Using sensory evaluation to drive how we handle fresh citrus fruit

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Why should sensory evaluation be included in postharvest research?
- Changing the minimum maturity standard for California navel oranges
- Examining the impact of storage and the packing line on navel orange eating quality
- Exploring the influence of temperature and other factors on mandarin fruit quality

Why should sensory evaluation be included in postharvest research?
- Improve selection of new varieties
- Improve understanding of how fruit handling strategies may affect eating quality
- Visual quality (“eye appeal”) persists longer than eating and nutritional quality

Flavor perception

Complex integration of human senses involving:
- Texture: mouth feel
- Taste: sweet, sour, astringent, salt, MSG
- Smell: volatile aroma components

Aroma Volatiles

Aroma (or smell or odor) is the sensation perceived when volatile compounds are drawn into the nose.

Ripe fruits generally produce tens to hundreds of volatiles. This mixture of volatiles is what we perceive as “aroma”.

What is a volatile compound?

- A small molecule which has a high tendency to evaporate.

- Volatiles are naturally produced by plants (from almost all plant organs) and animals.

- Fruit aromas are made up of complex mixtures of volatile compounds (strawberry has over 2001).
Aroma Analysis and Product Quality

• Odor descriptors
- 2-Ethyl hexanol
  - citrus, fresh, floral, oily, must
  - 270,000 ppb
- 2-Methyl butyl acetate
  - banana, candy, citrus
  - 5 ppb
- Hexyl acetate
  - apple, cherry, floral, pear, wine
  - 2 ppb

• Odor thresholds (minimum concentration of a substance at which a majority of test subjects can detect and identify the substance characteristic odor)

What is the minimum taste acceptability for CA navel oranges?

This work was carried out over a 4 year period
We examined several navel strains
We sampled over multiple locations (Year 3)
We utilized commercially handled fruit (Year 4)
Considered alternatives to sugar:acid ratio for predicting eating quality

Influence of sugar and acid on navel orange flavor

Responding to the Marketplace:
Providing the consumer with better early-season navel quality

The California Standard
April 1, 2012

Making the most of the orange

Quality
Constituents
% Juice
SSC
TA
Volatile (pooled)

Sensory Panel
Hedonic Score
Richness
Sweetness
Tartness

A Sensory-Based Alternative to Brix/Acid Ratio

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

This measure was believed to better account for the sweetness-reducing effect of the acid
**Overview of Results**

- The relationship of fruit acceptability to SSC/TA is not influenced by strain, location or year.
- Should consider increasing the minimum maturity standard of 8:1 SSC/TA to at least 10:1.
- Brim A, an alternative to SSC/TA should be considered since it is more closely related to acceptability.
- Volatiles were identified that were related to the development of flavor and could possibly act as markers to select better tasting fruit.

**The California Standard**

A modification of the BrimA calculation:

\[
(\text{SSC} - (4 \times \text{TA})) \times 16.5
\]

Minimum score = 90

This will hopefully minimize confusion with the SSC/TA ratio.

**Aroma active compounds are involved in sensory perception**

In year 3 we studied the changes in these compounds during fruit maturation.

We found 6 compounds (out of 19) significantly correlated with acceptability.
Practical Outcomes

- For minimum maturity, SSC and TA relationship can be a good predictive tool.
- The SSC/TA ratio may not be the best relationship to use for citrus.
- Brim A, a different way of looking at SSC and TA may be more appropriate.
- This forms the basis of the new California minimum maturity standard for navel oranges, the California Standard.

Does citrus postharvest handling influence eating quality of navel oranges?

Does the packing line affect fruit flavor?

Packing House Fruit Sampling Scheme

<table>
<thead>
<tr>
<th>Field Bin</th>
<th>Washer</th>
<th>Waxer</th>
<th>Packed Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

| 6.4 a | 6.1 a | 6.1 a | 6.0 b |

Average Hedonic Score

Does time in storage affect fruit flavor?

Fruit stored at 41F for 0, 3, 6 weeks followed by 4 days at 68 F and 3 days at 54 F

<table>
<thead>
<tr>
<th>Storage Time</th>
<th>0 wk</th>
<th>3 wk</th>
<th>6 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Hedonic Score</td>
<td>6.4 a</td>
<td>6.2 a</td>
<td>5.7 b</td>
</tr>
</tbody>
</table>

There were no significant handling x storage interactions.

Packing House/Storage Effect on Sensory Characteristics

<table>
<thead>
<tr>
<th>Test</th>
<th>Storage</th>
<th>Rich</th>
<th>Storage</th>
<th>Tart</th>
<th>Sweet</th>
<th>Hedonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>101.5</td>
<td>1</td>
<td>111.4</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>91.0b</td>
<td>3</td>
<td>96.5a</td>
<td>5.7b</td>
<td></td>
</tr>
</tbody>
</table>

There were no significant handling x storage interactions.

SSC increased with storage.
TA decreased with storage.
SSC/TA increased.

