The Aroma Story from Hops into the Final Beer

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Aroma Categories in Hops
Aroma Categories and Corresponding Hops

- Menthol: Polaris
- Tea: Columbus
- Green Fruits: Hallertau Blanc
- Citrus Fruits: M. Bavaria
- Green: Herkules
- Vegetal: Summit
- Cream Caramel: Triskel
- Woody/Aromatic: Relax
- Spicy/Herbal: Saaz
- Red Berries: Galaxy
- Sweet Fruits: Monroe
- Floral: Ella

All there is to know about hops!
Hop Aroma

- > 400 hop aroma compounds
- Since 150 years researcher try to unlock the mystery of hop aroma in beer
- Only one characteristic impact compound that is responsible for a typical hop aroma (linalool) does not exist
- The complex interaction of hop and beer aroma compounds determines the aroma and flavour and is unique for every beer
  - Different thresholds
  - Synergistic effects $\rightarrow$ hop aroma interactions
  - Biotransformation during the brewing process
  - Release of aroma components by enzyme activity
Factors Influencing Hop Aroma

Variety, time of harvest, crop year, kilning

Point of addition, solubility/evaporation

Adsorption/transformation/interactions

Dry hopping (with/out yeast), duration, temp, agitation...

Aroma in hops…

…to hoppy aroma in beer

Harvest

Brewhouse

Fermentation

Lagering
What Happens, When and Why?

Bitter - Boiling

Aroma – Whirlpool

Aroma – Dry Hopping

Bitter

Boiling Kettle Hop Aroma:
subtle, spicy

Soft resins, Polyphenols, oxidised Sesquiterpenes, Aglycones

Aroma – Whirlpool

Late Hop Aroma:
fruity, hoppy notes

Ester, Alcohols, Ketones, Linalool, Geraniol, Citronellol, 4 MMP, 3 MH, Ketone, Epoxide

Aroma – Dry Hopping

Dry Hopping

Raw hop character

Aldehydes e.g. Hexanal, hop oils (Myrcen)
Influence of Yeasts and Hops
What Do We Know About the Yeast?

Biotransformation by yeast or reactions triggered by beer pH

- Glycosidically bound aroma precursors are released
- Acids are converted into (ethyl) esters
- Esters are trans-esterified or hydrolysed
- Monoterpane alcohols isomerised
- Carbonyl compounds, epoxides, and ethers are reduced to alcohols / diols

Some odorants are efficiently removed (during fermentation)

- Binding / adsorption of on biomass
- Stripping of volatiles

SensoryEffect?
Experimental Setup

- **α-Acids:**
  - 11.0-13.0 %
  - 11.0-13.0 %
- **Oil Content:**
  - 2.2-2.8 mL/100g
  - 0.5-1.0 mL/100g
  - 2.4-2.7 mL/100g

US05
- **Control_US 05**
- **Citra_US 05**
- **Tradition_US 05**
- **Galaxy_US 05**

Abbaye
- **Control_Abbaye**
- **Citra_Abbaye**
- **Tradition_Abbaye**
- **Galaxy_Abbaye**

**Monitoring:**
- Extract
- Temperature

**Analysis:**
- pH
- Aroma compounds
- Sensorial evaluation

- **Cassie**
  - Peach
  - Apricot
  - Citrus
  - Orange
- **Spicy**
  - Jasmine
  - Gooseberry
  - Lychee
  - Geranium
Fermentation Marker Compounds

Alcohols

- Sum alcohols
- 2-phenylethanol
- 2-methylbutanol
- 3-methylbutanol
- isobutanol
- 1-propanol

Non-hopped beers

Ethylesters

- Sum ethyl esters
- ethyl decanoate
- ethyl octanoate
- ethyl hexanoate
- ethyl butanoate

Acetates

- Sum acetates
- phenylethyl acetate
- isoamyl acetate
- isobutyl acetate
- ethyl acetate

Level of almost all markers compounds:

