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Symposium Venue:
University College Cork, Ireland
Located in the heart of the country, Cork is the second largest city in Ireland.

How to submit an abstract:
Please use the formatting and links as in the template on the Symposium website
www.ymbd2008.com
Send abstract by email to: marty@ucc.ie

Roadmap:
- March 2008: Launch of the website and call for papers
- August 2008: Abstract submission deadline
- September 2008: Publication and distribution of the final programme
- September 2008: Registration deadline

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First International Symposium for Young Scientists and Technologists in Malting, Brewing and Distilling
Cork/Ireland 6.—7. November 2008
XIII. Chair Jean de Clerck

Martin Zarnkow

Flavours of Wheat Beers

Louvain-la-Neuve 7.–10. September 2008
Wheat Beer Production in Bavaria

output [thousand hl]  % of total output

- 1960: 0
- 1970: 1000
- 1980: 2000
- 1990: 3000
- 2000: 4000
- 2001: 5000
- 2002: 6000
- 2003: 7000

Yearly production has increased significantly from 1960 to 2003.
“Purity Law” => Vorläufiges Biergesetz

wheat beer is:

• malt charge has to be at least 50 % wheat malt

• mandatory top fermenting yeast with > 15 °C fermenting temperature
<table>
<thead>
<tr>
<th>aroma compound</th>
<th>range in wheat beer</th>
<th>range in pale beer</th>
</tr>
</thead>
<tbody>
<tr>
<td>propanol-1</td>
<td>mg/L 15–30</td>
<td>5–20</td>
</tr>
<tr>
<td>3-methyl-butanol-1</td>
<td>mg/L 40–100</td>
<td>30–50</td>
</tr>
<tr>
<td>hexanol-1</td>
<td>µg/L 15–50</td>
<td>10–30</td>
</tr>
<tr>
<td>octanol-1</td>
<td>µg/L 10–40</td>
<td>20–40</td>
</tr>
<tr>
<td>2-phenylethanol</td>
<td>mg/L 15–45</td>
<td>10–30</td>
</tr>
<tr>
<td>ethylacetat</td>
<td>mg/L 10–50</td>
<td>5–20</td>
</tr>
<tr>
<td>isobutylacetat</td>
<td>mg/L 0.05–0.8</td>
<td>0.05–0.1</td>
</tr>
<tr>
<td>isoamylacetat</td>
<td>mg/L 0.5–8</td>
<td>0.5–2</td>
</tr>
<tr>
<td>hexylacetat</td>
<td>µg/L 3–15</td>
<td>3–15</td>
</tr>
<tr>
<td>isovaleriansäure</td>
<td>mg/L 0.2–1</td>
<td>0.2–1</td>
</tr>
<tr>
<td>hexanacid</td>
<td>mg/L 1–4</td>
<td>0.5–2</td>
</tr>
<tr>
<td>octanacid</td>
<td>mg/L 2–10</td>
<td>2–10</td>
</tr>
<tr>
<td>gamma-nonalactone</td>
<td>µg/L 20–50</td>
<td>20–40</td>
</tr>
<tr>
<td>4-vinylguajakol</td>
<td>mg/L 0.5–3.5</td>
<td>0.1–1</td>
</tr>
</tbody>
</table>
Ester and Sensory Assessment (1)

The graph illustrates the relationship between ethylacetat concentration [µg/L] and estery flavour. Two groups are shown:

- **Group 1** with a lower concentration range and an $R^2 = 0.0005$.
- **Group 2** with a broader concentration range and a significantly higher $R^2 = 0.7689$.

The data points suggest a strong correlation between ethylacetat concentration and estery flavour in Group 2, indicating a more pronounced effect of ethylacetat on the sensory assessment in this group.
Ester and Sensory Assessment (2)

3-methylbutyrate and estery flavour

group 1
$R^2 = 0.6448$

group 2
$R^2 = 0.4934$
Ester and Sensory Assessment (3)

Additive and synergistic effects on ester

- Isoamylacetat ~ 4.0 mg/L
- Ethylacetat < 45 mg/L

Sensory evaluation

Intensity and quality

Isoamylacetat [mg/L]

Ethylacetat [mg/L]
Phenolic flavour:

• "pleasantly" phenolic (clove-like = 4-vinylguaiacol)
• "unpleasantly" phenolic (hard, bitter, "medicinal")
  (p-kresol high concentration of 4-VG and 4-VP)

Estery flavour:

• typical estery (fruity, banana-like = isoamylacetate)
• atypical estery (solvent-like = ethylacetate, apple-like = hexylacetate)
Yeasty flavour:

• neutral
• "pleasantly" yeasty (substances unknown)
• sulfuric-yeasty
• yeast autolysis flavour (various middle and short chain fatty acids)

