimA} = (\text{SSC} - 4*\text{TA})
\]

Consumers. Adults and children (ages 8–12 years) from the local (Davis, Woodland and Sacramento, CA) community were recruited for the tests. Potential participants were screened for appropriate age, lack of food allergies, and frequency of citrus consumption (at least once or twice per month, while is season). The age of the children was decided based on cognitive abilities required to use hedonic scales, intensity scales, and other sensory measures (Guinard, 2000). Children were accompanied by a parent/guardian at all times, but seated at their own individual booth.

The consumer tasting sessions took place in the Silverado Vineyards Sensory Theater of the Robert Mondavi Institute for Wine and Food Science at the University of California, Davis, across two sessions, one in January and one in March. In the first session (January), the consumers tasted the Clementine, Satsuma, and Tangerine samples. They evaluated the Murcott and Tangelo samples in the second session (March). Tasting dates and their relation to fruit acquisition are shown in Table 1. In total, 231 adults and 98 children completed the tasting. They tasted five samples on each occasion for a total of 10 samples, 9 unique samples and 1 blind replication. The blind replication was included in the experimental design to keep the number of samples consistent between sessions and was removed for all analyses. The consumers were separated by booth dividers to prevent interaction with their neighbors. Each consumer was given a ballot with a front and back page for the evaluation of each sample, napkins, water and crackers (palate cleaners), and a plastic knife (for peeling, if they desired). The fruit was served whole, in clear, 4 oz soufflé cups. The consumers were informed that they would be evaluating samples of mandarins from California and instructed on how to proceed through the ballot and survey. The consumers were briefed on the anonymity and voluntary nature of the study. All consumers consented to participate in the tasting. Consumers received a gift card ranging from $5 to $10 based on their age for their participation in the study. This study was approved for the use of human subjects by the Institutional Review Board of the University of California, Davis (ID 821014-1).

Exit survey. The adults participating in the study completed an online questionnaire between the tasting in January and March. This questionnaire aimed to collect information on their demographic, consumption habits, and psychographics. The survey was hosted by Survey Monkey (Palo Alto, CA). The survey asked a range of questions to the consumers including ethnicity, household income, number of children (if applicable), frequency of citrus and produce consumption, and questions regarding food neophobia. Some of these questions included familiarity with nutrition, adherence to diets, and personal histories with ethnic food. These questions were asked to separate consumer by their eating habits as has been effective in past research (Pliner and Hobden, 1992).

Ballots. Adult consumers rated their degree of liking on the 9-point hedonic scale (Peryam and Pilgrim, 1957) for appearance, internal color, OL, flavor, and texture, as well as the adequacy of sweetness, sourness, firmness, and juiciness on a 5-point just-about-right (JAR) scale (Rothman and Parker, 2009). Child consumers rated their liking of the appearance, taste, and texture of the fruit on a smaller, 7-point hedonic scale with cartoon faces (Guinard, 2000) and the adequacy of the sweetness, sourness, firmness, and juiciness of the fruit on a 3-point JAR scale from “too low” to “too high,” with “just right” as the midpoint. Both adults and children rated the difficulty of peeling the fruit on a 5-point and 3-point scale, respectively.

Data analysis. All data analysis was performed using R (R Core Team, Vienna, Austria). The level of alpha was set at 0.05 for all statistical parameters. A full-model, three-factor analysis of variance (ANOVA) was performed for each descriptive attribute. The three factors assessed were judges, replications, and products along with their two-way interactions using a pseudo-mixed model approach (King et al., 2012). Following the ANOVA, a Fisher’s least significant difference was applied to the product means. Principal components analysis was performed on the covariance matrix of the attributes, which were found to differ by ANOVA.

For the consumer data, univariate statistics, including means, standard deviation, and standard error, were performed on the hedonic questions. Penalty analysis, or mean-drop analysis (Rothman and Parker, 2009), was performed on the JAR scales for all modalities in comparison with OL (adults) or liking of taste (children). In case of missing values, data were imputed using the rounded average score for the product. Correlations were drawn using Pearson’s product-moment correlation. For preference clustering, all values for OL and for liking of taste (for adults and children, respectively) were scaled to mean of 0 and standard deviation of 1 to prevent clustering based on scale usage differences. Following the scaling, a Euclidean distance matrix was computed between consumers. Consumers were then clustered according to Ward’s Method (Qanniri et al., 1997). A two-way ANOVA was performed and a significant cluster by product interaction validated the clusters. Consumer preferences were modeled with the descriptive analysis measurements using a PLS2 regression model (Martens and Martens, 1986). Chi-square tests were performed on the consumer segments with respect to their answers on the exit survey to determine differences in demographics, psychographics, and citrus...
Results