Ethanol accumulated during storage and is influenced by packline handling.
We repeated this test and added detection of aroma active compounds

Differences in aroma active compounds were detected due to storage and handling

10 compounds changed significantly due to storage duration
5 compounds changed due to handling

Conclusions

- Storage had a negative effect on fruit flavor
  - SSC/TA↑, Richness rating↓, Hedonic rating↓
- The packing line/waxing had a more modest influence
  - Richness rating↓, Hedonic rating↓
  - Overall each step appeared to have a cumulative effect
- Volatiles may play an important role in the flavor changes

Practical Outcomes

- How we handle fruit in the postharvest environment can influence long term eating quality
- In long term storage, SSC and TA may play a lesser role; changes in aroma active compound may play a more important role
- The impact on eating quality is repeatable across multiple grower lots and multiple tests

Mandarin Orange or Tangerine

- Increasing importance to the California industry
- Several new varieties; activity continues looking for new varieties
- Peel is loose and easily separates from flesh so sometimes referred to as “zipper skinned” fruit
- Mandarins have a hollow core at maturity.
- Can be problematic in postharvest environment

Mandarins often develop off-flavor during storage

- Not fresh
- Over ripe
- Spoiled
- Really old
- Strange aftertaste
**What is the Impact of Warm Temperatures?**

Citrus is typically marketed in non-refrigerated cases

**Storage Tests**
- Continuous 5°C
- 1 and 2 wks 20°C
- 2 wks 5°C + 1 and 2 wks 20°C
- 4 wks 5°C + 1 and 2 wks 20°C

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**Response to Warm Temperature Storage – W. Murcott Afourer**

Warm temperature main cause of flavor loss

Time in cold storage influences response

Difference enhanced with greater fruit maturity

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**Response to Warm Temperature Storage – W. Murcott Afourer**

Some negative comments on this sample:
- Spoiled, rancid
- Really old
- Off-flavor
- Strange aftertaste
- Flavor not as intense
- Not fresh
- Over ripe

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**The loss in flavor quality is not explained by changes in soluble solids**

No clear effect of temperature on soluble solids

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**The flavor quality problems are not explained by acidity changes either**

Warm temperature storage causes a loss in acidity

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**Example of the change in aroma volatiles due to temperature**

Ethyl acetate - fruity, pineapple, solvent-like aroma

Large increase in ethyl acetate is prevented by cold storage
What determines off-flavor formation?

Do mandarin varieties differ in off-flavor development in storage and, if so, why?

Coatings provide a formidable barrier to gas exchange

Response to warm storage temperature - other mandarin types

- Subsequent tests showed that an intermediate temperature (50F) did not have the increase in volatiles associated with off-flavors.
- At 68F, increase occurs within 24 hours.

Coatings provide a formidable barrier to gas exchange.
Is ethanol accumulation predictive of the levels of other compounds (volatiles) important to flavor?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Gold Nugget (low)</th>
<th>Pixie (high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol (mg/L)</td>
<td>3445*</td>
<td></td>
</tr>
<tr>
<td>3-Methylbutanol</td>
<td>tr</td>
<td></td>
</tr>
<tr>
<td>2-Methyl-1-butanol</td>
<td>tr</td>
<td></td>
</tr>
<tr>
<td>Linalool</td>
<td>60*</td>
<td></td>
</tr>
<tr>
<td>4-Terpineol</td>
<td>24*</td>
<td></td>
</tr>
<tr>
<td>Esters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>5812*</td>
<td></td>
</tr>
<tr>
<td>Ethyl propanoate</td>
<td>320*</td>
<td></td>
</tr>
<tr>
<td>Ethyl isobutyrate</td>
<td>73*</td>
<td></td>
</tr>
<tr>
<td>Ethyl butanoate</td>
<td>466*</td>
<td></td>
</tr>
<tr>
<td>Ethyl 2-methylbutanoate</td>
<td>209*</td>
<td></td>
</tr>
<tr>
<td>3-Methylbutyl acetate</td>
<td>9*</td>
<td></td>
</tr>
<tr>
<td>2-Methylbutyl acetate</td>
<td>8*</td>
<td></td>
</tr>
<tr>
<td>Octyl acetate</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Decyl acetate</td>
<td>34</td>
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<tr>
<td>Ketones</td>
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</tr>
<tr>
<td>1-Penten-3-one</td>
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<tr>
<td>Carvone</td>
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<td>Aldehydes</td>
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<tr>
<td>Pentanal</td>
<td>15</td>
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<tr>
<td>Hexanal</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>E-2-Hexenal</td>
<td>47*</td>
<td></td>
</tr>
<tr>
<td>Heptanal</td>
<td>19</td>
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</tr>
<tr>
<td>Octanal</td>
<td>66*</td>
<td></td>
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<tr>
<td>E-2-Nonenal</td>
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</tr>
<tr>
<td>Nonanal</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Decanal</td>
<td>54*</td>
<td></td>
</tr>
</tbody>
</table>

Ethanol produced much greater for Pixie.

Conclusions

1. A great deal of variability exists in the amount of ethanol accumulated as a result of waxing and storage.
2. High ethanol accumulators tend to have higher carbon dioxide levels following waxing and storage than low accumulators.
3. Ethanol accumulation is linked to the formation of other aroma volatiles that are associated with flavor changes.

Future Work

1. Determine relationship of the ethanol accumulation differences and flavor.
2. Determine what causes mandarins to be high or low ethanol accumulators.
3. Coating effects?

Practical Outcomes

- Mandarins are a more diverse group and there is large differences between varieties.
- Visual quality is not indicative of eating quality.
- Cold chain crucial to maintain good eating quality.
- Loss in acceptability tied to:
  - Gas exchange characteristics
  - Changes in ethanol and ester compounds.

Thank you for your attention.