Malty flavour:

• in some pale and most dark wheat beers (Maltol, Furaneol)
Raw Material:

Wheat Malt
### Importance of Wheat Beer for the Rural Economy

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>Bavaria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>barley production</strong></td>
<td>(mio. t)</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>usage of brewing barley</strong></td>
<td>(mio. t)</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>usage of barley malt</strong></td>
<td>(mio. t)</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>% used for brewing industry</strong></td>
<td>(%)</td>
<td>48</td>
</tr>
<tr>
<td><strong>wheat production</strong></td>
<td>(mio. t)</td>
<td>16.0</td>
</tr>
<tr>
<td><strong>usage of brewing wheat</strong></td>
<td>(mio. t)</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>usage of wheat malt</strong></td>
<td>(mio. t)</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>% used for brewing industry</strong></td>
<td>(%)</td>
<td>0.7</td>
</tr>
</tbody>
</table>
## Characteristics of Pale Barley Malt and Wheat Malt

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pale barley malt</th>
<th>Pale wheat malt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extract (% dried malt)</strong></td>
<td>80.0 - 83.5</td>
<td>81.5 - 86.0</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>5.75 - 6.05</td>
<td>5.90 - 6.20</td>
</tr>
<tr>
<td><strong>Final Attn. (%)</strong></td>
<td>80.0 - 83.0</td>
<td>78.0 - 82.0</td>
</tr>
<tr>
<td><strong>Colour (EBC)</strong></td>
<td>2.2 - 3.8</td>
<td>3.0 - 4.5</td>
</tr>
<tr>
<td><strong>Colour, boiled (EBC)</strong></td>
<td>3.7 - 6.0</td>
<td>4.0 - 7.0</td>
</tr>
<tr>
<td><strong>Viscosity (mPas, 8.6%)</strong></td>
<td>1.50 - 1.57</td>
<td>1.55 - 1.80</td>
</tr>
<tr>
<td><strong>β-Glucan (Grist, mg/100g dried Malt)</strong></td>
<td>300 - 750</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>β-Glucan (EBC-Mash, mg/100g MT)</strong></td>
<td>70 - 200</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>solub. N (mg/100g MT)</strong></td>
<td>650 - 750</td>
<td>600 - 800</td>
</tr>
<tr>
<td><strong>Kolbach (%)</strong></td>
<td>38 - 42</td>
<td>35 - 45</td>
</tr>
<tr>
<td><strong>FAN (mg/100g MT)</strong></td>
<td>135 - 155</td>
<td>100 - 140</td>
</tr>
<tr>
<td><strong>DK (°WK)</strong></td>
<td>230 - 380</td>
<td>230 - 450</td>
</tr>
<tr>
<td><strong>α-Amylase (ASBC)</strong></td>
<td>35 - 60</td>
<td>30 - 60</td>
</tr>
</tbody>
</table>
## Processability of Wheat Varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Viscosity</th>
<th>sol. N</th>
<th>ß-Amlyase</th>
<th>α-Amylase</th>
<th>Malting technique</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1: low to medium viscosity and low to medium protein content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estica</td>
<td>0</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>no special technique</td>
</tr>
<tr>
<td>Obelisk</td>
<td>0</td>
<td>-</td>
<td>++</td>
<td>0</td>
<td>necessary</td>
</tr>
<tr>
<td>Andros</td>
<td>0</td>
<td>-</td>
<td>++</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Kanzler</td>
<td>--</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Orestis</td>
<td>0</td>
<td>--</td>
<td>++</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Atlantis</td>
<td>-</td>
<td>0</td>
<td>+++</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>Group 2: low to medium viscosity &amp; high protein content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>0</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>rising temperature and</td>
</tr>
<tr>
<td>Claudius</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>low steeping grade</td>
</tr>
<tr>
<td><strong>Group 3: high viscosity and low to medium protein content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longos</td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>0</td>
<td>falling temperature and</td>
</tr>
<tr>
<td>Boheme</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>high steeping grade</td>
</tr>
<tr>
<td>Piko</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Greif</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Group 4: high viscosity and high protein content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorbi</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>not possible</td>
</tr>
<tr>
<td>Toronto</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Herzog</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>
Influence of the Wheat Variety and Malting Technique on Wheat Attributes (1)

- **Viscosity**: Malting technique 8, Wheat variety 84, Other 8
- **Foam**: Malting technique 14, Wheat variety 28, Other 58
- **Anthocyanogenes**: Malting technique 42, Wheat variety 10, Other 48
- **Higher mol. N**: Malting technique 52, Wheat variety 29, Other 19
- **Total sol. N**: Malting technique 67, Wheat variety 21, Other 12
- **Colour**: Malting technique 51, Wheat variety 19, Other 30
- **Final attn., app.**: Malting technique 32, Wheat variety 58, Other 11