Abbaye > US05
Volatile Composition of Non-Hopped Beers

Abbaye Yeast

Isoamylacetate + 2-phenylethylacetate

US 05

- Ethyl butanoate
- Ethyl decanoate
- Ethyl dodecanoate
- Ethyl tetradecanoate
- Ethyl hexanoate
- Isoamyl octanoate
- Isoamyl decanoate
- Ethyl octanoate
- 2-methylbutyl octanoate
- Amyl decanoate

- Acetates
- Alcohols
- Acids
- B-damascenone
- Esters
Volatile Composition of Abbaye Beers

Citra

- Methyl geranate
- 3-methyl-2-butenyl 2-methylpropanoate
- Selinene

Galaxy

- Methyl geranate
- 3-methyl-2-butenyl 2-methylpropanoate
- Selinene

Tradition

- Highest % of compounds: Esters
  - Tradition: 46.7%
  - Galaxy: 56.4%
  - Citra: 70.2%

- Saturated esters
- Geranyl/neryl derived esters
- Sesquiterpene hydrocarbons
- Ketones
- Unsaturated esters
- Alcohols
- Oxygenated sesquiterpenoids
- Furans
Hop Oil Derived Compounds

- Monoterpane Alcohols
- Esters/Acetates
- Monoterpene Hydrocarbons
- Sesquiterpene Hydrocarbons
- Oxygenated Sesquiterpenoids

Monoterpane Alcohols:

- No Hops
- Galaxy
- Tradition
- Citra

Linalool, Geraniol, Nerol, α-Terpineol, p-Menth-1-en-4-ol, b-Citronellol, Citronellol isomer

Abbaye Yeast
PCA
PCA - Hop Oil Compounds

RESULT: X-Expl: 46%, 36%
PCA - Fermentation Compounds

RESULTS: $X_{\text{expl}}$: 75%, 12%
Understanding Aroma
# The Language of Hops

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>More Detailed Attributes</th>
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</thead>
<tbody>
<tr>
<td>Menthol</td>
<td>peppermint, melissa, sage, metallic, camphor</td>
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<tr>
<td>Tea</td>
<td>green tea, camomile, black tea</td>
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<tr>
<td>Green fruits</td>
<td>pear, quince, apple, gooseberry, enteric, cognac oil</td>
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<tr>
<td>Citrus</td>
<td>grapefruit, orange, lime, lemon, bergamot, lemongrass, ginger</td>
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<td>Green</td>
<td>green grass, tomato leaf, bell pepper</td>
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<td>Vegetable</td>
<td>selerie, leek, onion, artichoke, garlic</td>
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<td>Cream/Caramel</td>
<td>butter, chocolate, yoghurt, gingerbread, honey, cream, caramel, toffee, coffee</td>
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<td>Woody/Aromatic</td>
<td>tobacco, cognac, woody barique, leather, tonka bean, sweet woodruff, resinous, incense, myrrh, resinous</td>
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<tr>
<td>Spicy/herbal</td>
<td>Maggie, black pepper, chillies, curry, juniper berry, marjoram, estragon, dill, lavender, anis, liquorice, fennel</td>
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<td>Red berries</td>
<td>cassis, blueberry, raspberry, blackberry, strawberry</td>
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<td>Sweet fruits</td>
<td>banana, water melon, honeydew melon, peach, apricot, passion fruit, leeches, dried fruits, plum, pineapple, white jelly baby</td>
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<tr>
<td>Floral</td>
<td>elder, camomile flower, muguet, jasmine, apple blossom, rose, geranium</td>
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Conclusions

- Level of fermentation markers compounds non-hopped Abbaye > US05
- Characteristic compounds:
  - Tradition: α-humulene
  - Galaxy: saturated esters and citronellol isomer
  - Citra: methyl geranate
- No obvious correlation between aroma compounds and sensory evaluation → interaction between hop aroma components and fermentation components

### Threshold ppb

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<tr>
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<th>Linalool</th>
<th>Geraniol</th>
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<th>β-Caryophyllene</th>
<th>Nerol</th>
<th>α-Terpineol</th>
<th>Myrcene</th>
<th>Farnesene</th>
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*Hanke 2009*
Thank you!... Questions?

Many thanks to Dr. ing. Filip Van Opstael and the Team of Fermentis

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