brewing with honey

Dr. Hugo Patiño, Director Technical Services, First Key Consulting
Genus *Apis*: The honey bee

- Originated in South and Southeast Asia
- 20,000 known species of bees. Only seven species of honey bees are recognized
- Distinguished by production/storage of honey and construction of nests/hives
An amazing insect. An amazing story.

- Only insect that produces food eaten by humans
- 6 legs, 2 compound eyes, 3 simple eyes, 2 pairs of wings, a nectar pouch and a stomach
- Wing speed of 200 beats per second
FROM NECTAR TO HONEY

**Step One:** Nectar extracted from flower by bee’s tongue and stored in the bee’s stomach

**Step Two:** Bee passes nectar to another bee, and another, and ….

**Step Three:** Nectar deposited in the honeycomb

**Step Four:** Bees fan the honeycomb with their wings to remove extra water from honey

**Step Five:** Bees seal the comb with beeswax
BEES MAKE HONEY. NOT MANUFACTURING FACILITIES.

2015 Honey Production in the United States
- Colonies producing honey: 2.66 million colonies
- Honey production: 157 million pounds
- Yield per colony: 58.9 pounds
- Price: $2.09 per pound (down from 2014 record high of $2.17 per pound)

Top Honey Producing States
- North Dakota
- South Dakota
- Florida
- Montana
- California

FROM THE PRODUCER TO YOUR BREWERY

Your local beekeeper: Bought direct or at the farmer’s market

Honey producer / supplier: Purchase by varietal or color in large quantities ranging from pails to rail cars

Imported honey: Roughly 66% of U.S. honey consumption
  • Vietnam
  • Argentina
  • India
  • Brazil
  • Ukraine
HONEY COMPOSITION

- 38.2% Fructose
- 31.0% Glucose
- 17.1% Water
- 7.2% Maltose
- 4.2% Trisaccharides & Other Higher Carbohydrates
- 1.5% Sucrose
- 0.5% Minerals, Vitamins, Enzymes
HONEY’S FLAVOR

Dependent on where the bees foraged / floral source.

300 varietals in the United States.
3,000 types of honey worldwide.

Potential to develop complete product line with different varieties of honey.
brewing with honey
BREWING WITH HONEY

1. The characteristics of honey from a brewer’s perspective

2. Points in the brewing process where honey is used

3. Example for a Honey Blonde

4. Q&A
CHARACTERISTICS OF HONEY

Carbohydrate Composition

• Honey contains approximately 82.4% carbohydrates

• Oligosaccharides account for about 3 to 4% of the weight of honey

• About 90 to 95% of the carbohydrates in honey are fermentable

• With about 17% moisture, it is stable: i.e. sugars do not ferment
CHARACTERISTICS OF HONEY

Carbohydrate Composition

<table>
<thead>
<tr>
<th></th>
<th>Average ( % )</th>
<th>Range ( % )</th>
<th>Std. Dev. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose</td>
<td>38.4</td>
<td>30.9 - 44.3</td>
<td>1.77</td>
</tr>
<tr>
<td>Glucose</td>
<td>30.3</td>
<td>22.9 - 40.8</td>
<td>3.04</td>
</tr>
<tr>
<td>Sucrose</td>
<td>1.3</td>
<td>0.3 - 7.6</td>
<td>0.87</td>
</tr>
</tbody>
</table>

- Fructose and glucose are monosaccharides
- Sucrose separates into fructose and glucose
CHARACTERISTICS OF HONEY

The total extract in honey, expressed as Gravity Units (GU) is typically in the range of 30 to 37.

For instance:

- California Orange Blossom (37)
- Wild Blackberry (33)
- Vetches (36)
- Bay Area Blend (34)
- Poison Oak (36)
- Orange Blossom (34)
- Buckwheat (36)
- Wild West Wildflower (33)
CHARACTERISTICS OF HONEY

Calculating the amount to add

Example:
• Honey Wheat with 20% honey
• Target wort gravity: 1.050
• Volume: 5 gallons
• Honey GU: 34

\[
\left( \frac{(1.050 - 1) \times 1000}{34} \right) \times 5 \times 0.2 = 1.47 \text{ lbs}
\]

(100% efficiency)
CHARACTERISTICS OF HONEY

The impact of GU variability when used at a small % of the total extract (e.g. 10 or 20%) is modest.

