Mandarin or Orange? They both taste so good!

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To identify HLB-resistant/tolerant hybrids with good flavor quality (orange-like and grapefruit-like, +/- Poncirus background)

To characterize fruit and juice quality of HLB-tolerant scions, for either as stand-alone variety, or use in orange-like juice blends

https://programs.ifas.ufl.edu/scion-guide/
Hybrids Less Susceptible to CLas

*Citrus* (e.g. *Sugar Belle®* - University of Florida)

*Citrus X Poncirus trifoliata* in the background
(e.g. *US SunDragon* – ARS)
Fruit Quality from the USDA Breeding Program

- Fruit harvested at estimated maturity, multiple harvests
- Wash, sanitize, juice
- Take samples for volatiles, sugars, acids, SSC (Brix), TA, limonoids
Sensory Evaluation

- Trained panel (10 years+ experience)
- Line scale with tick marks 0 to 15
- Reference standards served at each panel
Since 2017-18 (5 seasons)

50+ orange-like hybrids & named varieties
Multiple harvests → 114 data points

<table>
<thead>
<tr>
<th></th>
<th>Orange flavor</th>
<th>Mandarin flavor</th>
<th>Sweet taste</th>
<th>Sour taste</th>
<th>Bitter taste</th>
<th>TA (% citric)</th>
<th>SSC (Brix)</th>
<th>SSC/TA</th>
<th>Limonin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>1.45</td>
<td>2.18</td>
<td>3.11</td>
<td>2.25</td>
<td>0.25</td>
<td>0.28</td>
<td>7.50</td>
<td>6.39</td>
<td>0.15</td>
</tr>
<tr>
<td>Max</td>
<td>8.12</td>
<td>7.69</td>
<td>8.57</td>
<td>11.14</td>
<td>9.12</td>
<td>1.82</td>
<td>15.94</td>
<td>54.76</td>
<td>18.91</td>
</tr>
</tbody>
</table>

Flavor & Taste on a 0-15 scale
Volatile Patterns

<table>
<thead>
<tr>
<th></th>
<th>Valencia</th>
<th>US SunDragon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohols</td>
<td>82.8</td>
<td>61.7</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>24.7</td>
<td>56.0</td>
</tr>
<tr>
<td>Esters</td>
<td>133.6</td>
<td>33.2</td>
</tr>
<tr>
<td>Monoterpenes</td>
<td>869.6</td>
<td>353.6</td>
</tr>
<tr>
<td>Sesquiterpenes</td>
<td>152.2</td>
<td>0.08</td>
</tr>
<tr>
<td>Others</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>1,263.0</td>
<td>504.8</td>
</tr>
</tbody>
</table>

US SunDragon (ARS)
“Clementine x Minneola ‘LB 8-9’: typical mandarin flavor if harvested at the correct maturity”
Consumer Surveys (2008)
Conducted by IPSOS Reid for University of Florida, Funded by FDOC

- Chicago, Baltimore, Tampa (153 participants total)
- 15 hybrids & varieties tested over 3 time periods to cover maturities
- Sugar Belle® ranked 1st for general, and 3rd for sensory attributes

**Sweetness**

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<table>
<thead>
<tr>
<th></th>
<th>Total (n=153)</th>
<th>Adults (n=101)</th>
<th>Kids (n=52*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much too sweet</td>
<td>3%</td>
<td>1%</td>
<td>6%</td>
</tr>
<tr>
<td>A little too sweet</td>
<td>7%</td>
<td>5%</td>
<td>12%</td>
</tr>
<tr>
<td>Just Right</td>
<td>69%</td>
<td>69%</td>
<td>73%</td>
</tr>
<tr>
<td>A little not sweet enough</td>
<td>18%</td>
<td>17%</td>
<td>19%</td>
</tr>
<tr>
<td>Not at all sweet enough</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
</tr>
</tbody>
</table>
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‘Not sweet enough’
Total : 21%

From House and Gao, 2009 report
Could HLB-Tolerant Mandarins be Blended?

