Sensory Evaluation and Product Concept Testing

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Department of Food Science
Why are they important?

Most new product introductions fail (AC Nielsen)

Why do they fail?
- Consumers don’t / can’t buy them
- They don’t generate sufficient revenues

Why?
- not relevant / valuable
- not new / distinctive
- not fashionable / fit with consumer style
Factors contributing to Failure

- Several factors relate to competencies and responsibilities
  - lack of consumer value
  - poor cooperation between functional groups (Marketing & R&D)
  - too much inward (rather than outward) looking
  - lack of consideration of real world competition
  - up-front home work
  - voice of the consumer (VOC)
  - sharp, stable and early product definitions
  - go / no go decision points / gates

- Too conservative; too close to what is already out there
  - methodology too much optimization – focused?
  - lack of precise tools for outside the box?
Sensory and the product Development Process

Performance evaluation

Idea generation

Idea Screening

Concept creation

Business/legality analysis

Product/Marketing development

Market Test

Reposition/Extension/Retire

Commercialization

Performance evaluation

Idea

Market adoption

Business feasibility
Focus Groups
- Group discussions
- 10-12 participants
- Moderator
- Guided Script
- 1-2 hours

Consumer Interviews/ Surveys
- Greater number of participants
- Assess satisfaction with current products
- Identify consumer needs/ trends

From Delgado, 2010
Sensory in product development

Discriminant Tests (e.g. triangle, duo-trio)
- Determine difference between two samples
- e.g. Reformulation new vs. current ingredient
- Product matching

Difference Tests
Can you discriminate between two very similar and confusable stimuli?

Prototypes evaluation, comparison and optimization

From Delgado, 2010
Sensory in product development

Descriptive Analysis (e.g. Spectrum, Tragon, Generic)

- Sensory characterization of samples
- Development of language to describe products (lexicon)
- Identification of differences/similarities among products
- Trained panelists

Prototypes evaluation, comparison and optimization

From Delgado, 2010
Sensory in product development

Hedonic Tests (e.g. preference, acceptance, intend to purchase)

- Understand consumer acceptance of products
- Measure attitudes
- Identification of segments
- Selection of best prototypes or directions for optimization

Prototypes evaluation, comparison and optimization

Market Testing

From Delgado, 2010
Quantitative methods are used to evaluate the response of consumers and should include larger panels (75-500).

The methods vary widely and can be used to evaluate:

- Preference
- Overall degree of liking
- Liking for specific sensory attributes (texture, flavor, appearance)
- Diagnostics for sensory attributes (JAR)
Hedonic Scales

- The 9-point verbal hedonic scale
- What is your overall impression of this product?

Like extremely
Like very much
Like moderately
Like slightly
Neither like nor dislike
Dislike slightly
Dislike moderately
Dislike very much
Dislike extremely

Overall consumer impression of products usually quantified on hedonic scale

- Hedonic ratings only because consumers cannot explain what they like
- Others have consumers rate specific attributes for intensity or appropriateness

Intensity or appropriateness ratings used to explain consumer hedonic ratings
Diagnostic Scales

Just Right Scales

Implied Just Right Scales

Please indicate your opinion about the following characteristics:

Gravy color
- Too light
- Just right
- Too dark

Amount of vegetables
- Too few
- Just right
- Too many

Amount of beef flavor
- Too low
- Just right
- Too high

Amount of saltiness
- Too low
- Just right
- Too high

Spiciness
- Too low
- Just right
- Too high

Thickness of gravy
- Too thin
- Just right
- Too thick

1. Color
   - Much too light
   - Much too dark

2. Cola flavor
   - Much too weak
   - Much too strong

3. Citrus flavor
   - Much too weak
   - Much too strong

4. Sweetness
   - Not at all sweet enough
   - Much too sweet

5. Thickness
   - Much too thin
   - Much too thick

6. Carbonation
   - Not at all carbonated enough
   - Much too carbonated
Choice of test

Monadic (marketing) or Sequential Monadic (R&D)

No presentation order effect

Sequential monadic allows the identification of consumer segments and the opportunity for product optimization
Methods for Optimization
How sensory attributes drive liking

- Liking vs. sensory level
  - Quadratic function
  - Identify optimal sensory level
  - Target landmarks for development
Sensory segments: How do you identify a true opportunity?