For instance, a change of 1 GU in honey (e.g. 33 vs 34):
• Will change wort OG by 0.07°Plato
• Will result in a change of 0.0003 units in finished wort gravity
• Will change the amount to add by about 0.04 lbs (for 5 gallon brew)
• Is equivalent to about a 2% change in malt extract (CG DB)
• Will change ABV by about 0.03%
### CHARACTERISTICS OF HONEY

#### Carbohydrate Composition

Comparing honey profile vs two examples of brewer’s wort:

<table>
<thead>
<tr>
<th></th>
<th>Honey</th>
<th>European Lager</th>
<th>British Pale Ale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose</td>
<td>46.2%</td>
<td>2.0%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Glucose</td>
<td>37.8%</td>
<td>8.9%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Sucrose</td>
<td>1.6%</td>
<td>2.2%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Maltose</td>
<td>8.8%</td>
<td>51.1%</td>
<td>41.3%</td>
</tr>
<tr>
<td>Maltotriose</td>
<td></td>
<td>12.5%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Maltotetraose</td>
<td></td>
<td>2.5%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Higher Sugars</td>
<td>1.8%</td>
<td>20.8%</td>
<td>24.7%</td>
</tr>
<tr>
<td>Fermentability</td>
<td>94.4%</td>
<td>76.7%</td>
<td>73.3%</td>
</tr>
</tbody>
</table>

Some brewer's wort sugar profile can be produced with a much higher fermentability (e.g. with the use of amyloglucosidase enzyme).
CHARACTERISTICS OF HONEY

Carbohydrate Composition

• Honey, therefore, will typically result in an increased Real Degree of Fermentation (RDF) in the finished beer, if the fermentable sugars are consumed by the yeast.

• If higher RDF becomes a concern, one can work on compensating through a modified mashing profile (e.g. moving some of the time spent at 140-150°F, to time spent at 158°F).
CHARACTERISTICS OF HONEY

Carbohydrate Composition

Simulating the fermentability impact of honey addition, example:

<table>
<thead>
<tr>
<th></th>
<th>Honey</th>
<th>Malt Wort</th>
<th>Final Wort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose</td>
<td>46.2%</td>
<td>2.0%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Glucose</td>
<td>37.8%</td>
<td>8.9%</td>
<td>11.8%</td>
</tr>
<tr>
<td>Sucrose</td>
<td>1.6%</td>
<td>2.2%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Maltose</td>
<td>8.8%</td>
<td>51.1%</td>
<td>46.8%</td>
</tr>
<tr>
<td>Maltotriose</td>
<td></td>
<td>12.5%</td>
<td>11.2%</td>
</tr>
<tr>
<td>Maltotetraose</td>
<td></td>
<td>2.5%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Higher Sugars</td>
<td>1.8%</td>
<td>20.8%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Fermentability</td>
<td>94.4%</td>
<td>76.7%</td>
<td>78.5%</td>
</tr>
</tbody>
</table>

Adding honey at a rate of 10% of the total extract, would increase fermentability by approximately 1.8%. 

CHARACTERISTICS OF HONEY

Carbohydrate Composition

Putting that fermentability change in context, here are three examples from the Brewers Association Beer Style 2015 Guidelines:

<table>
<thead>
<tr>
<th>Style</th>
<th>OG (High)</th>
<th>OG (Low)</th>
<th>FG (High)</th>
<th>FG (Low)</th>
<th>ADF (High)</th>
<th>ADF (Low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Stout</td>
<td>13.8°P</td>
<td>11.2°P</td>
<td>5.1°P</td>
<td>3.1°P</td>
<td>77.5%</td>
<td>54.5%</td>
</tr>
<tr>
<td>Blonde Ale</td>
<td>13.3°P</td>
<td>11.2°P</td>
<td>4.1°P</td>
<td>2.1°P</td>
<td>84.2%</td>
<td>63.4%</td>
</tr>
<tr>
<td>Vienna Lager</td>
<td>13.8°P</td>
<td>11.4°P</td>
<td>4.6°P</td>
<td>3.1°P</td>
<td>77.5%</td>
<td>59.6%</td>
</tr>
</tbody>
</table>

Addition of honey at rates of 10% or 20% of the total extract would not necessarily bring fermentability out of these Guidelines’ ranges.
CHARACTERISTICS OF HONEY

