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

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Abstract. Citrus consumers from Northern California—235 adults (age 18+) and 106 children (ages 8–12)—rated their overall liking and liking for appearance, flavor, and texture, as well as adequacy of sweetness, sourness, firmness, and juiciness for 10 commercially available, California-grown navel oranges (Citrus sinensis). Descriptive analysis measures and sugar/acid values were also collected for the fruit. Four adult and two child preference clusters were identified. Adult positive drivers of liking consisted of sweetness, soluble solids content (SSC), overall flavor, orange flavor, and juiciness. A small adult cluster showed a significant preference for acidic fruit. Both segments of child consumers mirrored most of the adults’ preferences. This study shows the homogeneity of multiple cultivars of navel oranges grown in California that are currently available to consumers and confirms past studies that the main drivers of liking consist of sweetness, juiciness, and orange flavor, among others. Just-about-right (JAR) ratings acted to confirm multiple attributes that correlated to liking. The findings presented here have implications for future marketing.

Production of citrus fruit in California has a substantial impact on the economy of the state, bringing in greater than $2.2 billion in 2016 alone (National Agricultural Statistics Service, 2017). Fresh and processed navel oranges (C. sinensis) alone contributed greater than $706 million in 2016 (National Agricultural Statistics Service, 2017). In the 2015–16 season, navel oranges produced for fresh market consumption represented a large portion of all citrus fruit produced in California, at 42% of total volume (National Agricultural Statistics Service, 2017).

Improving liking for a product requires consumer testing. Data from consumers are often nondescriptive, with consumers providing information solely about their liking. While this information is useful in determining which product each group of consumers may prefer, combining this information with detailed analysis of the sensory or chemical properties of a product allows for characterization of the drivers of liking for each consumer segment that is uncovered by preference mapping (Schlich, 1995). This technique has shown success in characterizing the preferences of consumers for different products in multiple markets (Greenhoff and MacFie, 1994; Guinard et al., 2001; Helgesen et al., 1997; Naes and Risch, 1996; Schlich, 1995; Sidel and Stone, 1993; Thybo et al., 2004; Yackinous et al., 1999). Data analysis consisting of partial least squares (PLS) regression to relate instrumental and descriptive analysis measures of sensory attributes to consumer liking has also been successful in the past for identifying key attributes that drive consumer preferences (Helgesen et al., 1997; Tenenhaus et al., 2005; Thybo et al., 2004).

Past work with navel oranges has found that high-quality fruit often has high concentrations of sugar in relation to acid (Ivans et al., 1987; Jordan et al., 2001; Obenland et al., 2009). Both sugar and acid components are measured by growers to determine whether the fruit is market ready by use of the California Standard. The California Standard indeed is a quality measurement, based on soluble solids concentration and acid concentration, that aims to enhance consumer acceptability of the fruit (Ferguson and Grafton-Cardwell, 2014). In other commercial citrus categories such as grapefruits, mandarins, and other oranges, a minimum ratio of soluble solids to acid (SSC/TA) is required before the fruit is deemed acceptable for market (Ferguson and Grafton-Cardwell, 2014). In other commercial citrus categories such as grapefruits, mandarins, and other oranges, a minimum ratio of soluble solids to acid (SSC/TA) is required before the fruit is deemed acceptable for market (Ferguson and Grafton-Cardwell, 2014). In other commercial citrus categories such as grapefruits, mandarins, and other oranges, a minimum ratio of soluble solids to acid (SSC/TA) is required before the fruit is deemed acceptable for market (Ferguson and Grafton-Cardwell, 2014).

This study set out to fulfill four objectives: 1) to uncover preference segmentation of adult and child consumers with respect to commercially available navel oranges; 2) to identify the key sensory attributes that drive liking for each preference cluster of consumers; 3) to characterize these segments using demographic, usage, and psychological information collected through an exit survey; and 4) to test the appropriateness of the current California Standard for navel oranges as it applies to consumers.