- Consumers show different liking patterns
- Identify preference segments
- Discover new niches
Preference Mapping

- Preference mapping
  - category of methods
  - understand the relationship between product liking and their sensory properties
- Can be used for several purposes including improving or optimizing existing products
Mapping methods yield a graphical representation of consumer preference and/or sensory differences for a set of products.

Consumers evaluate 6 or more products.

External versus Internal Preference Mapping:
- Some competitor products
- Some potential prototypes
**Context of Preference Mapping**

- **Consumer panel** assesses the products for liking
- **Set of competitive products** described in sensory terms by **Trained panelists**

**Hedonic Scores**

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>...</th>
<th>Cn-1</th>
<th>Cn</th>
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<tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Statistical modeling**

- **K** = number of products
- **T** = number of sensory attributes
- **N** = number of consumers

**Sensory Profiles**

<table>
<thead>
<tr>
<th>P1</th>
<th>S1</th>
<th></th>
<th></th>
<th>S1</th>
<th></th>
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<tr>
<td>P2</td>
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<tr>
<td>Pk</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

From P. Schlich
# Internal vs. External

<table>
<thead>
<tr>
<th>Internal preference analysis</th>
<th>External preference analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stimulus location based on liking (hedonic data drives orientation of the map)</td>
<td>• Stimulus locations based on similarity in sensory properties (sensory data drive orientation of the map)</td>
</tr>
<tr>
<td>• Sensory attributes can be fitted into preference space afterwards</td>
<td>• Preference data can be fitted into fixed space afterwards</td>
</tr>
<tr>
<td>• First dimension explains maximum variability in hedonic data</td>
<td>• First Dimension explains maximum variance in sensory attribute descriptions</td>
</tr>
</tbody>
</table>
Mapping perceptions or preferences?
Basics on Internal Preference Mapping
IPM Data

- Derives a multidimensional representation of products and consumers according to preference patterns
- Data used is liking data (e.g. 9-pt hedonic scale scores for overall impression)
IPM Data

Consumers (j,k)  
Products (i,n)  

From White Corn Tortilla Chips pages 9-18 in Multivariate and Probabilistic Analyses of Sensory Science Problems, Meullenet et al. 2007
Each dot represents a consumer

Shows significant segmentation of consumers

Direction of increased liking

MDPREF

PC1 (27.75%)

PC2 (17.48%)

P1

P2

P3

P4

P5

P6
Identifying Segments: Cluster analysis

- A group of multivariate techniques whose primary purpose is to group objects based on the characteristics they possess.
- Groups objects (respondents, products, variables, etc.) so that each object is similar to the other objects in the cluster and different from objects in all the other clusters.
Basic Concept

Between-Cluster Variation = Maximize

Within-Cluster Variation = Minimize
A Simple example

From Oupadissakoon and Dooley, 2008
A Simple example
A Simple example

From Oupadissakoon and Dooley, 2008
Effect of Centering

- For the raw data, the pattern of preference is the same.
- Scaling effect not very interesting.
- For centered data, P3 is favorite for the 1 cluster and P1-P2 favorite for the other. More interesting.
Internal Preference Mapping

Strengths

- Consumer data is the starting point of the analysis..after all, it is called **preference mapping**
- Allows the representation of consumer segmentation

Weaknesses

- The consumer data can be poorly represented by first 2-3 dimensions
- Consumers may like products equally but products are different sensorily (Optimization?)
- Not as fully researched as external mapping
Basics on External Preference Mapping
## Sensory Space