Color

- Honey is classified by the U.S. Department of Agriculture into seven color categories
- One challenge: no clear way to “translate” honey colors into equivalent wort color

<table>
<thead>
<tr>
<th>Honey Color</th>
<th>Pfund Scale (mm)</th>
<th>Absorbance @ 560 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water White</td>
<td>&lt; 8</td>
<td>0.0945</td>
</tr>
<tr>
<td>Extra White</td>
<td>9 - 17</td>
<td>0.189</td>
</tr>
<tr>
<td>White</td>
<td>18 - 34</td>
<td>0.378</td>
</tr>
<tr>
<td>Extra Light Amber</td>
<td>35 - 50</td>
<td>0.595</td>
</tr>
<tr>
<td>Light Amber</td>
<td>51 - 85</td>
<td>1.389</td>
</tr>
<tr>
<td>Amber</td>
<td>86 - 114</td>
<td>3.008</td>
</tr>
<tr>
<td>Dark Amber</td>
<td>&gt; 114</td>
<td>&gt; 3.1</td>
</tr>
</tbody>
</table>
CHARACTERISTICS OF HONEY

Polyphenol Level

- Darker honeys tend to have higher polyphenol content.
- However, the levels in honey provide a smaller contribution, compared to malt, to the final beer:

<table>
<thead>
<tr>
<th>Polyphenols in beer (low)</th>
<th>mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyphenols in beer (medium)</td>
<td>300</td>
</tr>
<tr>
<td>Polyphenols in beer (high)</td>
<td>400</td>
</tr>
<tr>
<td>Polyphenols added with honey (low)*</td>
<td>5</td>
</tr>
<tr>
<td>Polyphenols added with honey (high)*</td>
<td>8</td>
</tr>
</tbody>
</table>

*Assumes honey = 10% of the extract
CHARACTERISTICS OF HONEY

Nitrogen Compounds
• The levels are relatively low, compared to malted barley
• Levels of overall nitrogen compounds in honey are approximately 0.04% to 0.2%
• Levels of nitrogen in malt are typically in the range of 1.5% to 2.5% (dry basis)
• Overall, the use of honey as a partial replacement of malted barley will result in a decrease in the wort and final beer’s nitrogen content
• However, at low to moderate usage rates, honey usage would not represent a yeast nutrition issue
CHARACTERISTICS OF HONEY

Four major enzymes

**Invertase**: splits sucrose into simple sugars (fructose and glucose).

**Diastase / amylase**: breaks starches into sugars, dextrins. Its level was used as a marker to assess the heat exposure that honey has been subjected to.

**Glucose oxidase and catalase**:  
- Glucose oxidase results in the formation of gluconic acid, the principal acid in honey  
- It also forms hydrogen peroxide, good antibacterial but it may impact oxidation  
- Catalase decomposes hydrogen peroxide into water and oxygen
CHARACTERISTICS OF HONEY

Metals

Metal ion content in honey is high, relative to what is normally found in wort and beer.

<table>
<thead>
<tr>
<th>Metal</th>
<th>In Honey (mg/Kg)</th>
<th>In Malt (mg/Kg, dm)</th>
<th>In Wort (mg/L)</th>
<th>In Beer (mg/L)</th>
<th>In Hops (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>1100 - 21600</td>
<td>200 - 300</td>
<td>200 - 300</td>
<td>40 - 100</td>
<td>40 - 100</td>
</tr>
<tr>
<td>Ca</td>
<td>152 - 362</td>
<td>200 - 230</td>
<td>200 - 230</td>
<td>40 - 100</td>
<td>40 - 100</td>
</tr>
<tr>
<td>Mn</td>
<td>1 - 5</td>
<td>8 - 15</td>
<td>0.07 - 0.14</td>
<td>0.08 - 0.2</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Fe</td>
<td>136 - 407</td>
<td>10 - 60</td>
<td>0.1 - 0.5</td>
<td>0.02 - 0.3</td>
<td>15 - 25</td>
</tr>
<tr>
<td>Cu</td>
<td>13 - 35</td>
<td>2 - 7</td>
<td>0.02 - 0.4</td>
<td>0.02 - 0.1</td>
<td>35 - 45</td>
</tr>
<tr>
<td>Zn</td>
<td>31 - 106</td>
<td>10 - 15</td>
<td>0.1 - 0.3</td>
<td>0.00 - 0.02</td>
<td>35 - 45</td>
</tr>
</tbody>
</table>

