Wheat Beer Yeast and Fermentation
WHEAT BEER YEAST AND FERMENTATION

• Flavors and Aromas

• Brewing Techniques
Wheat beers are characterized specifically by:

‘spicy’
‘clove’
‘phenolic’

And generally as with other beers by different levels of:

‘fruity’
‘banana’
‘floral’
‘sulfury’
& others
The unique flavor of Wheat Beers comes from alcohols, esters, phenols as well as other compounds.
FU = \text{concentration in beer in mg/l} \quad \text{threshold in mg/l}

2 \text{ FU} = \text{Primary Flavor}

0.5 - 2.0 \text{ FU} = \text{Secondary Flavor}

< 0.5 \text{ FU} = \text{Tertiary Flavor}
Mainly produced during Primary fermentation

Fusel alcohols are produced through the metabolism of amino acids

Fusel alcohols are those other than ethanol

Common examples are isoamyl alcohol and phenyl ethyl alcohol

Increase complexity and fullness of beer at low level; harsh at high levels
# Higher Alcohols in Wheat Beers

## From the Literature

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Avg Value (ppm)</th>
<th>Characteristic Flavor or Aroma</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-propanol</td>
<td>18.80</td>
<td>fusel, solvent-like</td>
<td>?</td>
</tr>
<tr>
<td>2-methyl-1-propanol</td>
<td>36.50</td>
<td>alcohol, solvent-like</td>
<td>10-200 ppm</td>
</tr>
<tr>
<td>2-methyl-1-butanol</td>
<td>20.10</td>
<td>alcohol, solvent-like</td>
<td>10-65</td>
</tr>
<tr>
<td>(amyl alcohol)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-methyl-1-butanol</td>
<td>58.00</td>
<td>alcohol, banana</td>
<td>30-70</td>
</tr>
<tr>
<td>(isoamyl alcohol)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenyl ethyl alcohol</td>
<td>33.0</td>
<td>rose or rose oil</td>
<td>28-135</td>
</tr>
</tbody>
</table>
• Acetate ester excretion is rapid and complete after yeast growth complete

• Fatty acid ethyl esters take longer to produce

• Formed as a by-product of acetyl CoA and alcohols

• Most ale yeast produce lower levels of esters compared to lager yeasts under similar fermentation conditions

• Common examples are ethyl acetate, isoamyl acetate and ethyl hexanoate
<table>
<thead>
<tr>
<th>Ester:</th>
<th>Avg value (ppm)</th>
<th>Characteristic Flavor or Aroma</th>
<th>Threshold value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl acetate</td>
<td>32.0</td>
<td>solvent-like (acetone),</td>
<td>25-30</td>
</tr>
<tr>
<td>Isoamyl acetate</td>
<td>3.00-4.00</td>
<td>very fruity, banana</td>
<td>1.0-1.6</td>
</tr>
<tr>
<td>Hexanoic acid ethyl ester (ethyl caproate)</td>
<td>0.12</td>
<td>fruity, apple</td>
<td></td>
</tr>
<tr>
<td>Octanoic acid ethyl ester (ethyl caprylate)</td>
<td>0.25</td>
<td>fruity, winy</td>
<td></td>
</tr>
<tr>
<td>Decanoic acid ethyl ester (ethyl caprate)</td>
<td>0.05</td>
<td>fruity, winy</td>
<td></td>
</tr>
<tr>
<td>Phenyl ethyl acetate</td>
<td>0.98</td>
<td>rose</td>
<td></td>
</tr>
</tbody>
</table>
## OTHER ESTERS

<table>
<thead>
<tr>
<th>Ester:</th>
<th>Characteristic Flavor or Aroma</th>
<th>Threshold value (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl heptanoate</td>
<td>fruity, pineapple</td>
<td></td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>grape, apple</td>
<td>0.4</td>
</tr>
<tr>
<td>Isobutyl acetate</td>
<td>fruity, banana</td>
<td>0.4-1.6</td>
</tr>
</tbody>
</table>
• Increase in phenols follows the main and secondary fermentations

• Phenol-carbon acids are decarboxylated into phenols by yeast

• Weizen beer yeast can decarboxylate ferulic acid into 4-vinyl guaiacol

• Ferulic acid production occurs most successfully in mashing at 44°C and pH 5.7
# Phenolics in Wheat Beers from the Literature