LB8-9 mandarin: Sugar Belle® (SB)

Sweet orange (O) cultivars: Hamlin (H) & Valencia (V)

Two sensory studies (spring & summer) on consumer preference and acceptance

5 different citrus juice blends

- 100% SB
- 100% O (H in summer, V in spring)
- 10% SB/90% O
- 50% SB/50% O
- 100% NFC-OJ
Consumers Prefer SB/O Juice over Pure OJ (Appearance & Flavor)

50% Sugar Belle®/ 50% Hamlin

Figure 1A. Overall ratings (Spring)

* Different letters within groups indicate significant differences (p <0.05).
Consumers Prefer SB/O Juice over Pure OJ (Appearance & Flavor)

**Figure 1B. Overall ratings (Summer)**

* Different letters within groups indicate significant differences (p < 0.05).
Consumer preference is positively correlated with WTP.

Consumers are willing to pay an average of 50 cents more for 50/50 and 90/10 blended juice than commercial OJ.

Figure 2. Willingness-to-Pay (WTP) for sample citrus juice blends (52 FL oz)
Figure 3. Willingness-To-Pay (WTP) for different citrus juice blends (52 FL oz)

Figure 4. Consumption habits of Tangerine/Mandarin juice
Up to 30% TJ Blending Considered as OJ

Figure 5. Orange juice label perception on citrus juice blends
Orange and Mandarin Are Genetically Related

- Pure mandarins (Type 1)
- Early-admixture mandarins (Type 2)
- Late-admixture mandarins (Type 3)

Introgression

Pummelos

Sweet orange

(Wu et al., 2018)
Aroma Is the Key

Orange juice
Mandarin juice

Close nose
Open nose

Flavor perception
Which one is orange?

(Feng et al., 2018)
Aroma Is the Key

The aroma played a key role in the differentiation of orange flavor and mandarin flavor

(Feng et al., 2018)
An image illustrating Gas Chromatography-Mass Spectrometry/Olfactometry for aroma identification. The diagram shows a juice sample being introduced into a GC column, with the sniffing port allowing odors to be perceived. The chromatogram displays peaks for linalool, α-pinene, and octanal, indicating their presence in the aroma profile.

(Feng et al., 2018)
Determine the Most Aroma-Active Compounds

SPME-AEDA

Solid Phase MicroExtraction-Aroma
Extract Dilution Analysis
Flavor Dilution (FD) factor

FD=1  FD=5  FD=10  FD=500
1:5 dilute  1:10 dilute  1:500 dilute
(Feng et al., 2018)
Differences in Key Aroma Profiles

Orange-like aroma
- Ethyl butanoate
- Ethyl 2-methylbutanoate
- Acetaldehyde

V.S.

Mandarin-like aroma
- (E,E)-2,4-Decadienal
- α-Pinene
- Linalool
- Limonene
- Octanal

(Feng et al., 2018)
Orange-like Mandarin

Juice of Orange-like Mandarin (6-2-55)

Flavor perception
Orange OR Mandarin

<table>
<thead>
<tr>
<th>Sensory results</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange</td>
<td>11</td>
</tr>
<tr>
<td>Mandarin</td>
<td>4</td>
</tr>
<tr>
<td>Not sure</td>
<td>1</td>
</tr>
</tbody>
</table>

(Feng et al., 2018)
Most mandarins are closely grouped together. Bitter and sour attributes are highly correlated with mandarins. Some of Orange-like Mandarin (O) are grouped closely with oranges. Mandarins (O) are highly correlated with sweet, fruity/floral and citrusy attributes.

(Feng et al., 2021)
Figure 7. Loading plot of the PCA performed from the sensory attributes and selected chemicals in mandarins

(Feng et al., 2021)
Flavor Compounds in Orange-Like Mandarins

Figure 9. Loading plot of the PCA performed from the sensory attributes and selected chemicals in orange-like mandarins

(Feng et al., 2021)
Potential Use of Mandarins/Mandarin Hybrids

- Improve flavor quality of juice
- Develop consumer-accepted varieties through breeding based on the preferred flavors
The Teams

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

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Horticulture Breeding

Flavor Chemistry & Sensory

Flavor Chemistry Sensory & Consumer Studies
AGFD Symposium: Citrus Flavor in the Omics Era

Yu Wang & Anne Plotto co-Organizers
Thank You!

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UF/IFAS
UNIVERSITY of FLORIDA