An overview of beer flavour and sensory training

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11 August 2016
Overview

- Beer flavour overview
- Flavours from malt
- Flavours from hops
- Flavours from yeast
- Flavour defects
  - Off flavours and taints
  - Aged beer flavours
Beer flavour overview
A great diversity of beer styles is available in many markets today

The ability of consumers to access this diversity of styles increases daily

Examples of beer styles include:

- Pale Lager | Pilsner | Bock | Dopplebock
- Pale Ale | India Pale Ale | Red Ale | Barley Wine
- Hefeweizen | Witbier | Saison | Gueuze
- Rauchbier | Porter | Stout | Framboise
Most craft ales have between 30 and 40 positive flavour characters.

Originate from raw materials and process conditions.

Typically 15 – 20 main flavour characters:
- Burnt sugar | Caramel | Chocolate
- Bitter | Citrus hop | Floral Hop
- Isoamyl acetate | Ethyl acetate | 4-Vinyl guaiacol

Potentially 50 – 60 off-flavours and taints from microbial contamination, tainted processing aids or packaging materials.
Origins of fresh beer flavour

- Water
- Malt
- Adjuncts
  - Brewing salts
  - Acids
- Hops
- Fruits
- Spices
- Herbs
- Yeast
Flavours derived from malt
# Flavours from malt

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Flavour</th>
<th>Origins</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Acetyl pyridine</td>
<td>Malty-biscuity</td>
<td>Formed during kilning</td>
</tr>
<tr>
<td>Isobutyraldehyde</td>
<td>Grainy</td>
<td>Formed during wort boiling</td>
</tr>
<tr>
<td>Isovaleraldehyde</td>
<td>Grainy</td>
<td>Formed during wort boiling</td>
</tr>
<tr>
<td>Methional</td>
<td>Warty</td>
<td>Formed during wort boiling</td>
</tr>
<tr>
<td>Methyl sulphide</td>
<td>DMS</td>
<td>Precursor in malt</td>
</tr>
<tr>
<td>Various sugars</td>
<td>Sweet taste</td>
<td>Derived from barley starch</td>
</tr>
<tr>
<td>Furaneol</td>
<td>Burnt sugar</td>
<td>Formed during kilning and fermentation</td>
</tr>
<tr>
<td>Furfuryl thiol</td>
<td>Coffee</td>
<td>Formed during kilning</td>
</tr>
<tr>
<td>Guaiacol</td>
<td>Smoky</td>
<td>Introduced during drying or kilnling</td>
</tr>
<tr>
<td>2,3,5-Trimethylpyrazine</td>
<td>Chocolate</td>
<td>Formed during roasting</td>
</tr>
<tr>
<td>Vanillin</td>
<td>Vanilla</td>
<td>Formed during kilning</td>
</tr>
</tbody>
</table>
Grainy

▲ Positive flavour in some types of beer - off-flavour in other beer types
▲ Derived from precursors in malt
▲ Concentration depends on malt specifications, brewhouse procedures and fermentation practices
▲ Isobutyraldehyde and other aldehydes such as isovaleraldehyde also contribute to the grainy characteristics of beer
▲ Flavour thresholds 0.01 – 0.025 mg/l
Positive flavour in some types of beer - off-flavour in other beer types

Derived from precursors in malt

Dimethyl sulphide from S-methyl methonine

Concentration depends on malt specifications, brewhouse procedures and fermentation practices

Can also be produced by contaminant microorganisms

Flavour threshold 0.03 – 0.05 mg/l
Positive flavour in beer
Taste characteristic
Contributed to beer by sugars such as glucose, maltose and maltotriose
Derived from precursors in malt
Concentration depends on brewhouse procedures and fermentation practices
Flavour threshold of sugars is in the range of 1 – 5 g/l
Interaction with other taste characteristics in beer
Flavours derived from hops
# Flavours from hops

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Flavour</th>
<th>Origins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hop bitter acids</td>
<td>Bitter</td>
<td>Developed from precursors in hops</td>
</tr>
<tr>
<td>Isovaleric acid</td>
<td>Isovaleric, cheesy</td>
<td>Forms in hops during storage</td>
</tr>
<tr>
<td>β-Damascenone</td>
<td>Damascenone</td>
<td>Developed from precursor in hops</td>
</tr>
<tr>
<td>Geraniol</td>
<td>Floral, rose-like</td>
<td>Extracted from hops</td>
</tr>
<tr>
<td>Linalyl acetate</td>
<td>Fragrant, bergamot</td>
<td>Developed from precursor in hops</td>
</tr>
<tr>
<td>4-Mercapto-4-methylpentanone</td>
<td>Blackcurrant, catty</td>
<td>Developed from precursor in hops</td>
</tr>
<tr>
<td>α-Humulene</td>
<td>Spicy</td>
<td>Extracted from hops</td>
</tr>
<tr>
<td>Myrcene</td>
<td>Raw hop</td>
<td>Extracted from hops</td>
</tr>
<tr>
<td>Ethyl-2-methylbutyrate</td>
<td>Apple, strawberry</td>
<td>Developed from precursor in hops</td>
</tr>
<tr>
<td>Mercaptohexyl acetate</td>
<td>Passionfruit, lychee</td>
<td>Developed from precursor in hops</td>
</tr>
</tbody>
</table>
Bitter