Many descriptive attributes differed significantly among the tested fruit, including appearance, peel, aroma, taste, and texture attributes (Table 3). The flavor differences between the samples are quite clear. The Minneola sample, the only tangelo, was the most sour, and highest in lemon and lime flavors. The Clementine and Murcott samples had firmer textures and were sweeter than the Minneola. The SSC and TA values for the March samples are shown in Table 4. This table shows that the Minneola had the highest SSC, the highest TA, and the lowest SSC/TA ratio. The Murcott samples differed both in sugar and acid levels. Murcott 1 and 2 had higher SSC than the other two samples and Murcott 1 was more acidic.

The adult consumers liked nearly all aspects of the fruit. Their liking ratings for consumption habits. Chi-square tests were also performed to compare JAR ratings.

Table 2. Categories, descriptors, definitions, and references used for descriptive analysis of the mandarin/tangelo samples. Terms were generated by the panel on a variety of commercially available mandarins during the weeks before testing.

| Descriptor | Definition | Anchor or reference (if given) |
|------------|------------|--------------------------------|
| Exterior whole fruit | Size | Diameter of the fruit | Low = less than 2 inches |
| | Color hue | Hue of the peel | High = more than 2.5 inches |
| | Color intensity | Lightness of the peel | Low = green |
| | Speckles | Frequency of oil gland spots on the peel | High = dark orange |
| | Shininess | Amount of light reflected by the peel | Low = dark/white |
| | Skin feel | Roughness of peel | Low = no noticeable dark spots |
| | Fruit firmness | Firmness of the whole fruit | High = many noticeable dark spots |
| | Skin thickness | Thickness of the peel after peeling | Low = marred |
| | Visible defects | Relative amount of scars on the fruit | High = very shiny |
| Interior color | Internal color hue | Hue of the interior segments | Low = smooth peel |
| | Whole fruit feel | Peelability | High = very firm fruit |
| | Peel elasticity | The ease of bending the peel after it has been taken off of the fruit without tearing it | High = very firm peel |
| Aromas and flavors | Aroma intensity | The overall aroma intensity | High = dark orange |
| | Orange intensity | The aroma intensity of orange-like notes | Ref: 5 mL Essential Oils orange oil diluted in 40 mL tap water |
| | Mandarin intensity | The aroma intensity of mandarin oil | Ref: 5 mL Healing Solutions tangerine essential oil diluted in 40 mL tap water |
| | Lemon | The aroma intensity of lemon-like notes | Ref: 1 tablespoon each of lemon zest, lemon membrane, and lemon juice from a fresh eureka lemon |
| | Lime | The aroma intensity of lime-like notes | Ref: 1 tablespoon each of lime zest, lime membrane, and lime juice from a fresh lime |
| | Grapefruit | The aroma intensity of grapefruit-like notes | Ref: One tablespoon each of grapefruit zest, grapefruit membrane, and grapefruit juice from a fresh grapefruit |
| Fruity non-citrus | The intensity of aroma of fruits other than citrus, like that of strawberry, melon, and fruit cups | Ref: Two tablespoons Del Monte fruit cocktail |
| Floral | The aroma intensity of flowers, like that of orange blossom | Ref: 40 mL Carlo Enterprises orange blossom water |
| Pine | The aroma intensity of pine-like notes | Ref: 10 g hand-crushed needles from a white fir tree (Abies concolor) |
| Cut grass | The aroma intensity of grass-like notes | Ref: 5 g chopped grass (Poa pratensis) |
| Earthy | The aroma intensity of dirt/soil-like notes | Ref: 30 g potting soil mixed with 10 mL water and 5 g chopped white mushroom |
| Fermented | The intensity of fermented flavor associate with old or rotten fruit | Ref: One CedarFresh ball |
| Cardboard, woody | The aroma associated with fresh cut wood and cardboard | |
| Taste | Sweet | The intensity of sweet taste, like that of canned orange/mandarin | Ref: 30 mL Del Monte canned mandarins in syrup |
| | Sour | The intensity of sour taste, like that of fresh lemon | Ref: 30 mL fresh Eureka lemon juice |
| Texture/mouthfeel | Firmness of membrane | The amount of force required to break the membrane of a mandarin wedge by the teeth when biting into it | Ref: 30 mL fresh grapefruit juice |
| | Firmness of juice vesicles (fibrousness) | The level of force required to break the juice vesicles inside the membrane | |
| | Juiciness | The amount of juice released when chewing the segment | |
| | Residual fiber | The amount of solids left in the mouth after all the juice has been extracted by the teeth | |
| Astringency | Sensation of drying in the mouth | Ref: 30 mL of 0.02% alum dissolved in water |
| Flavor duration | The relative amount of time that the sensation of flavor lasts in the mouth | |
Table 3. Attributes that differed among the mandarins evaluated by the descriptive analysis panel. The panel rated each attribute on a 10-point scale using FIZZ software in the week following the consumer tastings. Attributes with a following “A” or “F” indicate aroma and flavor attributes, respectively.

