Aroma Properties of Lager Beer
Dry-Hopped with Oxidized Hops

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Agenda

• Introduction & Background
• Experimental Approach
• Sensory Evaluation
  • Consumer Panel
  • Trained Panel
• Results & Discussion
• Industrial Implications
Justification & Rationale

• “Noble” Hop Aroma
• Based on research completed in the late 1980s, early 1990s
  • Oxidized compounds critical to Noble Hop Aroma (Peacock, 1980)
  • Storage stability is cultivar dependent (Foster, 1985)
  • Aged hops produce beer that is more “herbal” and “spicy” (Lam, 1986)
• Force Aging Studies are completed in other food systems
• What about hops?
  • Raw material chemical changes
  • Changes in beer characteristics as result of using oxidized hops as dry hops?
Oxidized Hallertauer Mittelfruh Hop Project Overview

Phase 1

Part I:
- Hallertauer Mittelfrüh (HHA) Raw Hops (2013)

Part II:
- Qualitative GC-MS with Retention Index (Spring 2013)
- Exploratory GC-O on Fresh/Oxidized Pellets (Spring 2013)

Phase 2

Part I:
- Consumer Study DH Lager Beer (Winter 2014)

Part II:
- Difference Testing DH Lager Beer (Winter 2014)
- Trained QDA DH Lager Beer (Spring 2014)
Introduction

Fall 2012 – Oxidized Hallertauer Mittelfruh Hop Pellets

Raw Material Instrumental Analysis
- SPME GC-O, GC-MS – Retention Index

Results Presented at 2013 ASBC Meeting – Tucson, AZ
Result of Pro-Oxidative Storage

Based on peak area “relative changes”

*Decrease:*
  - Myrcene

*Increase:*
  - Limonene
  - Geranyl Acetate*
  - Linalool Oxide*
  - Linalool
  - Caryophyllene Oxide
Qualitative Results of Pro-Oxidative Storage

**Outputs:**
- Generalized decrease in hydrocarbons
- Generalized increase in oxygenated fraction
- GC-O work revealed subjectively positive aroma changes in raw material

<table>
<thead>
<tr>
<th>Compound</th>
<th>Control</th>
<th>Oxidized</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>myrcene</td>
<td>3.0E+09</td>
<td>4.7E+08</td>
<td>84%</td>
</tr>
<tr>
<td>limonene</td>
<td>1.9E+08</td>
<td>2.5E+08</td>
<td>31%</td>
</tr>
<tr>
<td>geranyl acetate</td>
<td>ND</td>
<td>6.9E+06</td>
<td>***</td>
</tr>
<tr>
<td>linalool oxide</td>
<td>ND</td>
<td>5.6E+07</td>
<td>***</td>
</tr>
<tr>
<td>linalool</td>
<td>3.1E+08</td>
<td>4.8E+08</td>
<td>55%</td>
</tr>
<tr>
<td>β - caryophyllene</td>
<td>1.5E+09</td>
<td>1.5E+09</td>
<td></td>
</tr>
<tr>
<td>α - humulene</td>
<td>2.7E+09</td>
<td>2.6E+09</td>
<td></td>
</tr>
<tr>
<td>caryophyllene oxide</td>
<td>2.1E+07</td>
<td>1.0E+08</td>
<td>376%</td>
</tr>
</tbody>
</table>

- Changes occur in the raw material as a result of exposure to pro-oxidative conditions
- *Are these changes detectable when used in a lager beer system?*
Project Goal & Research Question

Part I: (Lager DH @ 150 g/hL)
Difference Tests:
• Can trained panelists detect a difference between oxidized and properly stored HHA DH beer

Consumer Evaluation:
• Assess level of consumer acceptance of lager beer prepared with oxidized HHA
• Determine the attributes consumers use to describe dry hop flavor

Part II: (Lager DH @ 380 g/hL)
Quantitative Descriptive Analysis:
• Trained Panelists
• Able to detect a difference
• Able to describe that difference
Part I: Beer Preparation & Dry Hopping

Grist Bill:
• 98% Great Western 2-row
• 2% acidulated

Yeast:
Wyeast 2126 (lager yeast)

Hop Addition(s):
Kettle: 15 ppm IAA
Dry-Hop: 150 g/hL – 72 hours, 15.5 C
  • Hallertauer Mittelfruh
  • Yeast present

Processing:
• Filtered post DH – Plate & Frame
• Carbonated (2.0 v/v CO₂ & Bottled)
Part I: Hop Treatments

Control: HHA Hops
• $N_2$ atmosphere/vapor lock bags
• -20 C storage

Oxidized: HHA Hops
• $O_2$ atmosphere/glass containers
• 37 C storage – two weeks
Part I - Sensory Methods

• Difference Test
  • Triangle Tests
  • 10 Trained panelists

• Consumer Test
  • Acceptance Test
    • 60 consumers
    • 9-point hedonic scale
  • Lexicon Usage
    • Describe hop aroma
Part I – Consumer Demographics

Age

- 21-24 years
- 25-30 years
- 31-35 years
- 36-40 years
- 41-45 years
- 46-50 years
- 51-55 years
- 56-60 years
- 61-65 years

Gender

- Female 52%
- Male 48%
Part I – Consumer Demographics

**Beer Consumption - General**

- At least 2 to 3 times per week: 31
- Once a week: 19
- Twice a month: 7
- Once a month: 1
- Once every 6 months: 1
- Less than once every 6 mos: 1
- Never: 0

