Influence of beer color on bitterness perception: A consumer-sensory study

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Purpose

- Determine the differences (if any) of using black malt vs. Weyermann Sinamar® during darkening beer color

- Determine whether beer color impacts the perceived bitterness of beer
Hypotheses

Throughout this study it is expected that:

I. There will be no chemical or perceived sensory difference between darkening beer with Sinamar and a dark malt during brewing.

II. Beer brewed with darkening agents will not be discriminable from un-darkened beer when color is obscured.

III. Consumers in Philadelphia (represented by Drexel University students, staff, and faculty) will perceive a darker colored beer as more bitter, despite color being the only changed variable.
Experiment 1: Darkening Techniques

Black malt used during brewing

Experiment 2: Color Perception
Experiment 1: Darkening Techniques
Methods

- **Beer Production**
  - Standard American Pale Ale
  - Base (L), Dark Sinamar (DS), Dark Grain (DG)

- **Biological/Chemical Analysis**
  - Microbiological Testing
    - Various wild yeast and bacteria medium
    - 25°C, 6% CO₂, 120 hours
  - Color (SRM)
  - Bitterness (IBU)
Methods

Sensory Evaluation

- Exempt Institutional Review Board (IRB) # 3 (Adult/Social Behavioral)

- Discrimination test
  - Yards Brewing Company (Philadelphia, PA)
  - Company employees \( (n = 24) \)
  - Y vs. DG, Y vs. DS
  - Data was analyzed following the normal approximation to the binomial distribution \( (p < 0.05) \)
    - With null-hypothesis chance of a correct answer \( p_0 = 1/3 \)
# Results

## Biological/Chemical Analysis

- Based on gravity readings all ABV ≈ 5.5%

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>DG</th>
<th>DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWYM</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>LCSM</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>WLD</td>
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<tr>
<td>HLP</td>
<td>-</td>
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</table>

<table>
<thead>
<tr>
<th>Color (SRM)</th>
<th>L</th>
<th>DG</th>
<th>DS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.4 ± 0.2</td>
<td>54.0 ± 0.3</td>
<td>54.4 ± 0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bitterness (IBU)</th>
<th>L</th>
<th>DG</th>
<th>DS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>43.4 ± 0.8</td>
<td>44.0 ± 0.9</td>
<td>43.7 ± 0.2</td>
</tr>
</tbody>
</table>
Results

Sensory Evaluation

- 24 subjects participated in 2 different triangle tests
- 1-tailed (upper) critical number of correct decisions for a binomial distribution with $p_0 = 1/3$ and $n = 24$ is 13 correct responses
- L vs. DG: 12/24
- L vs. DS: 9/24
- There is not evidence of significant discriminability between the Y and DG or Y and DS beers
Conclusions

- The initial darkening test was completed to compare two potential methods to be used later in this study.
- Both the use of Sinamar and addition of black malt during brewing have been found to effectively darken beer color while remaining apparently flavor neutral (at normal-use levels).
- No statistically significant difference ($p < 0.05$) between darkening methods.
- Sinamar was selected for use throughout color perception testing for its ease of use.
Experiment 2: Color Perception
Methods

- **Beer Production**
  - Standard American Pale Ale
  - Darkened with Sinamar
  - Light Yellow (L), Medium Brown (M), Dark Black (D)

- **Biological/Chemical Analysis**
  - Microbiological Testing
    - Various wild yeast and bacteria medium
    - 25 °C, 6% CO₂, 120 hours
  - Color (SRM)
  - Bitterness (IBU)
  - Additional testing
    - Carbonation, fill, and pH
Methods

Sensory Evaluation

- Exempt Institutional Review Board (IRB) # 3 (Adult/Social Behavioral)
- Discrimination Test
  - Yards Brewing Company (Philadelphia, PA)
  - Company employees \( n = 21 \)
  - Three Blind Triangle Tests (L, M, and D) – repeated twice
- Data was analyzed following the normal approximation to the binomial distribution \( \phi < 0.05 \)
  - With null-hypothesis chance of a correct answer \( p_0 = 1/3 \)
Methods