These charts represent relative variance components for different attributes of wheat, with separate sections for each component: Malting technique, Wheat variety, and Other.
Influence of the Wheat Variety and Malting Technique on Wheat Attributes (2)

The image shows bar charts for various wheat attributes, including Body, Taste, Smell, Pentandion, Diacetyl, Isoamylacetate, Ethylacetate, 2-Methyl-Butanol, and 2-Methyl-Propanol. Each bar chart is divided into three sections representing Malting technique, Wheat variety, and Other variance components. The relative variance components are shown on a scale from 0 to 100.
Malt Aroma Compounds Depending on Provenience

- 3-me-butanal
- 3-me-butanol
- tr,2-cis,6-nonadienale
- hexanal

Provenience:
- Reith
- Giebelstadt
- Günzburg
- Nossen
Wheat malt has a significantly lower ferulic acid content than barley malt. The barley/wheat ratio is therefore a decisive factor in determining the phenolic flavour of wheat beers.

It is the predecessor to 4-Vinylguaiacol. It arises through thermic (boiling) and mainly enzymatic (i.e. yeast strain) decarboxylization of ferulic acid.

Ferulic acid is bound to arabinoxylan in wheat and barley malt and is released during mashing by hydrolytic enzymes.

\[
\text{Ferulic Acid} \quad \text{R} \quad \text{OH} \\
\text{O} \quad \text{O} \quad \text{CH}_3 \\
\text{O} \quad \text{OH} \\
\text{OH}
\]
Overview Wheat Beer Technology
<table>
<thead>
<tr>
<th>Technolog. parameter:</th>
<th>Range:</th>
</tr>
</thead>
<tbody>
<tr>
<td>malt charge (wheat)</td>
<td>50–100 %</td>
</tr>
<tr>
<td>Mashing regime</td>
<td>40 % decoction</td>
</tr>
<tr>
<td></td>
<td>60 % infusion</td>
</tr>
<tr>
<td>Mashing-in temperature</td>
<td>30–57 °C</td>
</tr>
<tr>
<td>Intensity of the proteolytic rest</td>
<td>45–58 °C, 10–26 minutes</td>
</tr>
<tr>
<td>Intensity of the amylolytic rest</td>
<td>59–69 °C, 20–200 minutes</td>
</tr>
<tr>
<td>Mash acidification</td>
<td>18 %</td>
</tr>
<tr>
<td>Boiling time</td>
<td>50–210 minutes</td>
</tr>
<tr>
<td>Technolog. parameter</td>
<td>Range:</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Cold trub separation</td>
<td>25 %</td>
</tr>
<tr>
<td>Fermentation vessel</td>
<td>25 % vat</td>
</tr>
<tr>
<td></td>
<td>19 % horizontal tank</td>
</tr>
<tr>
<td></td>
<td>25 % vertical tank</td>
</tr>
<tr>
<td></td>
<td>31 % CV</td>
</tr>
<tr>
<td>Fermentation temperature</td>
<td>18–25,5 °C</td>
</tr>
<tr>
<td>Fermentation time</td>
<td>2–7,5 days</td>
</tr>
<tr>
<td>„Speise“ (Feed) addition</td>
<td>42 % cast wort</td>
</tr>
<tr>
<td></td>
<td>8 % sweet wort</td>
</tr>
<tr>
<td></td>
<td>23 % bottom-fermenting crausen</td>
</tr>
<tr>
<td></td>
<td>7 % mixture of bottom/top fermenting crausen</td>
</tr>
<tr>
<td>Technolog. parameter</td>
<td>Range:</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Bottle - Tank conditioning</td>
<td>75 % bottle</td>
</tr>
<tr>
<td></td>
<td>25 % tank</td>
</tr>
<tr>
<td>Warm storage</td>
<td>16–22 °C</td>
</tr>
<tr>
<td>Cold storage</td>
<td>4–10 °C</td>
</tr>
<tr>
<td>Yeast addition for conditioning</td>
<td>40 % no additional yeast</td>
</tr>
<tr>
<td></td>
<td>7 % top-fermenting yeast</td>
</tr>
<tr>
<td></td>
<td>25 % bottom-fermenting yeast</td>
</tr>
<tr>
<td></td>
<td>7 % bottom- and top-fermenting yeast</td>
</tr>
<tr>
<td>Flashing</td>
<td>47 % use flashing</td>
</tr>
<tr>
<td></td>
<td>53 % do not use flashing</td>
</tr>
</tbody>
</table>
Mashing
Technological Parameters (1)