**Beer Consumption - Lager**

- At least 2 to 3 times per week: 5
- Once a week: 17
- Twice a month: 12
- Once a month: 9
- Once every 6 months: 10
- Less than once every 6 mos: 5
- Never: 2
Part I: Attribute Recognition - *Fresh*

Citrus, Floral, Herbal, Woodsy, Grassy
Part I: Attribute Recognition - *Oxidized*

Citrus, Floral, Woodsy, Grassy
Part I: Attribute Recognition - Fresh v Oxidized

Difference in attribute recognition between treatments according to consumers
Part I - Sensory Results – Consumer Acceptance

Average Score (Oxidized) = 5.88
Average Score (Fresh) = 5.78

ANOVA (Fischer LSD) $p = .6983 - NSD$
Part I - Results

- **Consumer Acceptance (150 g/hL)**
  - NSD on acceptance

**Attribute Recognition**
- Citrus, Floral, Woodsy, Grassy, (Herbal)
- Consumers are using correct terminology

- **Triangle Tests (150 g/hL)**
  - 8 out of 10 trained panelists could detect a difference

**Differences** were only detected by trained panelists at this hopping rate
Part II: Beer Preparation & Dry Hopping

Grist Bill:
• 66.6% Great Western 2-row
• 32.5% Clear Sweet 95
• 2.0% acidulated malt

Yeast:
Wyeast 2126 (lager yeast)

Hop Addition(s):
Kettle: 15 ppm IAA
Dry-Hop: 380 g/hL – 72 hours, 15.5 C
• No yeast present
• Hallertauer Mittelfruh

Processing:
• Filtered post DH – Plate & Frame
• Carbonated (2.0 v/v CO₂ & Draft Dispense)
Part II: Hop Treatments

Control: HHA Hops
• \( N_2 \) atmosphere/vapor lock bags
• -20 C storage

Oxidized: HHA Hops
• \( O_2 \) atmosphere/glass container
• 37 C storage – two weeks

Super Oxidized: HHA Hops
• \( O_2 \) atmosphere/glass container
• Container replenished daily with \( O_2 \)
• 37 C storage – two weeks
Part II – Sensory Methods - Quantitative Descriptive Analysis

• Each sample was observed 54 independent times (6 reps x 9 panelists)

Attributes:

• Aroma:
  • Woody
  • Herbal
  • Floral
  • Fruity
  • Earthy
  • Sweaty

• Flavor
  • Metallic
  • Bitterness Intensity
Part II – Results - Quantitative Descriptive Analysis

![Graph showing the quantitative descriptive analysis of different odor profiles.

Categories include Woody, Metallic, Herbal, Sweaty, Earthy, and Fruity. The graph shows the intensity levels for each category for different conditions: Control, Oxidized, and Super Oxidized.](image-url)
Part II: Results - Summary

Trained Panelists - QDA (380 g/hL)

Significant Differences:
- Woody, Herbal, Metallic, Bitterness Intensity

Non Significant:
- Floral, Fruity, Earthy, Sweaty

Treatments:
- Impact of oxidation - plateau after 2 weeks
- No difference between Oxidized v. Super

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Control</th>
<th>Oxidized</th>
<th>Super Oxidized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woody*</td>
<td>1.74 (1.47)</td>
<td>2.93 (1.64)</td>
<td>2.85 (1.63)</td>
</tr>
<tr>
<td>Herbal*</td>
<td>1.57 (1.38)</td>
<td>2.78 (1.97)</td>
<td>2.52 (1.87)</td>
</tr>
<tr>
<td>FloralNS</td>
<td>1.37 (1.26)</td>
<td>2.09 (1.40)</td>
<td>1.78 (1.31)</td>
</tr>
<tr>
<td>FruityNS</td>
<td>1.91 (1.23)</td>
<td>2.74 (1.51)</td>
<td>2.39 (1.46)</td>
</tr>
<tr>
<td>EarthyNS</td>
<td>1.43 (1.28)</td>
<td>2.02 (1.27)</td>
<td>2.17 (1.54)</td>
</tr>
<tr>
<td>SweatyNS</td>
<td>0.63 (1.10)</td>
<td>1.04 (1.35)</td>
<td>1.24 (1.30)</td>
</tr>
<tr>
<td>Metallic***</td>
<td>2.37 (1.34)</td>
<td>3.74 (1.23)</td>
<td>3.57 (1.41)</td>
</tr>
<tr>
<td>Bitterness Intensity*</td>
<td>1.22 (1.71)</td>
<td>1.87 (1.71)</td>
<td>2.06 (1.97)</td>
</tr>
</tbody>
</table>
Results & Discussion

• Brewing trials in 1986 with oxidized HHA (Lam et. al) resulted in a beer that was more:
  • Herbal & Spicy
  • Dry-hop aroma attributes *woody* and *herbal* align with the previous work

• Instrumental Work (2012-2013)
  • Qualitative differences detected
  • *Decrease* in hydrocarbons & *increase* oxygenated compounds

• Chemical changes occur in the hop after exposure to pro-oxidative conditions – cultivar specific

• Oxidized HHA and “fresh” HHA contribute to no particular *level of acceptance* at 150 g/hL

• Trained panelists were able to discern qualitative differences

• DH lager beer with oxidized dry-hops, used at 380 g/hL is quantitatively different than control
Industrial Implications

• Storage conditions can impact hop quality – cultivar specific
  • Coincides with Sigma Value work (Foster – 1985)
• Qualitative changes that occur after exposing the hops to pro-oxidative conditions did not adversely impact the dry-hopped beer.
  • Aroma (increased Woody, Herbal character)
  • Flavor (increased bitterness intensity, metallic)
• Method to add hop derived nuance to lager beer
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