- Consumer Test
  - Drexel University (Philadelphia, PA)
  - Faculty, staff, and students ($n = 85$)
  - Rate Taste Attributes
    - Bitter, sweet, sour, and salty taste
    - Scale from 1 to 15 (no taste to extreme taste)
  - Liking on 9-point hedonic scale
    - “dislike extremely” to “like extremely”
  - Demographic information
  - One-way analysis of variance (ANOVA) with repeated measures ($p < 0.05$)
    - Analyzed with “R” statistical program
Results

L      M      D
Results

- Biological/Chemical Analysis
  - Based on gravity readings all ABV ≈ 5.5%

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<thead>
<tr>
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<th>M</th>
<th>D</th>
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<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>M</th>
<th>D</th>
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</thead>
<tbody>
<tr>
<td>Carbonation (Volumes CO₂)</td>
<td>2.85 ± 0.03</td>
<td>2.81 ± 0.03</td>
<td>2.82 ± 0.02</td>
</tr>
<tr>
<td>Fill (mL)</td>
<td>646 ± 2</td>
<td>642 ± 3</td>
<td>645 ± 3</td>
</tr>
<tr>
<td>pH</td>
<td>4.31 ± 0.01</td>
<td>4.32 ± 0.03</td>
<td>4.40 ± 0.01</td>
</tr>
<tr>
<td>Color (SRM)</td>
<td>13.0 ± 0.2</td>
<td>30.7 ± 0.3</td>
<td>55.1 ± 0.4</td>
</tr>
<tr>
<td>Bitterness (IBU)</td>
<td>45.2 ± 0.3</td>
<td>45.2 ± 0.2</td>
<td>45.2 ± 0.1</td>
</tr>
</tbody>
</table>
Results

Sensory Evaluation

- **Discrimination Test**
  - 21 subjects participated in 3 triangle tests, replicated twice
  - Independence of repeated tested between subjects was tested
  - Statistically independent, results pooled
  - No results found to be significant
  - At two concentrations, Sinamar had no apparent impact on flavor profile of beer

<table>
<thead>
<tr>
<th>Triangle Test Samples</th>
<th>Replications (# correct)</th>
<th>Independent Replications?</th>
<th>Overall Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light vs. Dark</td>
<td>7/21</td>
<td>11/21</td>
<td>11 &lt; n_{crit} (=13): NS 18 &lt; n_{crit} (=20): NS</td>
</tr>
<tr>
<td>Light vs. Medium</td>
<td>8/21</td>
<td>4/21</td>
<td>8 &lt; n_{crit} (=10): NS 12 &lt; n_{crit} (=20): NS</td>
</tr>
<tr>
<td>Medium vs. Dark</td>
<td>8/21</td>
<td>9/21</td>
<td>9 &lt; n_{crit} (=13): NS 17 &lt; n_{crit} (=20): NS</td>
</tr>
</tbody>
</table>
Results

Sensory Evaluation

- Consumer Test
  - No significant impact of color on sweet, salty, sour, or liking ratings
  - Color had significant effect on perception of bitterness
  - Light yellow beer was perceived as most bitter
    - $F(2,164) = 5.15, \ p = 0.007$
Results

Sensory Evaluation

- Consumer Test
  - Further analysis through “expertise” groups
    - Based on demographic information (beer liking and consumption habits)
    - “Experts” $n = 51$, “Novices” $n = 34$
  - Bitterness perception effect by both expertise and beer color
    - Between-subjects variable (expertise): $F(1, 81) = 5.73, p = 0.019$
    - Within-subjects variable (color): $F(2, 162) = 5.18, p = 0.007$
    - “Novice” group perceived beer as more bitter in general
Effect of beer color and expertise level on perception of bitterness
Conclusions

- Beer can be darkened in color with both black malt or Sinamar with no detectable change in flavor.
- When color was visible, lighter yellow beer was perceived as significantly ($p < 0.05$) more bitter than a darker black beer.
  - “Novice” beer drinkers seemed to drive sensory results.
  - Experience played a significant role on beer perception.
Further Work

- Evaluate effect of color on other desirable flavors
  - “malty” or “fruity”
- Intensity of off-flavors
  - Diacetyl, acetaldehyde, trans-2-nonenal
- Style perception
  - Between or Within
- Expected flavors
- Bottles vs. cans
- Specific selection of participants
  - Beer drinking/liking habits, training, etc.
Acknowledgements

- Drexel University, Center for Hospitality and Sports Management
- Yards Brewing Company
- Dogfish Head Craft Brewery
Thank You! Questions?

Cheers!