How much of these metal ions would end up in the final beer will significantly depend on the point in the brewing process where the honey was added:

- Partial removal in the whirlpool
- Uptake by the yeast
CHARACTERISTICS OF HONEY

Microbial Profile

• Honey is not a sterile ingredient, it has microorganisms (yeast and bacteria)
• One of the sources of microorganisms are the bees. Recent work at NCSU Raleigh has began looking for yeasts carried by wasps than can bring new beer traits. Their first beer turned sour due to that yeast’s characteristics
• Beyond bees, secondary sources of microbes in honey are humans, equipment, containers and wind
CHARACTERISTICS OF HONEY

Microbial Profile

- Most bacteria and other microbes cannot grow or reproduce in honey (i.e. they are dormant, due to antibacterial activity of honey)
- It is only the spore forming microorganisms that can survive in honey at low temperature
- Honey diluted with water supports the growth of non-pathogenic bacterial strains
- Honey’s pH is low, around 2.8 to 4.5
HONEY USAGE IN BEER

Overview of honey usage in beer
• For different beer styles
• Usage in various points in the process
HONEY USAGE IN BEER

Overview of honey usage in beer

<table>
<thead>
<tr>
<th>Floral Source</th>
<th>Typical Color</th>
<th>Typical Flavor</th>
<th>Suggested Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clover</td>
<td>Light</td>
<td>Mild</td>
<td>Light, dry, sour beers, brown ale, stout, herb/spice beers</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Light</td>
<td>Mild</td>
<td>Ale and lagers</td>
</tr>
<tr>
<td>Sage</td>
<td>Light</td>
<td>Mild</td>
<td>Pale ale</td>
</tr>
<tr>
<td>Tupelo</td>
<td>Light</td>
<td>Distinct delicate</td>
<td>Ales and lagers</td>
</tr>
<tr>
<td>Orange Blossom</td>
<td>Light</td>
<td>Mild, heavy body</td>
<td>Ginger, spice beers, holiday beer, light beer, Belgian White</td>
</tr>
<tr>
<td>Raspberry</td>
<td>White to light</td>
<td>Delicate</td>
<td>Ales, spice beer, fruit beer</td>
</tr>
<tr>
<td>Blueberry</td>
<td>Medium to dark</td>
<td>Distinct, fruity</td>
<td>Spice, fruit beers, stouts</td>
</tr>
<tr>
<td>Wildflower</td>
<td>Medium to dark</td>
<td>Medium to strong</td>
<td>Pale ale, specialty beer</td>
</tr>
<tr>
<td>Industrial blend</td>
<td>Medium</td>
<td>Medium</td>
<td>Cream stout, porter</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Dark</td>
<td>Strong</td>
<td>Stout, porter</td>
</tr>
</tbody>
</table>
HONEY USAGE IN BEER

Overview of honey usage in beer

A variety of options for usage in various points in the process:

• In the kettle (late addition)
• During fermentation
• During maturation
• In conditioning (keg or bottle)
• In barrel aging
testing done
HONEY BLONDE ALE

Test Design

1. **Control Brew**: No honey addition, 100% malt. Carbonated, filtered and packaged and pasteurized.

2. **Test 1**: Brew with honey added *5 minutes prior to the end of wort kettle boil*. Carbonated, filtered, packaged and pasteurized.

3. **Test 2**: Brew with pre-pasteurized honey (PPH) added *at start of fermentation*. Carbonated, filtered, packaged and pasteurized.

4. **Test 3**: Brew with PPH added *at approximately 48 hours after the start of fermentation*. Carbonated, filtered, packaged and pasteurized.

5. **Bottle Conditioned**: Same beer as Control. Not filtered or carbonated. PPH honey added for bottle conditioning, not pasteurized.
HONEY BLONDE ALE

Testing Site: CMBTC

The capacity of this state-of-the-art brewery is 250 Litres, or about 750 bottles of beer.
## HONEY BLONDE ALE

The Honey Used in This Test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color (mm)</td>
<td>71 to 85</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>&lt; 18.5</td>
</tr>
<tr>
<td>pH</td>
<td>3.6 to 3.9</td>
</tr>
<tr>
<td>Average density (lbs/gal)</td>
<td>14</td>
</tr>
<tr>
<td>HMF (ppm)</td>
<td>&lt; 40</td>
</tr>
<tr>
<td>Distase activity</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>
HONEY BLONDE ALE

The Honey Used in This Test

Actual analysis (honey diluted to an approximately 12% solution).