<table>
<thead>
<tr>
<th>Phenolic substances:</th>
<th>Avg value (ppb)</th>
<th>Characteristic Flavor or Aroma (threshold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-vinyl guiacol</td>
<td>1500</td>
<td>clove-like (~1000ppb)</td>
</tr>
<tr>
<td>4-vinyl phenol</td>
<td>970</td>
<td>phenolic</td>
</tr>
<tr>
<td>4-hydroxy benzaldehyde</td>
<td>125</td>
<td>phenolically bitter</td>
</tr>
<tr>
<td>phenol</td>
<td>40</td>
<td>phenolic, cresol-like</td>
</tr>
<tr>
<td>4-vinyl syringol</td>
<td>310</td>
<td>smoky aroma and flavor</td>
</tr>
<tr>
<td>guaiacol</td>
<td>120</td>
<td>phenolic, medicinal, smoky</td>
</tr>
<tr>
<td>vanillin/acetovanillon</td>
<td>153</td>
<td>vanilla</td>
</tr>
<tr>
<td>eugenol</td>
<td>70</td>
<td>phenolic</td>
</tr>
<tr>
<td>isoeugenol</td>
<td>38</td>
<td>clove-like, nutmeg-like</td>
</tr>
<tr>
<td>styrene</td>
<td></td>
<td>resiny, plastic-like, harsh</td>
</tr>
</tbody>
</table>
### OTHER FLAVOR COMPONENTS FROM THE LITERATURE

<table>
<thead>
<tr>
<th>Flavor component</th>
<th>Avg value (ppm)</th>
<th>Characteristic Flavor or Aroma</th>
<th>Threshold value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta-damascenone</td>
<td></td>
<td>dried fruit, rose</td>
<td></td>
</tr>
<tr>
<td>Maltol</td>
<td>42.0 ppb</td>
<td>sweet</td>
<td>50.0-80.0 ppb</td>
</tr>
<tr>
<td>DMS</td>
<td>0.04</td>
<td>cooked vegetable</td>
<td>0.10-0.15</td>
</tr>
<tr>
<td>Diacetyl</td>
<td>0.40</td>
<td>butterscotch</td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td></td>
<td>acidic, pungent, sharp</td>
<td>10</td>
</tr>
</tbody>
</table>
Ester Production is supported through

- Increasing the wort concentration above 13%
- Increasing the ADF
- Decreasing wort aeration
- Increasing fermentation temperatures
- Decreasing hydrostatic pressure during fermentation (shallow fermenters)
Fermentation

• Pitching Rate 12-18 million cells/ml

• Starting Temperature 12-15 C (lower starting temps more common when starting tank is used to settle cold trub and then transfer to fermenter before start of fermentation where free rise occurs)

• Max temperature 18-22 C

• Main fermentation is 2-4 days

• Maximum Cell count is 60-80 million

Bottle Conditioning

• Lager yeast is less likely to autolyze and settles better

• If top-fermenting yeast is used, shelf life should be limited to 4-6 weeks

Fermenter Shape

• Cylindrical tanks produce only 2/3 the esters of shallow open fermenters

• Horizontal tanks perform like open fermenters
Selection of yeast strain exercises a large influence on phenol production

Small test fermentations at 15, 20 and 25 C indicated that both 4VG and 4VP reached a maximum at 20 C. Levels of both showed declines after main fermentation through bottle conditioning and lagering.

From observations at 5 different weizen production breweries:

Cylindrical fermenters - CO2 evolving through deeper tanks comparatively to open fermenters scrubs more flavor compounds.

Flotation without yeast – Flotation with the yeast produces more phenols than without.

DE filtration reduces 4VG and 4VP, presumably the low molecular phenols are attached to the larger protein and phenol compounds removed by filtration.

The use of wort(speise) to prime the beer for secondary fermentation increase the phenol content.
• The taste and smell threshold is 0.8 mg of 4VG/L

• 4VG levels over 2 mg/L bring a strong/severe character to the beer

• The fact that the levels of ferulic acid can fluctuate widely in malt can effect the levels of 4VG in beer

• As a rule, wheat malt has less ferulic than barley malt

• The highest levels of 4VG occur after the final limit of attenuation is reached

• More 4VG is present when the final limit of attenuation is reached in 4 days as opposed to 2 days

• The levels of 4VG don’t decrease significantly with the age of the beer, although other staling by-products may cover up the taste of 4VG
Pitching Rate and Aeration

• Under pitching may increase esters

• Many breweries pitch 5-10 million cells/ml

• Pitch 15-20 million cells/ml for Weizenbocks
  
  • Yeast cells double more times at warm temps
  • Yeast growth promotes higher ester production

• Under aeration may increase esters (some aerate only 50% of knockout)
OBSERVATIONS BY HANS PETER DREXLER (SCHNEIDER) ON WEISSBIER

• Longer the rest at 44°C, the higher the 4-V-G (clove phenol)

• Low Kolbach index (≤ 38%) for wheat and barley needed for estery beer

• Removal of cold break creates neutral taste and is not necessary

• Open fermenters increase esters

• Bottle conditioning increases phenols

• O₂ reduction at bottling important
Open fermentation

• Some Bavarian brewers have switched to cylindroconical fermenters

• Many of these brewers pitch fresh yeast every batch

• Pitching fresh yeast every batch common; many smaller breweries borrow culture from larger breweries

• Open fermenters still common for Weissbier, brewpubs, and traditional Bavarian lager breweries

• Open fermenters allow the brewer to remove/skim the hop resins carried by yeast to the surface from 12-24 hours after pitching