Influence of the mashing-in temperature on 4-VG content
Influence of the mashing in temperature on the organoleptic acceptance of the yeasty flavour

Technological Parameters (2)

Influence of the mashing in temperature on the organoleptic acceptance of the yeasty flavour

30 - 43 °C

44 - 56 °C

> 57 °C

Acceptance of the yeasty flavour

Temperature
Influence of the mashing-in intensity on the isoamylacetate content

![Bar chart showing the influence of mashing-in intensity on isoamylacetate content. The chart indicates that:

- None: Approximately 4.0 mg/l
- 10 - 25 min: Approximately 3.5 mg/l
- > 26 min: Approximately 2.5 mg/l

The chart suggests that increasing the mashing-in duration reduces the isoamylacetate content.]
Influence of the mashing-in intensity on the 4-VG content

- **None**: 0 mg/l
- **10 - 25 min**: 2.0 mg/l
- **> 26 min**: 3.5 mg/l
Influence of mash acidification on organoleptic values

Acceptance

- phenol. smell
- estery smell
- yeast smell
- phenol. taste
- estery taste
- yeastly taste

w/o MA
with MA
Influence of the FAN on higher alcohols and esters

**Technological Parameters (7)**

- **2-Methylbutanol**
- **Ethylacetate**

![Graph showing the influence of FAN on higher alcohols and esters](image-url)
Relative amounts of Acetaldehyde, Ethylacetate, Isoamylacetate in dependency of the sugar composition of the wort.
Fermentation
Technological Parameters (6)

Influence of the yeast strain

- Yeast strain
- Total acetic acid esters/ mg/l
- 4-Vinylguaiacol / mg/l
Impact Factors on Ester Formation

- CO₂
- unsaturated fatty acids
- protein metabolism
- oxygen
- carbohydrates
- nitrogen
- temperature
- higher alcohols
- estersynthases
- ester
- acetyl-CoA/acyl-CoA
- carbohydrates and fatty acid metabolism
- growth substances!

Impact Factors on Ester Formation

- **Bei 2 Mio. Zellen**
  - 4:2
  - 8:2
  - 12:2
  - "2", "4", "6"

- **Bei 8 mg/l**
  - 8:2
  - 8:4
  - 8:12
  - "4", "2", "0.67"

<table>
<thead>
<tr>
<th>Isoamylacetat [mg/l]</th>
<th>Yeast cells [mio./mL]</th>
<th>Oxygen [mg/mL]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>1.5</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
<td>3.6</td>
</tr>
<tr>
<td>2.5</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>2.4</td>
</tr>
<tr>
<td>3.5</td>
<td>3.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

- Yeast cells [mio./mL]
- Oxygen [mg/mL]
Generic parameters:

- Increased ester content with higher fermentation temperature.

- Increased ester content with higher oxygenation level.

- Increased ester content with higher pitching rate (usual pitching rate: 2 Mio. cells/ml)

- Neither temperature, oxygenation nor pitching rate influence the 4-Vinylguaiacol content significantly.
Fermentation Vessels
Influence of the fermentation vessel on 4-VG and IAA content

Technological Parameters (10)
Influence of the fermentation vessel on Ethylactate content

- Vat
- horiz. tank
- vert. Tank
- CV

mg/l
Influence of the fermentation vessel on the taste

- Vat
- horiz. tank
- vert. Tank
- CV

Acceptance: phenol. estery yeasty
Influence of the fermentation vessel on the smell

- Vat
- horiz. tank
- vert. Tank
- CV

Acceptance

- phenol.
- estery
- yeasty
Impact of CO$_2$-Partial Pressure

Conditioning
Comparison between tank and bottle conditioned wheat beers

- Estery smell
  - Tank conditioning: 2.8
  - Bottle conditioning: 3.4

- Estery taste
  - Tank conditioning: 3.1
  - Bottle conditioning: 3.3
Comparison between tank and bottle conditioned wheat beers

- Yeasty smell
  - Tank conditioning
  - Bottle conditioning

- Yeasty taste
  - Tank conditioning
  - Bottle conditioning
Effects of warm storage temperature on the 4-VG and IAA content

Temperature

- 16 - 18 °C
- 19 - 21 °C
- > 22 °C

mg/l

Isoamylacetate
4-Vinylguaiacol
Effects of the warm storage duration on the phenolic flavour

- 3 - 4 days
- 5 - 7 days
- > 7 days

Acceptance

phenol. smell
phenol. taste
Conclusion

four types of wheat beer aroma:

• phenolic
• estery
• yeasty
• malty

wide range of influence
Acknowledgement

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Werner Back  Tech I
Bertram Sacher  Doemens
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