Materials and Methods

Fruit samples. Ten types of navel oranges, each consisting of five to six 88-count boxes, were obtained from growers and packers through the California Citrus Research Board during the week of 17 Jan. 2016. The samples consisted of specified and unspecified varieties (Table 1). Unspecified varieties were samples for which no variety information was provided. The fruit were treated according to current industrial processing practices, which include washing, rinsing, waxing, grading, and boxing (Ferguson and Grafton-Cardwell, 2014). On reception, the fruit were stored at 5°C and 85% humidity. When the fruit were tested, instrumental, sensory, and consumer evaluations were all performed within a 10-d span to limit changes to the fruit. Samples tested were taken out of cold storage ≤2 h before descriptive analysis or consumer testing to equilibrate them to room temperature.

Descriptive analysis. A generic descriptive analysis that combined elements of the Quantitative Descriptive Analysis and Spectrom methods (Lawless and Heymann, 2010) was used with eight judges (six females, two males; ages 21–57 years old) with prior descriptive analysis experience. All panelists completed 10 training sessions before evaluation. The first two sessions involved term generation based on navel oranges found in local retail outlets. The following sessions focused on concept alignment, aided by the use of references, to end a list of descriptive terms (Table 2). Some of these terms

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Table 1. Commercial navel oranges tested. All fruit were received during the week of 17 Jan. 2016. The fruit were stored at 40 °F until tested by consumers. Once the fruit were first tested by consumers, the descriptive analysis and instrumental measurements were completed within 10 d.

| Products          | Dates tested by consumers          |
|-------------------|-------------------------------------|
| Navel 1           | 23 and 30 Jan.                      |
| Navel 2           |                                     |
| Navel 3           |                                     |
| Organic Washington 1 | 13 and 20 Feb.                    |
| Atwood 1          |                                     |
| Atwood 2          |                                     |
| Fisher 1          |                                     |
mirrored past descriptive work that has been performed on orange juice (Plotto et al., 2010), such as orange, sweet, sour, astringent, and fruity, non-citrus. During training, judges used a sample ballot, which listed each of the terms with an adjacent 10-cm line scale anchored at 1 cm indentations to limit scale end-use effects (Lawless and Heymann, 2010). The scale anchors denoted high and low intensity of the respective attribute. An electronic ballot was designed for data collection through FIZZ (BioSystèmes, Couternon, France) for the actual descriptive analysis. The judges were presented with the fruit in whole form, instructed to peel it, and then evaluate it for the attributes on the ballot. Unsalted crackers (Mondelez, East Hanover, NJ) and water were provided to cleanse their