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>...</th>
<th>St-1</th>
<th>St</th>
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<tbody>
<tr>
<td>1</td>
<td>2.5</td>
<td>10.3</td>
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<td>7.0</td>
<td>10.1</td>
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<td>13.5</td>
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<tr>
<td>3</td>
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<td>8.8</td>
<td>1.1</td>
<td>7.5</td>
<td>14.2</td>
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<tr>
<td>4</td>
<td>5.2</td>
<td>6.6</td>
<td>2.0</td>
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<td>6.8</td>
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<tr>
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<td>7.0</td>
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<td>5.1</td>
<td>6.8</td>
<td>12.9</td>
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<tr>
<td>7</td>
<td>9.0</td>
<td>9.9</td>
<td>0.2</td>
<td>6.9</td>
<td>12.1</td>
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<tr>
<td>8</td>
<td>9.0</td>
<td>9.9</td>
<td>0.2</td>
<td>6.9</td>
<td>12.1</td>
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<tr>
<td>9</td>
<td>2.5</td>
<td>2.2</td>
<td>0.5</td>
<td>7.4</td>
<td>13.5</td>
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<tr>
<td>10</td>
<td>1.3</td>
<td>7.7</td>
<td>1.0</td>
<td>7.5</td>
<td>14.5</td>
</tr>
<tr>
<td>11</td>
<td>1.8</td>
<td>6.3</td>
<td>0.6</td>
<td>7.1</td>
<td>10.9</td>
</tr>
</tbody>
</table>

**Principal Component Analysis**

- thick
- creamy
- sweet
- strawberry
- smooth
- dairy
- sour
### Fitting consumers in the sensory space

<table>
<thead>
<tr>
<th>Model</th>
<th>Formula</th>
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</thead>
<tbody>
<tr>
<td><strong>Quadratic Surface Model</strong></td>
<td>( OL = \sum_i a_i PC_i + \sum_i b_i PC_i^2 + \sum_{ij} c_{ij} PC_i PC_j )</td>
</tr>
<tr>
<td><strong>Vector Model</strong></td>
<td>( OL = \sum_i a_i PC_i )</td>
</tr>
<tr>
<td><strong>Circular Model</strong></td>
<td>( OL = \sum_i a_i PC_i + \sum_i b_i=\text{constant} PC_i^2 )</td>
</tr>
<tr>
<td><strong>Elliptical Model</strong></td>
<td>( OL = \sum_i a_i PC_i + \sum_i b_i PC_i^2 )</td>
</tr>
</tbody>
</table>
Four Types of Consumers

- Expressing Liking
- Expressing Dislike
- non-discriminator
- Eclectic
Known as the Danzart method

Surface response model used to fit individual consumers

Acceptable area for individuals identified based on predicted values

All consumer overlaid=density of satisfied consumers
External Preference Mapping

Strengths

• Very well researched
• Nice maps including density maps of satisfied consumers (Danzart)

Weaknesses

• Representation of products based on sensory properties not necessarily driving liking
• Resulting in poor consumer fit
• Use of quadratic models tend to overfit data
Alternative Data

Consumer intensity ratings, cata
Quantitative consumer research is a key tool in R&D.

Overall consumer impression of products usually quantified on hedonic scale:
- Hedonic ratings only because consumers cannot explain what they like
- Others have consumers rate specific attributes for intensity or appropriateness

Traditionally, sensory properties have been measured by trained panelists.

Intensity or appropriateness ratings used to explain consumer hedonic ratings.
Set of competitive products

Trained panelists describe the products in sensory terms

Sensory Profiles

Hedonic Scores

Consumer panel assesses the products for liking

The OP&P way!

Statistical modeling

\( K = \text{number of products} \)
\( T = \text{number of sensory attributes} \)
\( N = \text{number of consumers} \)

Consumers describe the products in sensory terms

Van Trijp, Punter, Mickartz and Kruithof, 2007, FQP 18:729-740
Consumer Intensity Ratings

To answer the question, click any point on the line scale which best represents how you feel about the sample. You may use the ENTIRE scale.

How intense is the orange color in the sample you just tasted?

Sample 392

Weak | Strong

What is your ideal intensity of orange color in orange juice?

Sample 392

Weak | Strong

How much orange flavor is in the sample you just tasted?

Sample 392

Weak | Strong

What is your ideal intensity of orange flavor in orange juice?

Sample 392

Weak | Strong

Question 3 of 7
Sample 1 of 2
Preference mapping with consumer sensory profiling

- Sensory profiling with consumers actually works! An orange juice external preference shows that consumer liking scores were well fitted ($R^2=0.73$) to a sensory space derived from consumer intensity ratings.
Stability of Consumer data

This plot represents consumers’ stated ideal products based on ideal intensity ratings given to 9 orange juices by 100 consumers.

Ideal intensity ratings vary by consumers but seem to be reproducible across the samples tested.

This clearly shows that consumers have the ability to rate intensities in a reproducible manner.
Ballots with intensity ratings can become very cumbersome when many products are evaluated.