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose (gr/L)</td>
<td>57.98</td>
</tr>
<tr>
<td>Glucose (gr/L)</td>
<td>60.94</td>
</tr>
<tr>
<td>Maltose</td>
<td>1.10</td>
</tr>
<tr>
<td>Maltotriose (gr/L)</td>
<td>7.17</td>
</tr>
<tr>
<td>Maltotetraose (gr/L)</td>
<td>0.04</td>
</tr>
</tbody>
</table>
HONEY BLONDE ALE

The Honey Used in This Test

Honey Solution (12 P)
HONEY BLONDE ALE

The Recipe Tested: Control

Original gravity: target 12.0°Plato (48 GU)
Final gravity: target 2.6°Plato (~ 10 GU)
BU: target 20
Color: target 4.5°SRM
ABV: target 4.6%
Carbonation: target 2.60 V/V
Malts:
• Malted wheat (10%)
• Crystal 15 Malt (5% to 10 % to hit color target)
HONEY BLONDE ALE

The Recipe Tested: Control

Hops:

60% of the BU from Magnum, added at the start of boil

40% of the BU from Willamette:

• 20% of the total BU added 30 minutes prior to kettle knockout

• The last 20% added 5 minutes prior to knockout
HONEY BLONDE ALE

The Recipe Tested - Mashing Temperatures:

Test Series I:
Control: Mash in at 153°F, rest for 24 mins. Ramp to 171°F.
Tests: Mash in at 153°F, rest for 15 mins, ramp to 160°F, rest until conversion, ramp to 171°F.

Test Series II:
All brews had the same mashing schedule: Mash in at 153°F, rest for 24 mins. Ramp to 171°F.
Fermentation:
• Yeast: WLP001
• Oxygenate wort to approximately 8 to 10 ppm
• Fermentation temperature: start at 63°F, with a free rise to 66°F. Hold for VDK reduction.. Crash cool to 0°C, maturation time 6 days
HONEY BLONDE ALE

The Recipe Tested: Bottle Conditioning

\[ H = 0.534 \times V_b \times (\Delta \text{CO}_2) \]

Where:

- \( H \) = honey to add (ounces)
- \( V_b \) = volume of beer to condition (gal)
- \( \Delta \text{CO}_2 \) = carbonation to be added (V/V)

For instance, if \( V_b = 5 \) gallons, and \( \Delta \text{CO}_2 = 1.8 \) v/v then

\[ H = 0.534 \times 5 \times 1.8 = 4.8 \text{ ounces}. \]
# HONEY BLONDE ALE

## Wort Carbohydrate Profile:

<table>
<thead>
<tr>
<th>Test Series I</th>
<th>Test Series II</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Honey @ kettle knockout</td>
<td>No Honey Addition</td>
<td>Difference (No Honey - Honey)</td>
<td>Honey @ kettle knockout</td>
<td>No Honey Addition</td>
<td>Difference (No Honey - Honey)</td>
</tr>
<tr>
<td>Maltotriose (%)</td>
<td>15.4%</td>
<td>18.4%</td>
<td>3.0%</td>
<td>14.4%</td>
<td>20.3%</td>
<td>5.9%</td>
</tr>
<tr>
<td>Maltose (%)</td>
<td>56.6%</td>
<td>64.1%</td>
<td>7.5%</td>
<td>59.7%</td>
<td>71.5%</td>
<td>11.8%</td>
</tr>
<tr>
<td>Glucose (%)</td>
<td>18.5%</td>
<td>16.2%</td>
<td>-2.3%</td>
<td>14.4%</td>
<td>8.1%</td>
<td>-6.4%</td>
</tr>
<tr>
<td>Fructose (%)</td>
<td>9.4%</td>
<td>1.2%</td>
<td>-8.2%</td>
<td>11.5%</td>
<td>0.1%</td>
<td>-11.3%</td>
</tr>
</tbody>
</table>
HONEY BLONDE ALE