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

| Category                        | Descriptor                   | Definition                                                                 |
|---------------------------------|------------------------------|---------------------------------------------------------------------------|
| Exterior whole fruit            | Color hue                    | Hue of the peel                                                          |
|                                 | Low = green                  | Lightness of the peel                                                    |
|                                 | High = dark orange           | Light of the peel                                                        |
| Color intensity                 | Low = dark/black             | Frequency of black spots on the peel                                      |
|                                 | High = light/white           | Frequency of noticeable dark spots                                       |
| Speckles                        | Low = no noticeable dark spots| Frequency of noticeable dark spots                                       |
|                                 | High = many noticeable dark spots| Frequency of dark spots on the peel                                      |
| Shininess                       | Low = matted                 | Lightness of the peel                                                    |
|                                 | High = very shiny            | Lightness of the peel                                                    |
| Skin feel                       | Low = smooth peel            | Lightness of the peel                                                    |
|                                 | High = coarse peel           | Lightness of the peel                                                    |
| Fruit firmness                  | Low = very soft fruit        | Lightness of the peel                                                    |
|                                 | High = very firm             | Lightness of the peel                                                    |
| Skin thickness                  | Low = matted                 | Lightness of the peel                                                    |
|                                 | High = very firm             | Lightness of the peel                                                    |
| Interior color                  | Internal color hue           | Lightness of the interior segments                                       |
| Whole fruit peel                | Peelability                   | Lightness of the peel                                                    |
|                                 | Low = peel stuck firmly to fruit| Lightness of the peel                                                    |
|                                 | High = peel comes off very easily| Lightness of the peel                                                    |
| Peel elasticity                 | Low = peel breaks easily when bent| Lightness of the peel                                                    |
|                                 | High = peel is very elastic  | Lightness of the peel                                                    |
| Aromas and flavors              | Aroma/flavor intensity       | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Orange intensity                | Mandarin intensity           | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Mandarin intensity              | Lemon                        | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Lemon                           | Lime                         | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Lime                            | Grapefruit                   | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Grapefruit                      | Fruity non-citrus            | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Fruity non-citrus               | Floral                       | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Floral                          | Pine                         | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Pine                            | Cut grass                    | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Cut grass                       | Earthy                       | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Earthy                          | Fermented                    | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Fermented                      | Cardboard, woody             | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Cardboard, woody                | Taste                        | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Taste                           | Sweet                        | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Sweet                           | Sour                         | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Sour                            | Bitter                       | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Bitter                          | Texture/mouthfeel            | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Texture/mouthfeel               | Firmness of membrane         | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Firmness of membrane            | Firmness of juice vesicles (fibrousness) | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Firmness of juice vesicles (fibrousness) | Juiciness                   | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Juiciness                       | Residual fiber               | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Residual fiber                  | Astringency                  | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
| Astringency                     | Flavor duration              | Lightness of the aroma given off by the fruit during peeling (orthonasal) and eating (retronasal) |
palates between samples. The samples were coded with randomized three digit codes and evaluated in triplicate under white light. Presentation order of the samples was randomized using a William’s Latin square (Williams, 1949) design provided by the FIZZ system. Performance of the panel (i.e., ability to discriminate among samples, reproducibility, and concept alignment) was checked through evaluation of a two-sample set of oranges during the final training sessions using analysis of variance (ANOVA).

Sugar and acid measurements. Eight oranges of each sample were juiced separately. Fifty milliliters of the juice from each of the eight replicates was then placed into a 60 mL calibrated with randomized three digit codes and evaluated in triplicate a nd rated the performance of the panel (i.e., ability to discriminate among samples, reproducibility, and concept alignment) was checked through evaluation of a two-sample set of oranges during the final training sessions using analysis of variance (ANOVA).

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Table 4. Significantly different attributes among the oranges tested through descriptive analysis. The judges evaluated the samples in triplicate and rated the samples on a 10-point scale. The attributes were subjected to the trained judges within 10 d of the consumer evaluations. The judges were presented with a whole fruit, instructed to evaluate the appearance, peel the fruit, and then evaluate it for the remaining attributes.

Table 5. Overall liking and liking of specific modalities for adults (n = 235) and children (n = 106), respectively, for the oranges. The adults rated the products on the 9-point hedonic scale with 1 = “dislike extremely” and 9 = “like extremely.” The children rated the products using a modified 7-point hedonic scale with 1 = “I hate it” and 7 = “I love it.”

Letters within the same column indicate significant differences (P ≤ 0.05) according to Fisher’s least significant difference test.
independent variables and the consumer cluster averages were the dependent variables. χ² tests were performed on the consumer segments with respect to the JAR questions and their answers on the exit survey to determine differences in demographics, psychographics, and citrus consumption habits. All data analysis and figures were produced using R (R Core Team) except for the JAR penalty analysis, which was created using XLSTAT-Sensory® 2017 (Addinsoft, New York, NY).