| Product | Color | Flavor | Membrane | Vesicle | Textural | Visual | Exterior Color | Fruit Feel | OL | Firmness | Astringency |
|---------|-------|--------|----------|---------|----------|--------|----------------|------------|----|-----------|-------------|
| Clem 1  | 6.68  | 3.82   | 3.73     | 3.16    | 3.26     | 3.52   | 3.16           | 3.94       | 6.5 | 3.73      | 3.16        |
| Clem 2  | 6.04  | 4.83   | 4.04     | 4.04    | 4.28     | 4.28   | 4.83           | 5.18       | 6.6 | 4.28      | 4.83        |
| Dancy 8 | 9.67  | 2.48   | 2.75     | 2.67    | 2.67     | 2.67   | 2.48           | 2.82       | 7.6 | 2.67      | 2.67        |
| Murcott 1| 3.44  | 4.02   | 3.82     | 3.44    | 3.82     | 3.82   | 4.02           | 4.02       | 7.6 | 3.82      | 3.82        |
| Murcott 2| 4.30  | 3.82   | 3.58     | 3.34    | 3.82     | 3.82   | 3.58           | 3.82       | 7.6 | 3.82      | 3.82        |
| Murcott 3| 8.96  | 2.48   | 2.75     | 2.67    | 2.67     | 2.67   | 2.48           | 2.82       | 7.6 | 2.67      | 2.67        |
| Murcott 4| 4.30  | 3.82   | 3.58     | 3.34    | 3.82     | 3.82   | 3.58           | 3.82       | 7.6 | 3.82      | 3.82        |

Numbers within the same column that share the same letter are not significantly different (P ≤ 0.05) by Fisher’s least significant difference test.
Table 5. Proportions of just-about-right (JAR) ratings of mandarin and tangelo samples as rated by the adult consumers. The consumers were given one entire fruit and asked to evaluate it for hedonic and degree of intensity for sweetness, sourness, firmness, and juiciness on a 5-point scale. Ratings of 1 and 2 have been combined to “Too little,” whereas ratings of 4 and 5 have been combined to “Too much.”

| Modality     | Rating | Clem 1 | Clem 2 | Dancy | Minneola | Murcott 1 | Murcott 2 | Murcott 3 | Murcott 4 | Satsuma |
|--------------|--------|--------|--------|--------|----------|-----------|-----------|-----------|-----------|---------|
| Sweetness*   | JAR    | 0.67   | 0.37   | 0.45   | 0.32     | 0.55      | 0.39      | 0.27      | 0.65      | 0.42    |
|              | Too much| 0.05   | 0.05   | 0.10   | 0.03     | 0.06      | 0.13      | 0.03      | 0.06      | 0.06    |
|              | Too little| 0.15  | 0.47   | 0.52   | 0.04     | 0.24      | 0.34      | 0.25      | 0.29      | 0.16    |
| Soursness*   | JAR    | 0.69   | 0.45   | 0.44   | 0.29     | 0.61      | 0.57      | 0.45      | 0.59      | 0.40    |
|              | Too much| 0.16   | 0.08   | 0.04   | 0.67     | 0.16      | 0.10      | 0.30      | 0.12      | 0.44    |
|              | Too little| 0.03  | 0.13   | 0.35   | 0.53     | 0.09      | 0.06      | 0.06      | 0.11      | 0.58    |
| Firmness*    | JAR    | 0.74   | 0.68   | 0.50   | 0.36     | 0.81      | 0.72      | 0.76      | 0.78      | 0.40    |
|              | Too much| 0.23   | 0.19   | 0.15   | 0.11     | 0.10      | 0.22      | 0.18      | 0.11      | 0.02    |
|              | Too little| 0.30  | 0.44   | 0.24   | 0.06     | 0.19      | 0.32      | 0.38      | 0.20      | 0.12    |
| Juiciness*   | JAR    | 0.67   | 0.53   | 0.60   | 0.50     | 0.75      | 0.66      | 0.61      | 0.75      | 0.69    |
|              | Too much| 0.03   | 0.03   | 0.16   | 0.43     | 0.06      | 0.02      | 0.00      | 0.05      | 0.19    |

