Sensory Directed Mixture Study of Beers Dry-Hopped with Cascade, Centennial, and Chinook

Thomas H. Shellhammer
Oregon State University
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Brewer’s Association Research Update
Sensory directed mixture study design

- Unhopped beer base
- 15 blends of Chinook, Centennial and Cascade for dry-hopping
  - % Cascade, % Chinook, % Centennial
- Descriptive analysis used to scale attributes of these blends
Raw Material and Processing Methodology
Brewing unhopped beer

Beer Specifications:
- Grist:
  - 85% Pale 2-row
  - 13.5% Carmel 10L
  - 0.5% Carmel 120L
- Original Gravity: 10.6 P
- Real Extract: 3.16 P
- BU = 20 mg/L (iso-extract)
- ABV = 4.8 % ABV
## Hops from 2015 harvest

- Whole cone hops procured from Crosby Hop Farm

<table>
<thead>
<tr>
<th></th>
<th>Cascade</th>
<th>Chinook</th>
<th>Centennial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Oil (mg/100g)</td>
<td>1.00</td>
<td>1.82</td>
<td>1.93</td>
</tr>
<tr>
<td>State Origin</td>
<td>OR</td>
<td>WA</td>
<td>ID</td>
</tr>
<tr>
<td>Farm</td>
<td>Crosby</td>
<td>Puterbaugh</td>
<td>Obendorf</td>
</tr>
</tbody>
</table>
Hop Preparation and Dry-Hopping Parameters

Hop Preparation For Dry Hopping
• Blended whole cone hops of Cascade, Chinook and Centennial*
  • Mixed and homogenized by grinding
  • Weighted into different ratios
  *sample also taken for oil analysis

Dry Hopping Parameters
• Added to 40 L finished beer at 3.8 g/L for 24 hrs
  • CO₂ blanket during addition
  • 18°C during dry-hopping
Blending & Filtration

- All dry-hop events occur in duplicate (40 L beer each)
  - Mixing pre-filtration
  - During filtration 2 kegs are blended during filtration into 1 keg
  - Oxygen monitoring

DH Event 1
Mix_1
25% Cas
25% Chin
50% Cent

DH Event 2
Mix_1
25% Cas
25% Chin
50% Cent

2 events per lot, 3.8 g/L 24 hrs

Mix_1
Filtration
DO
DO
Spec. 100 ppb
Carbonated
Oxygen Control – Bright beer tank dissolved oxygen

- **Dissolved oxygen bright beer specification limit - 100 ppb**
- **Average Bright Beer Tank DO ~86 ppb**
Sensory Methodology
Evaluations using draft beer

- Minimized total package oxygen
- Great for sensory testing implementation
Sensory Evaluation - Descriptive Analysis

Sensory protocol
• 9 panelists
  • (8 males, 1 female; 27-54 yrs. old)
• 18 products; 15 samples and 3 controls
• 3 replications
• 4 training sessions in advance

Attributes Assessed
Overall Hop Aroma Intensity
Citrus
Herbal/Tea
Tropical Fruity
Tropical Catty
Pine/Resinous/Dank
## Sensory Evaluation – Descriptive analysis external controls

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Unhopped base</th>
<th>Chinook</th>
<th>Centennial</th>
<th>Cascade</th>
<th>Sierra Nevada Pale Ale</th>
<th>Ballast Point Pineapple Sculpin</th>
<th>10-Barrel Joe</th>
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<tbody>
<tr>
<td>Overall Hop Aroma Intensity</td>
<td>0</td>
<td>6</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>10 - 11</td>
<td>14-15</td>
</tr>
<tr>
<td>Citrus</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>5 - 6</td>
</tr>
<tr>
<td>Herbal/Tea</td>
<td>0</td>
<td>3</td>
<td>4 - 5</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Tropical/Catty</td>
<td>0</td>
<td>4 - 5</td>
<td>2 - 3</td>
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<td>4 - 5</td>
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Results
Internal Replications - Difference Testing

- 3 **true** replications of the dry hop process (3 DH events)
- Difference testing (triangle testing).
  (NSD, p-value < 0.05, two-tail t-test)

<table>
<thead>
<tr>
<th>Hop Cultivar</th>
<th>Rep</th>
<th>Number of correct Responses</th>
<th>Total # of Participants</th>
<th>Z-Score</th>
<th>p-value (two-tail)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Centennial</td>
<td>Rep 1</td>
<td>13</td>
<td>40</td>
<td>-0.28</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Rep 2</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Chinook</td>
<td>Rep 1</td>
<td>16</td>
<td>40</td>
<td>0.73</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Rep 2</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Cascade</td>
<td>Rep 1</td>
<td>18</td>
<td>40</td>
<td>1.40</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Rep 2</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
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</table>
Hierarchical agglomerative clustering – Ward’s method