Results

Chemical and descriptive analysis. There were significant differences among the samples in each of the chemical measurements (Table 3). All of the fruit samples had a California Standard value above the minimum requirement of 90, and all samples had a SSC/TA value above 10, the previous minimum standard. The panelists found significant differences in 14 of the 32 sensory attributes measured, consisting of seven appearance and peak attributes, one taste attribute, two flavor attributes, and four textural attributes (Table 4). For the flavor attributes, many showed correlation, with sweeter samples often having high overall and orange flavor ratings. Likewise, some textural attributes were negatively correlated. For example, fibrousness and membrane firmness were rated nearly opposite of juiciness. Some of the samples stood out because of their unique sensory properties. Navel 2 and Thomson Improved, for example, had low ratings for sweetness, overall flavor, orange flavor, and juiciness, whereas receiving high ratings for membrane firmness and fibrousness.

Consumer hedonic ratings. The liking ratings of adults and children for all products are shown in Table 5. Overall, both the adult and child consumers liked the samples that were tested. All of the fruit were rated above “neither like nor dislike” for adult overall liking and child liking of taste. One sample, Navel 2, received the lowest ratings from both the adults and children but this fruit was not disliked, receiving a score of 5.07 on a 9-point hedonic scale from the adults and 4.63 on a 7-point scale in “liking of taste” from the children.

There was a weaker correlation among the liking ratings of the children (Table 7). Liking of taste and appearance were the least correlated (r = 0.24) compared with the highest correlated likings of taste and texture (r = 0.49). JAR scaling. Consumers also rated the products for adequacy of sweetness, sourness, firmness, and juiciness on a JAR scale.

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| Modality | Appearance | Overall liking | Flavor | Texture |
|----------|------------|---------------|--------|---------|
| Appearance | 1 | 0.43* | 0.38* | 0.46* |
| Overall liking | 0.43* | 1 | 0.90* | 0.73* |
| Flavor | 0.38* | 0.90* | 1 | 0.67* |
| Texture | 0.46* | 0.73* | 0.67* | 1 |

*Denotes significance (P < 0.05) by Pearson correlation.

Table 7. Correlations between liking of attributes for child consumers (n = 106) for the navel oranges.

| Modality | Appearance | Taste | Texture |
|----------|------------|-------|---------|
| Appearance | 1 | 0.24* | 0.34* |
| Taste | 0.24* | 1 | 0.49* |
| Texture | 0.34* | 0.49* | 1 |

*Denotes significance by Pearson correlation at P ≤ 0.05.
The distribution of JAR ratings for the adults is shown in Table 8, where the JAR attributes have been condensed to “too little,” “JAR,” and “too much.” None of the oranges received equal distributions across the three JAR levels, meaning that the fruit were skewed. For sweetness and sourness, all of the samples showed a substantial number of “too little” ratings, with Navel 2 standing out in terms of a lack of sweetness and sourness. For the textural attributes, the Navel 2 sample and the Thomson Improved samples show wider distributions in their JAR ratings than the other samples. The children had similar proportions in rating the same fruit (data not shown). The combination of low juiciness, sweetness, and sourness can help to explain why Navel 2 and Thomson Improved received the lowest liking ratings from both adults and children (Table 5).

Preference segmentation. Both the adults and children showed statistically significant segmentation based on their overall liking and liking of taste as seen in Figs. 2 and 3. The adults were segmented into four distinct clusters and the children into two clusters. Whereas a product may perform well on average (i.e., across all consumers), segmentation is indicative of different groups having different liking patterns. Significant differences in liking were seen among the segments in nine fruit samples for the adults and five for the children, respectively (Figs. 2 and 3). This is more distinct than the liking differences when the consumers are considered together (Table 5).