Intensity scaling can be a difficult concept for consumers.

Intensity or appropriateness questions can have an impact on hedonic ratings.
CATA is a compromise between only liking and asking intensity ratings.

Check **all attributes** that describe this sample:

- Buttery
- Sweet
- Milk/dairy flavor
- Custard/eggy flavor
- Corn Syrup
- Artificial vanilla
- Natural vanilla
- Creamy Flavor
- Soft
- Hard
- Gummy
- Icy
- Creamy/Smooth
Previous CATA research

Type of methodology allowing a more instinctive description of the main sensory properties of the product tested

Type of question which can be about attributes, product usage or concept fit

<table>
<thead>
<tr>
<th>Product Attributes</th>
<th>Concept Deliverables</th>
<th>Occasion/Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Indulgent</td>
<td>As a meal</td>
</tr>
<tr>
<td>Salty</td>
<td>Energizing</td>
<td>As a snack</td>
</tr>
<tr>
<td>Creamy</td>
<td>Comforting</td>
<td>While driving</td>
</tr>
<tr>
<td>Soft</td>
<td>Artificial</td>
<td>Watching TV</td>
</tr>
<tr>
<td>Tough</td>
<td>Bland</td>
<td>After exercising</td>
</tr>
</tbody>
</table>

Advantages and uses of check-all-that-apply response compared to traditional scaling of attributes for salty snacks.

J. Adams, A. Williams, B. Lancaster, M. Foley; Frito Lay, USA Rose Marie Pangborn Sensory Science Symposium, 2007
Multiple Factor Analysis

The counts for each of 13 ice cream attributes in a check-all-that-apply question were compared to the descriptive profiles via Multiple Factor Analysis (MFA), using FactoMineR in R ©2008, v.2.6.2.
MFA: CATA and Descriptive

Overall good agreement between sensory and CATA profiles

Agreement for icy, sweet, buttery, soft and rate of melt

Correlation circle

Dim 1 (31.96 %)

Dim 2 (19.24 %)
MFA on product & ideal configurations

Product configurations not identical but similar

Ideal location fairly stable and closest to F and A

Greatest disagreement among methods for products J, F and A

Individual factor map

Dim 1 (46.32 %)

Dim 2 (34.24 %)

Descriptive
CATA
Internal
Group Ideal closest to products Blue Bell and Best Choice

78% of consumers satisfied by the Ideal

Average $R^2$ for consumers $= 0.61$
Descriptive based external map

Ideal Point closest to Eddy’s

Average $R^2=0.59$ for consumers

76% of consumers satisfied by this ideal
Consumers can be used to describe food products and data used for preference mapping studies.

- Intensity rating given by consumers are reproducible.
- CATA attribute data applied to preference mapping gave similar results to internal and external preference mapping.
Alternative Modeling Methods

Ideal Point Modeling, Unfolding (Prefscal)
Ideal Point Mapping

Point of maximum density in the sensory space taken as group ideal

If correlation not different from the minimum correlation this second location is added to the acceptable region of the sensory space for a consumer.

Significance of the correlation can be assessed (defined by $\alpha = 0.05$)

Correlation between the hedonic scores and the product distances can easily be calculated.

Correlation should be negative: ideal closest to products with high OL.

Significance of the correlation can be assessed (defined by $\alpha = 0.05$).

Correlations for the neighboring points in the grid are statistically compared to minimum correlation. If correlation not different from the minimum correlation this second location is added to the acceptable region of the sensory space for a consumer.

Individual maps overlaid to yield final density map. Point of maximum density in the sensory space taken as group ideal.
The unfolding model is a geometric model to deal with preference and choice data.

Locates individuals and alternatives (products) in a joint space.

Has the advantage of representing individual ideals in a geometric fashion.

Useful for defining ideal product.
Unfolding degenerate solution
Busing, Groenen and Heiser (2005) proposed a penalty approach and succeeded in avoiding degeneracy.
PCA vs. Prefscal

- Based on product configurations from PCA and Prefscal
- EDIPM applied
- Ideal point defined as that minimizing the correlation between distances to the objects and hedonic scores ($R_{\text{min}}$)
- PREFSCAL allows to better fit consumers as $R_{\text{min}}$ distribution is shifted to greater $|R_{\text{min}}|$
- Better estimation of group ideal and ideal sensory profiles

![Graph showing PCA 2D EDIPM, PCA 3D EDIPM, and UNFOLDING 3D EDIPM compared to Rmin values.](image)
Ideal Points: Unfolding is best!