*Attributes marked by * are significant ($P = 0.05$) by χ² test. The test was performed on the distribution of all ratings then combined.

points. To these consumers, the textural attributes were markedly less important than those of sweetness and sourness. It is also possible that the magnitude of difference for textural attributes between the fruit was not large. The children showed a similar penalty trend to the adults (data not shown). They provided a stronger penalty for “too little sweetness” at just more than 2.25 hedonic points and a weaker penalty for “too much sourness” at just less than 2 hedonic points. However, these penalties should be noted as stronger than the adults because of the shorter scale used by the children (7-point instead of the 9-point scale for the adults).

The adults were clustered according to their OL ratings, which means that consumers who provided similar preferences among the products were placed into groups through a method called agglomerative hierarchical clustering. Three consumer segments were found consisting of 53, 98, and 80 consumers for clusters 1, 2, and 3, respectively. Cluster mean liking ratings, as shown in Fig. 3, revealed large discrepancies in comparison with the average ratings of all adults (Fig. 1), a fact most notable with the Minneola, Satsuma, and Dancy samples. The first cluster liked the Minneola sample the most and rated it higher than any other cluster. The other two clusters rated this fruit as “dislike slightly.” In addition, cluster 1 also disliked Clem 2 and Dancy, with similar ratings to cluster 2. Cluster 2 disliked the Satsuma. Adult cluster 3 liked the fruit more overall, but showed the strongest dislike for the Minneola.

In addition to their heterogeneous preferences, the consumer clusters also used the JAR scales differently, as shown in Table 6. The first cluster showed a drastic difference in ratings for sourness across all of the products, rating the products as “not sour enough” 42% of the time, compared with 25% and 21% for the other two clusters. In addition, these consumers rated the fruit as “too sour” only 7% of the time, compared with 28% and 26% for the other consumers.

The children showed a similar pattern to the adults in terms of their liking of taste, as shown in Fig. 4. Their lowest ratings were given to Minneola, Satsuma, and Murcott 3. Their favorite samples were Clem 1 and Murcott 1. Similar to the adults, there was a low correlation between the children’s liking for taste and liking for appearance. From their JAR ratings, the children found Minneola, Murcott 3, and Satsuma to be too sour (data not shown), in similar fashion to the adults (Table 5). The Minneola was the most intense; 63% of the children marked this sample as too sour.

The children were clustered into two groups, containing 66 and 32 children based on their preferences. Preferences for fruit between child clusters are shown in Fig. 5. Child cluster 1 was much more accepting of the Minneola sample, similar to a combination of adult clusters 1 and 2. Child cluster 2 was strongly driven away from the Minneola sample, similar to adult cluster 3. Other differences in the children clusters included their use of JAR ratings. Overall, child cluster 1 showed significantly ($P \leq 0.05$) more desire for sourness with 24% of their ratings marked as “not sour enough,” compared with only 16% by child cluster 2 (data not shown).

The relation between descriptive analysis data and adult consumer liking ratings was examined by PLS regression, where the descriptive attributes and the consumer cluster preferences were compared (Figs. 6 and 7 for the adults and children, respectively). In these figures, objects that are closer are more
correlated. Circles, triangles, and squares represent descriptive attributes, consumer clusters, and products, respectively. For example, Fig. 6 shows that the Minneola sample is well described by lime flavor, astringency, lemon flavor, bitterness, and sourness. The Dancy sample was high in sourness, lemon and lime flavors, bitterness, and astringency. The second cluster preferred samples with higher textural firmness, darker interior color, and mandarin aroma. The third cluster preferred the samples that were sweet and easy to peel. For the children (Fig. 7), findings were similar to the second and third clusters of the adults. Most of the children preferred the samples that were more balanced in flavor, with high mandarin aroma, sweetness, and textural firmness.