After the consumers were clustered by their overall liking ratings, their JAR ratings were separated, as shown in Table 9. This table shows the differences between the clusters in their overall use of the JAR ratings across all products. Adult clusters 3 and 4 used the sweetness rating differently from the other two groups. Cluster 3 was stricter with their JAR sweetness ratings, meaning they rated more samples to have “too little” sweetness more than any other group. The fourth cluster did just the opposite. For sourness, cluster 4 gave more “too little” ratings than the other groups, expressing a desire for tarter fruit. Textural attributes showed much higher acceptability among the consumers. Most of the adults felt the samples were appropriately juicy and firm. One slight difference is that the third adult cluster showed a smaller majority with regards to the juiciness level of the samples, indicating that they may prefer if the fruit they consumed were even juicier.

The children used the JAR scales similarly. Cluster 2 showed slightly more particularity toward sweetness, whereas cluster 1 was more sensitive to textural attributes of juiciness and firmness (data not shown). This trend is reflected in the children’s liking of texture (Fig. 4), where cluster 1 had lower ratings than cluster 2.

Drivers of liking. PLS regression was performed to compare liking of all six of the

Table 8. Proportion of adult just-about-right (JAR) ratings for sweetness, sourness, firmness, and juiciness of all orange samples. The judges were given two wedges of the same orange to evaluate all of the JAR attributes on a 5-point scale. Ratings of 1 and 2 and 4 and 5 have been combined into “too little” and “too much,” respectively. χ² test was performed on the separated ratings before being converted to proportions and combined.

| Sample          | Sweetness* | Sourness* | Firmness* | Juiciness* |
|-----------------|------------|-----------|-----------|------------|
|                  | Too little | JAR       | Too much  |            |
| Atwood 1        | 0.43       | 0.52      | 0.05      |            |
| Atwood 2        | 0.35       | 0.58      | 0.06      |            |
| Fisher 1        | 0.49       | 0.48      | 0.03      |            |
| Navel 1         | 0.37       | 0.57      | 0.06      |            |
| Navel 2         | 0.75       | 0.21      | 0.04      |            |
| Navel 3         | 0.40       | 0.57      | 0.03      |            |
| Organic         | 0.31       | 0.60      | 0.09      |            |
| Thomson Improved| 0.49       | 0.44      | 0.07      |            |
| Washington 1    | 0.45       | 0.51      | 0.12      |            |
| Washington 2    | 0.29       | 0.60      | 0.11      |            |
| Average         | 0.43       | 0.51      | 0.06      |            |

*indicates significance (P < 0.05) by χ² test.
consumer clusters with the chemical and descriptive attributes as seen in Fig. 5. This analysis compares the descriptive and chemical analyses to the consumer liking. Objects on the plot that are located closer to each other are more correlated. This analysis shows drivers of liking, or attributes that were strongly correlated to the clustered consumer liking. The drivers of liking for the first two adult clusters were sweetness and SSC, both of which were strongly correlated to the California Standard rating scale. The preferences of the second and third adult clusters were driven by juiciness, orange flavor, and overall flavor. The fourth cluster preferred samples higher in TA.

As for the children, some of them largely mirrored their adult counterparts. The first child cluster was driven strongly by the same attributes as the second and third adult clusters—orange flavor, overall flavor, and SSC. The second cluster of children was not as well described by the model. These children had more homogenous ratings for taste, liking all of the samples. One of the negative drivers of liking for almost all clusters was fibrousness, which makes sense given the preferences of the consumers for juicy fruit.

**Exit survey.** The adults were asked to answer a few questions about their demographics, consumption of citrus, and psychographic information. The adults were also asked to answer a few questions about their child’s eating habits. These data were collected to help characterize the preference segments of consumers. Adults showed significant differences in what time of the year they ate citrus. Adult cluster 4 ate citrus year around more frequently than the other three.
clusters ($P < 0.05$). This cluster also showed liking for the more acidic fruit. They may be more used to citrus that is not quite in season, therefore sourer.