Using all descriptive attributes:
OHAI, Tropical Fruity, Tropical Catty, Citrus, Herbal/Tea, Pine/resinous/dank

100% Cascade
100% Centennial
100% Chinook

% Cascade, % Chinook, % Centennial
Principal Component Analysis - Covariance

Biplot (axes F1 and F2: 87.61 %)

- Pine/Resinous/Dank
- Tropical/Catty
- OHAI
- Herbal/Tea
- Citrus
- Tropical/Fruity
Principal Component Analysis - Covariance

Biplot (axes F1 and F2: 87.61 %)

100% Cascade
100% Chinook
100% Centennial

Tropical/Catty
Pine/Resinous/Dank
OHAI
Citrus
Herbal/Tea
Tropical/Fruity
Principal Component Analysis - Covariance

Biplot (axes F1 and F2: 87.61 %)

% Cascade, % Chinook, % Centennial
Principal Component Analysis - Covariance

Biplot (axes F1 and F2: 87.61 %)

- F1 (71.52 %)
- F2 (16.09 %)

Biplot showing:
- 100% Cascade
- 100% Chinook
- 100% Centennial

% Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial

50% Cascade

100% Chinook

100% Centennial

%100 Cascade
Ternary Plots - % Cascade, % Chinook, % Centennial

25% Cascade

100% Chinook

100% Centennial

%100 Cascade
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots - % Cascade, % Chinook, % Centennial
Ternary Plots – Colored by Ward Clusters

The diagram shows a ternary plot with points colored by Ward Clusters. The plot uses the following ratios:

- 0:100:0
- 0:100:0
- 0:75:25
- 25:75:0
- 0:50:50
- 25:50:25
- 50:50:0
- 0:25:75
- 25:25:50
- 50:25:25
- 75:25:0
- 0:0:100
- 25:0:75
- 50:0:50
- 75:0:25
- 100:0:0

The colors represent different Ward Clusters.

Chinook

Centennial

Cascade
Hierarchical agglomerative clustering – Ward’s method

Using all descriptive attributes:
OHAI, Tropical Fruity, Tropical Catty, Citrus, Herbal/Tea, Pine/resinous/dank
# Hop cultivar pedigrees

- Possible explanation for similarities?
- Chinook and Centennial have a common ancestor in Brewers Gold
- Cascade and Centennial have common ancestor in Fuggle

<table>
<thead>
<tr>
<th>Parentage of Cascade</th>
<th>Parentage of Centennial</th>
<th>Parentage of Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serebranka x Fuggle (Russian)</td>
<td>Fuggle x Unknown Male</td>
<td><strong>Brewers Gold</strong> x Utah wild male</td>
</tr>
<tr>
<td>(Russian)</td>
<td>Fuggle x Male</td>
<td>Petham x USDA 63012M Golding male</td>
</tr>
<tr>
<td>Fuggle x Unknown (English)</td>
<td>19040 Male x <strong>Brewers Gold</strong></td>
<td>Chinook</td>
</tr>
<tr>
<td>cascade</td>
<td>62025 Male x <strong>Brewers Gold</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OR6619-04 x unknown male</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Centennial</strong></td>
<td></td>
</tr>
</tbody>
</table>
Hop cultivar pedigrees

- Possible explanation for similarity in CICs?
- Chinook and Centennial have a common ancestor in Brewers Gold
- Cascade and Centennial have common ancestor in Fuggle
Hop cultivar pedigrees

- Possible explanation for similarity in CICs?
- Chinook and Centennial have a common ancestor in Brewers Gold
- Cascade and Centennial have common ancestor in Fuggle
Conclusions

• Similar overall dry-hop character/quality grouping is achievable by using hop blends

  No significant differences ≠ true similarity

• Hops blends produced greater dry-hop aroma intensity than single variety beers
I’d like to acknowledge...

- Scott Lafontaine – OSU doctoral student
- Dr. Cliff Pereira – Statistics Consultant
- Jeff Clawson – Pilot Brewery Manager
- Dr. Dan Vollmer
- OSU Undergraduates
  - Cameron McDaniel, Andrew Sutton
- Crosby Hop Farm
  - Staci Wallace
- BridgePort Brewing Company
  - Jeff Edgerton and Christian Engstrom
The International Brewers Symposium on Hops Flavor & Aroma in Beer
LaSells Stewart Center | Oregon State University
Corvallis, Oregon | July 25–28, 2017

Keynote presentations – Japan, Germany, Belgium, USA
Roundtable discussions – Dry-hopping, breeding/local, adv. products
Oregon hops farm tour – OSU breeding + Coleman Farms

hopsflavor2017.com