The exit survey taken by the adults revealed information about their habits as clusters and as a group. No demographics or psychographics, including questions about food neophobia, were consistent to separate the clusters, but the groups differed in their consumption of orange juice. Adult cluster 1 drank orange juice much less frequently than the other two adult clusters. One hypothesis for this is that juice may be too sweet for these consumers. This product may appeal more to them if it came with higher acidity.

As a group, the consumers ate citrus very frequently, with 83% of them consuming the fruit at least two to three times per week. Many obtained their fruit from the grocery store (89%), farmer markets (49%), and wholesale retailers (37%). Interestingly, 80% of the consumers felt that the quality of citrus fruit is highly variable and nearly 24% of them were often disappointed in the fruit they bought.

Discussion

The use of a trained descriptive analysis panel to evaluate the organoleptic properties of mandarins provided insight into the sensory properties of the fruit. The panelists identified 34 attributes that differed among cultivars and producers of mandarins, of which 20 attributes were found to differ in the fruit tested by the consumers. The attributes that were found to not be significant included attributes that either did not differ between the groups of tested fruit or their
values were not agreed upon by the trained tasters. The ratings from the descriptive panel, paired with consumer liking values, showed that no mandarin is “one size fits all.” Consumer preferences for mandarins covered a broad range of attributes but rely mainly on flavor and texture, as shown in Figs. 6 and 7.

The three clusters of adult consumers showed preferences of unique attributes with respect to the tested fruit. The first adult cluster clearly preferred the sour samples; the Minneola was their favorite, as shown in Fig. 3. This group not only rated this sample high but also rated it higher than any other cluster-product rating. They showed surprising preferences, characterized by fruit that are higher in astringency, bitterness, and lemon/lime character (Fig. 6). Although likely negative traits by themselves, the astringency and bitterness may merely be tolerated by these consumers in cluster 1 because of the association with acidity. However, ratings from overall JAR sourness (Table 6) suggested that these consumers could be specifically targeted through words such as “tart,” as they rated samples mostly as “not sour enough.” At only 23% of the consumer population, adult cluster 1 was the minority. The other 77% of consumers and nearly all children, however, preferred fruit with higher mandarin aroma, sweetness, and peelability (Figs. 6 and 7). These consumers did not prefer fruit that were characterized as bitter, sour, fermented, pine-like, or astringent.

For the children, sweetness was a crucial component of the liking. Both of the child clusters were driven toward the sweeter fruit (Fig. 7), a finding that is in agreement with the past research (De Graaf and Zandstra, 1999; Desor et al., 1975; Kühn and Thybo, 2001; Zandstra and de Graaf, 1998). For the second cluster of children, their lowest ratings went to the samples that were rated more
Although only five samples were tested for et al., 2004; Schifferstein and Frijters, 1990).

Sour by the descriptive panel, as shown in Fig. 4. This cluster reacted strongly to the Minneola. However, for the larger cluster of children, sweetness and sourness were not the only factors. They were not deterred as much as the other group of children by the strong acidity of the tangelo sample. These consumers required a balance between these attributes, with firm fruit flesh contributing to a positive sensory experience, as shown by their location in Fig. 7. Interestingly, the children in cluster 1 were significantly older (P ≤ 0.05 by χ² test) than the children in cluster 2, with an average age of 9.9 and 9.3 years, respectively. Past research has found that sour taste is innately distasteful (Steiner, 1977). It seems possible that the younger children had fewer exposures to sour citrus fruits and rejected the Minneola based on the novelty and intensity of this sample.

Of the samples tested for chemical measurements, the Minneola had the numerically highest SSC (Table 4) even though it clearly had the lowest perceptible sweetness value, as confirmed by both the adult consumers (Table 5) and descriptive panels (Table 3). The relatively high acidity of the fruit clearly masked the sweetness, which can be attributed to mixture effects (Bonnans and Noble, 1993; Lawless and Heymann, 2010; Pelletier et al., 2004; Schifferstein and Frijters, 1990). Although only five samples were tested for SSC and TA, the information provided gives a glimpse into the consumer preferences for SSC and TA values. Most of the consumers, adult clusters 2 and 3, preferred the samples with higher BrimA values and SSC/TA ratio. However, whether this ratio (SC/TA) acts as a predictor of consumer preference remains debated (Campbell et al., 2008; Jordan et al., 2001; Obenland et al., 2009; Tietel et al., 2011). Regulation in California is currently set to ensure that only fruit above a SSC/TA of 6:1 is released to market (Ferguson and Grafton-Cardwell, 2014). In addition, past research has found that consumer preference seems to decrease when sourness increases (Goldenberg et al., 2015; Obenland et al., 2009). The BrimA values, as shown in Table 4, showed a similar relationship to SSC/TA in this instance and also mirrored the liking patterns of adult clusters 2 and 3. Future work should investigate if a similar relationship between consumer liking and BrimA values also applies to mandarins as it does to oranges. It seems plausible that consumer liking is a function of many factors, including SSC and TA values, and consumer cluster. It also seems likely that too much acidity will act as a repellent for all consumers if it reaches high enough levels.