**Discussion**

Overall, the oranges that were tested were liked by both consumer groups, with all products but one receiving ratings of "liked slightly" or better (Figs. 2 and 3). If there is room for improvement though, it may be in the intensity of both sourness and sweetness of the fruit. Past work with mandarins has found that highly preferred mandarins had an average total soluble solids and acid content of 13.1% and 1.1%, respectively (Goldenberg et al., 2015). None of the fruit tested in this study exhibited quantities of either attribute at these levels. In fact, all of the fruit samples were quite low in acidity, with all samples at or below 0.8% TA. Given that the period of testing was late January through early February, it seems surprising that all of the fruit would register so low in acid. Nevertheless, these values are quite low for traditional acid measurements in oranges and do indicate that the fruit was quite mature. Despite the low acid content, however, the consumers still felt that the fruit was not sweet enough. Even though the fruit may have been overly mature, the JAR ratings of "too little" sweetness were still marked at 41% of the time for the adults (Table 8) and 26% for the children, indicating that there are still improvements to be made.

The low acid flavor of the fruit was not the only attribute that was similar among the samples. The trained descriptive panel provided results that confirm the similarities among the fruit between the different sensory attributes (Table 4). Despite the panel having many metrics by which to measure flavor differences, only three flavor attributes showed significant differentiation. Of the 32 attributes in the scorecard, less than half were found to be significant, a small proportion indeed for a descriptive analysis. More variation in the chemical and sensory properties of the fruit would have provided stronger insight into consumer preferences.

Looking to the future, the information presented here may have implications for marketing. One commonly cited issue with using consumers to provide any sort of descriptive data, JAR ratings in this instance, is that consumers often do not agree on the stimulus (Lawless and Heymann, 2010). This issue is remedied in descriptive analysis through the use of reference standards, providing consensus among the panelists. However, in this study, we found certain instances in which consumers used JAR attributes which mirrored their preferences. For the
adults, the fourth cluster rated the samples as “not quite sour/tart enough” more than any other cluster (Table 9) and their liking was strongly correlated to the measured value of TA (Fig. 5). For the children, the first cluster was more sensitive to sweetness, indicating that they felt the samples to be “JAR” less than the other cluster of children. These children are then shown to be mapped closer to soluble solids than the other child cluster (Fig. 5). Although mapping their preferences to specific attributes provides insight for the growers, evidence presented here shows that consumers may be aware of their attribute preferences. These consumers may respond well to advertisement. For example, adult cluster 3 may be enticed by a label indicating the juiciness of the orange, adult cluster 4 might be inclined to purchase a “tart” fruit, and child cluster 1 might be drawn toward packaging that emphasizes sweetness. This study also confirmed that juiciness, overall flavor, orange flavor, and sweetness are critical attributes in determining consumer liking of navel oranges, which is in agreement with past studies (Gao et al., 2011; Obenland et al., 2009; Poole and Baron, 1996). However, these attributes cannot be appropriately conveyed through the external appearance of the fruit (Tables 6 and 7). In this study, liking of appearance showed the lowest correlation among taste and texture to overall liking of the fruit. To remedy this, packers could provide consumers with additional information, such as a sugar or acid range from the lot of fruit, provided to consumers at their point-of-purchase. Ranges of soluble solids or acids, accompanied by words such as “tart” or “extra sweet,” could provide insight for the consumers. A system like this might reward high-quality producers with higher sales and repeat consumers who appreciate clarity and consistency in their fruit.

These data come together to provide a market assessment of 10 commercially produced navel oranges in Northern California. If the 10 fruit samples we collected for this study were any indication, the fruit offered to consumers appear to be very consistent, of relatively high quality, or one that meets consumer expectations. This sampling of fruit, although liked strongly, may not fully represent the entirety of navel oranges produced commercially in California. The similarity of soluble solid and acid levels does not represent fruit harvested at varying levels of maturity or ripeness which would be seen across the entire harvest period. The homogeneity observed may be due in part to the legislative change in quality evaluation from the SSC/acid ratio in favor of the California Standard value. For most of the consumers, liking showed a strong correlation to this new standard, a welcome sign that this new tool is working well.

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