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean Difference</th>
<th>t-Ratio</th>
<th>DF</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfolding/3D</td>
<td>-0.7311</td>
<td>-7.65254</td>
<td></td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Internal/PCA/3D</td>
<td>-0.7012</td>
<td></td>
<td>1639</td>
<td></td>
</tr>
<tr>
<td>External/PCA/3D</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>External/PCA/2D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal/Unfolding/3D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- N = 1650
Adding a third dimension to preference mapping problems creates problems with the representation of ideal points and group ideals.

Consumer ideal points and products represented in a 3 dimensional scatter plot.

Lacks actionability.
Representation of 3D maps

- Adding a 3rd dimension complicates the representation of maps, especially when density of likers are overlaid on the maps.

- The same representations can be achieved using either the internal or external framework.

- This makes internal maps much more user friendly and equivalent in output quality to external maps.
Ideal Vanilla?

<table>
<thead>
<tr>
<th>Attribute</th>
<th>LSA</th>
<th>Density Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>8.96</td>
<td>8.31</td>
</tr>
<tr>
<td>Bitter</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>Sour</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Salt</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>Vanilla</td>
<td>5.70</td>
<td>5.16</td>
</tr>
<tr>
<td>Cooked Milk</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Milky</td>
<td>3.06</td>
<td>3.20</td>
</tr>
<tr>
<td>Butterfat</td>
<td>4.46</td>
<td>4.56</td>
</tr>
<tr>
<td>NFDM</td>
<td>0.12</td>
<td>0.15</td>
</tr>
<tr>
<td>Caramelized</td>
<td>2.35</td>
<td>1.82</td>
</tr>
<tr>
<td>Oxidized</td>
<td>0.63</td>
<td>0.56</td>
</tr>
<tr>
<td>Woody</td>
<td>0.95</td>
<td>0.43</td>
</tr>
<tr>
<td>Metallic</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>Astringent</td>
<td>4.12</td>
<td>3.72</td>
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<tr>
<td>Scoopability</td>
<td>10.44</td>
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<tr>
<td>Hardness</td>
<td>8.68</td>
<td>8.62</td>
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<tr>
<td>Denseness</td>
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</tr>
<tr>
<td>Degree of Ice</td>
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<td>1.31</td>
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<tr>
<td>Smoothness</td>
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<tr>
<td>Rate of Melt</td>
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<td>6.93</td>
</tr>
<tr>
<td>Mouth-coat</td>
<td>2.46</td>
<td>2.43</td>
</tr>
<tr>
<td>Elasticity</td>
<td>0.43</td>
<td>0.62</td>
</tr>
</tbody>
</table>

\( R^2 = 0.9937 \)
## Comparison of Best Choice to Optimal Profile

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Best Choice</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>8.50</td>
<td>8.31</td>
</tr>
<tr>
<td>Bitter</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>Sour</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Salt</td>
<td><strong>0.94</strong></td>
<td><strong>0.66</strong></td>
</tr>
<tr>
<td>Vanilla/Vanillin</td>
<td>5.26</td>
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<tr>
<td>Cooked Milk</td>
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<tr>
<td>Milky</td>
<td>3.23</td>
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<td>Butterfat</td>
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<tr>
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<tr>
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<td>0.20</td>
<td>0.20</td>
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<td>Astringent</td>
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<td>Scoopability</td>
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<tr>
<td>Hardness-Oral</td>
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<td>8.62</td>
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<tr>
<td>Denseness</td>
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<td>4.62</td>
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<td>Degree of Ice</td>
<td><strong>2.23</strong></td>
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<tr>
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<td>Rate of Melt</td>
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<td>Mouthcoat</td>
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<tr>
<td>Elasticity</td>
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<td><strong>0.62</strong></td>
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Final Thoughts

- It is about the consumer!
- They are hard to understand
- You don’t often have time to understand them
- We need to make time
- We need to become more sophisticated in the use of sensory and consumer tool

- Even when we develop vanilla ice cream
Muchas Gracias!