Process Results (Test Series I).
Lower pH, color and final apparent extract seen for Test 1 vs Control:

<table>
<thead>
<tr>
<th>Replicate</th>
<th>Wort pH</th>
<th>Wort Color</th>
<th>AE of forced fermentation (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.24</td>
<td>6.58</td>
<td>2.32</td>
</tr>
<tr>
<td>2</td>
<td>5.28</td>
<td>5.82</td>
<td>2.35</td>
</tr>
<tr>
<td>3</td>
<td>5.26</td>
<td>6.66</td>
<td>2.26</td>
</tr>
<tr>
<td>Control</td>
<td>5.24</td>
<td>6.58</td>
<td>2.32</td>
</tr>
<tr>
<td>Test 1 (Honey 5' before KO)</td>
<td>4.96</td>
<td>5.62</td>
<td>2.06</td>
</tr>
<tr>
<td></td>
<td>5.23</td>
<td>5.42</td>
<td>2.08</td>
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<tr>
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<td>5.18</td>
<td>6.97</td>
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<tr>
<td>Difference (Test 1-Control)</td>
<td>-0.28</td>
<td>-0.96</td>
<td>-0.26</td>
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<td>-0.05</td>
<td>-0.4</td>
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<tr>
<td></td>
<td>-0.08</td>
<td>0.31</td>
<td>-0.12</td>
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</table>
HONEY BLONDE ALE

Process Results (Test Series II):
Minor fermentation rate differences observed.

Fermentations in Test Series II

Apparent Extract (P)

0 2 4 6 8 10 12 14

0 24 48 72 96 120 144

- Control (No Honey Added)
- Honey Added At End of Kettle Boil
HONEY BLONDE ALE

Process Results (Test Series II):
Minor fermentation rate differences observed.
### HONEY BLONDE ALE

#### End of Fermentation Beer Chemistry (Series I):

<table>
<thead>
<tr>
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<th>Control (No Honey Addition)</th>
<th>Honey Added At End of Boil</th>
<th>At Fermentation Start</th>
<th>At 48 hours of Fermentation</th>
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<tbody>
<tr>
<td>Apparent Extract (oP)</td>
<td>2.4</td>
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<td>2.2</td>
<td>2.4</td>
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<tr>
<td>Ethanol (% v/v)</td>
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<td>4.9</td>
<td>5.0</td>
<td>4.9</td>
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<td>ADF (%)</td>
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<td>RDF (%)</td>
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<td>Calculated OE (oP)</td>
<td>11.4</td>
<td>11.6</td>
<td>11.6</td>
<td>11.7</td>
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<tr>
<td>Real Extract (oP)</td>
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<tr>
<td>Ethanol (% w/w)</td>
<td>3.7</td>
<td>3.8</td>
<td>3.9</td>
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<tr>
<td>Color (srn)</td>
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<td>pH</td>
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<td>4.2</td>
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</table>
HONEY BLONDE ALE  Sensory Evaluation

Oxidation 6
Body 5
Sourness 4
Sweetness 3
Bitterness 2
Flavor Intensity 1
Palate 0
Esters
Sulphurs
Diacetyl
Phenols
Maltiness

Test 1
Test 2
Test 3
HONEY BLONDE ALE

Sensory Evaluation

- Oxidation
- Body
- Sulphurs
- Sourness
- Diacetyl
- Sweetness
- Phenols
- Bitterness
- Maltiness
- Flavor Intensity
- Palate
- Esters

Control

Test 1

Test 2

Test 3

Bottle Conditioned Control
HONEY BLONDE ALE

Conclusions

When used at a rate of 10% of the total extract, relatively small changes in beer chemistry were noted (higher fermentability, lower color, lower pH). Differences were larger for bottle conditioned.

Significant sensory differences were found, and these varied depending on the honey pre-treatment and point of use.
Areas of future research

• What is the minimum heat treatment needed (to inactivate enzymes and microorganisms) but retain as much of the flavor/aroma characteristics?
• A better understanding of the impact of metals in honey in finished beer.
• The use of (not heat-treated) honey in sour beers &/or barrel aged beers.
• The use of (not heat-treated) honey in keg or bottle conditioning.
• The role that honey can play in formulating more sessionable craft beers.
• Optimal storage conditions of honey in brewing applications.
QUESTIONS?