It is interesting that only a few aroma/flavor attributes were found to differ signif-

icantly between the tested samples as evaluated by the descriptive panel. Past research has had difficulty defining mandarin and orange flavors, and chemical analysis has been inconclusive to define the aroma in terms of a single or group of impact compounds (Miyazaki et al., 2012; Obenland et al., 2009; Tietel et al., 2011; Yu et al., 2017). This research used a sample of mandarin essential oil to provide a standard for the descriptive panel to rate mandarin aroma. Aromas of each variety of mandarins differ (Yu et al., 2017) and there does not seem to be any single or group of impact compounds that define the aroma. Despite this, the descriptive panel found that some samples were notably higher in perceived mandarin aroma. The samples they found highest in mandarin aroma were the Clementines and Murcotts, the most popular commercial varieties. In terms of consumer acceptance, mandarin aroma seemed to drive the preferences of many consumers, including adult cluster 2 and child cluster 1, as shown in Figs. 6 and 7. The other significant aroma attribute, pine, was not important in the statistical models. A thorough analysis of descriptive analysis for a larger number and variety of mandarins may be required to elucidate consumer perception and preference for aromas, including mandarin. More research is needed to confirm that is a desirable flavor property and how it could be increased in marketed samples throughout the growing season.

This research was conducted to determine if consumers of California mandarins differ in their preferences for commercially available mandarins. As processing and storage have major effects on the flavor of citrus (Goldenberg et al., 2015; Hagenmaier, 2002; Mannheim and Soffer, 1996; Tietel et al., 2012, 2010), research with true commercial samples and average consumers is lacking. Overall, the consumer sentiment regarding the fruit was positive. Consumer liking of the fruit was centered around their liking of the taste/flavor, with high correlations between OL, liking of flavor, and texture. These correlations may be attributed to the halo effect (Lawless and Heymann, 2010), a property where distinct attributes are rated higher because a consumer likes the product overall. As for the appearance of the fruit, importance is less clear. The consumers were first asked how much they liked the appearance of the product before tasting it and provided an unbiased assessment of the look before evaluating. The weaker correlations between appearance and OL suggest that appearance does not strongly drive how much they like the mandarins overall. Appearance, if quite poor, likely does matter but the appearance of the fruit tested here was good. Past work with Satsumas has found that blemishes, price, and seeds all play an important role in the desirability of the fruit (Campbell et al., 2004); however, this research did not inquire about the importance of good flavor. Evidence presented here urges high-quality producers and grocers to work together to provide tasting samples of the fruit or
additional information, such as the sugar and acid measurements from the lot for the consumers. Sampled measurements, accompanied through descriptive language such as “tart,” “tangy,” “lemon-lime,” or “low-acid” could key consumers in to fruit that they prefer. This would encourage consumers to repeatedly purchase fruit that is the best fit for them. However, with produce often sold generically, this is unlikely to happen. A combination of good farming practices, beneficial postharvest practices (including cold storage), and branding may help to clue consumers to fruit from preeminent producers. Any weaknesses in the supply chain could disrupt the ability of consumers to either find or receive high-quality fruit. High standards may, therefore, require auditing by the packing house by periodic, random testing at retailers.

There is a notable lack of consumer testing that has been performed on California commercial mandarins. Because of the high economic value of the crop in California, mapped consumer testing can allow for determination of the main drivers that predict consumer liking. This study has confirmed that California consumers react similarly to those of other geographic locations, in which juiciness, sourness, and sweetness are important properties of mandarins (Goldenberg et al., 2015; Tietel et al., 2011), but relative intensities of these attributes differed by cluster. Consumer segmentation allowed for enlightened consumer insight, a technique that may help to contextualize past research and improve citrus for consumers in the future.

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