• Then the yeast crop is harvested by skimming at high krausen 24-36 hours after pitching
SCHNEIDER YEAST PROPAGATION PLANT
WEISSBIER FERMENTER
SCHNEIDER
FERMENTATION AND CONDITIONING

• After 2-4 days fermenting, the green beer is cooled and conditioned 1-4 weeks

• Cooling temperature depends on if weizen yeast or lager yeast will be used for bottle conditioning

• Conditioning is normally done in horizontal tanks

• Some beers are filtered before being bottle conditioned with fresh yeast

• New yeast, speise and new yeast is sometimes mixed in a mixing tank before bottling
OPEN BREWPUB FERMENTERS
FLIEGERBRAEU, MUNICH
SCHONRAM OPEN FERMENTERS
BOTTLE CONDITIONING
BOTTLE CONDITIONING

- Speise is added to raise the specific gravity by 1.004-1.006 depending on the final desired CO2 levels
- Timing can be difficult to collect wort for speise
- Krausen beer can be used for priming either from another batch of weissbeer or from a lager fermentation
- Bavarian brewers with local distribution tend to use weizen yeast for bottle conditioning
- Weizen yeast need warm conditioning (20-25 C) for 2-5 days then transferred to a cold box
FREILASSING
PAULANER BREWPUB
SCHNEIDER WEISSE ORIGINAL
KELHEIM

Malt: 60% wheat malt, 40% pale barley malt (color comes from <1% carafa)
Water: Grist Ratio: 5.5 to 1 (very liquid)
Mash (2 decoctions) 35°C, mash in
44°C, 10-15 min (ferulic acid → 4VG)
52°C, protein rest
62°C, gelatinize
72°C, saccharification
Mash off
Lautering 3.5 hr
Boil 58 min @ ??°C with external calandria
Hops 12 IBU
Whirlpool
Knockout 12.8° P @ 16°C
Aeration 5 mg of O₂ in-line
Yeast proprietary yeast @ 4-7MM cells/ml (don’t reuse yeast – top crop)
Primary ? Days @ 16-24°C in open fermenters – fully attenuated
centrifuge to drop yeast count to 0.3 to 0.5MM cells/ml
cool beer to 2.5g CO₂/L (8°C)
Mix Speise in tank for 6.5g CO₂/L (3.2 CO₂ v/v)
Fob bottles after filling
1 week @ 20°C, then 2 week @ 10°C
HEFEWEIZEN BEER
DOEMENS AKADEMIE

OG
BU
ADF
CO2
Malt
Water: Grist 3.75:1

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Rest (min)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>20</td>
<td>Precursor ferulic acid for 4VG formed</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>by direct heat to mash tun</td>
</tr>
<tr>
<td>62</td>
<td>10</td>
<td>After 10 min. pull 1st decoction</td>
</tr>
<tr>
<td>decoction</td>
<td>in 10 min</td>
<td>raise to 72°C, hold 15 min, then boiling for 15 min</td>
</tr>
<tr>
<td>72</td>
<td>15</td>
<td>Add decoction to raise main mash to 72°C</td>
</tr>
<tr>
<td>78</td>
<td>--</td>
<td>Transfer to lauter tun</td>
</tr>
</tbody>
</table>

Hops
Ferment
Bottling

Hallertau Perle pellets, one addition 10 min after start of boil
at ≈ 20°C until fully attenuated,
add Speise held back from brew day, and condition at room temperature
HEFEWEIZEN
(SMALL BAVARIAN BREWER)

OG
12.4%

BU
na

H₂O treatment
none

Malt
56% wheat, 28% pale barley, 12% Munich, 4% Caradunkel; Farbebier equal to 1.5% added to kettle

(1 decoction)

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<tr>
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<th>Rest (min)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>15</td>
<td>Mash in</td>
</tr>
<tr>
<td>52</td>
<td>5</td>
<td>Optional, may begin heating immediately to next rest</td>
</tr>
<tr>
<td>62</td>
<td>20</td>
<td>Pull decoction, boil 20 min, add back for next rest</td>
</tr>
<tr>
<td>72</td>
<td>72</td>
<td>Optional, add decoction to raise main mash to 72°C</td>
</tr>
<tr>
<td>75</td>
<td>--</td>
<td>Transfer to lauter tun</td>
</tr>
</tbody>
</table>

Lautering
2:20 hr total; 1:00 first runnings, 1:20 for 2 sparge additions

Boil
1:45 hr

Hops
1 addition of Hallertau Perle 10 min after boil start

Ferment
Cool to 16-17 °C in 65 min.
YEAST SELECTION

• **Weihenstephan 68** balanced ester/phenol profile **WL300**

• **Weihenstephan 175** moderately high, spicy, phenolic overtones reminiscent of cloves **WL351, W3638**

• **Weihenstephan 66** Subtle flavor profile for wheat yeast with unique sharp tart crispness, fruity, sherry-like palate **W3333**
  Large clove and phenolic aroma and flavor, with minimal banana. Refreshing citrus and apricot notes **WL380**
TIME TO ENJOY
Special thanks to
Stephen Holle and Marty Velas