- Positive taste in beer
- Contributed by hops or hop extracts
- Hop alpha acids in the wort kettle
- Six different iso-alpha-acids, together with a wide range of related compounds contribute to this characteristic
- Laboratory measurements expressed as International Bitterness Units (IBU)
- Flavour threshold 3 - 5 mg/l
Positive flavour in beer
Contributed by hops or hop extracts
Geraniol from hops imparts a floral, rose-like flavour to beer
During fermentation yeast can convert some of the geraniol to geranyl acetate – this depends on yeast strain and fermentation conditions
Flavour threshold 0.4 mg/l
 Isovaleric

- Off-flavour in lager beer – positive character in some types of ale
- Contributed by hops or hop extracts
- Concentration depends on recipe, hop product and variety, and age of hops or hop product
- Flavour intensity increases as beer pH value is reduced
- Flavour threshold 3 mg/l
Flavours derived from yeast
# Flavours from yeast

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<tr>
<th>Chemical</th>
<th>Flavour</th>
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</thead>
<tbody>
<tr>
<td>Isoamyl acetate</td>
<td>Banana</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>Solvent, nail varnish</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Ethyl hexanoate</td>
<td>Apple</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Diacetyl</td>
<td>Butter-like</td>
<td>Developed from precursor produced by brewer’s yeast</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>Green apple</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>Vinegar</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>Boiled egg</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>Methanethiol</td>
<td>Mercaptan</td>
<td>Produced by brewer’s yeast</td>
</tr>
<tr>
<td>4-Vinyl guaiacol</td>
<td>Clove-like</td>
<td>Produced by speciality yeast</td>
</tr>
<tr>
<td>4-Ethyl phenol</td>
<td>Horse, blue cheese</td>
<td>Produced by speciality yeast</td>
</tr>
</tbody>
</table>
Isoamyl acetate

Positive flavour in beer – off-flavour at high concentration

Produced by yeast during fermentation

Concentration depends on yeast strain, wort quality and fermentation conditions

Especially dependent on wort clarity, dissolved oxygen and fermenter depth

Flavour threshold 1.1 mg/l
Ethyl acetate

- Positive flavour in beer – off-flavour at high concentration
- Produced by yeast during fermentation
- Concentration depends on yeast strain, wort quality and fermentation conditions
- Especially dependent on fermentation temperature - can also be produced by contaminant wild yeasts
- Flavour threshold 10 mg/l
Ethyl hexanoate

- Positive flavour in beer
- Produced by yeast during fermentation
- Concentration depends on yeast strain and fermentation conditions
- Especially dependent on yeast health and yeast generation number
- Flavour threshold 0.2 mg/l
Ethyl Butyrate

- Contributes a pleasant ‘tropic fruit ester’, pineapple-like note to ales and lagers.
- Associated with the use of particular yeast strains and hop varieties (usually ‘Noble’ hop varieties).
- One of a number of hop derived esters
- Flavour threshold 0.3 mg/l
Diacetyl

- Positive flavour in some beers - off flavour in other beer types
- Precursor is produced by yeast during fermentation
- Warm rest after fermentation ensures removal
- Influenced by wort amino acid concentrations and beer pH value
- Can also be produced by contaminant bacteria – *Lactobacillus* and *Pediococcus* spp
- Flavour threshold 0.01 mg/l
Acetaldehyde

Positive flavour in some beers - off-flavour in others

Produced by yeast during fermentation

Critically affected by wort [Zn] and yeast health

Can also be produced by contaminant bacteria and as a result of beer oxidation

Flavour threshold 5 mg/l
Sulphur dioxide

- Positive flavour in lager beer
- Contributes to ‘freshness’
- Provides protection against oxidation of packaged beer
- Produced by yeast during fermentation
- Concentration depends on yeast strain, yeast health and fermentation conditions
- Flavour threshold *ca* 5 mg/l
Positive flavour in beer - off-flavour at high concentrations

Produced by yeast during fermentation and maturation

Concentration depends on yeast strain, yeast health and fermentation conditions

Can also be produced by contaminant microorganisms

Flavour threshold 0.004 mg/l
Mercaptan

- Off-flavour in lager beer – positive flavour in craft ale
- Produced by yeast during maturation or contributed to beer by dry hopping
- Thiols such as methanethiol
- Concentration depends on yeast strain, yeast health, fermentation conditions and hopping regime
- Can also be produced by contaminant microorganisms
- Flavour threshold 0.0015 mg/l
Flavours
defects
# Flavour defects

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<tr>
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<th>Origins</th>
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<tbody>
<tr>
<td>Sodium hydroxide</td>
<td>Caustic</td>
<td>Accidental contamination</td>
</tr>
<tr>
<td>Butyric acid</td>
<td>Baby vomit, mango</td>
<td>Produced by brewhouse bacteria</td>
</tr>
<tr>
<td>2-Bromophenol</td>
<td>Inky, museum</td>
<td>Taint</td>
</tr>
<tr>
<td>2,6-Dichlorophenol</td>
<td>Medicinal</td>
<td>Taint</td>
</tr>
<tr>
<td>2,3,6-Trichloroanisole</td>
<td>Musty</td>
<td>Produced by moulds</td>
</tr>
<tr>
<td>Ferrous ion</td>
<td>Metallic</td>
<td>Corrosion of plant</td>
</tr>
<tr>
<td>Guaiacol</td>
<td>Smoky</td>
<td>Exposure of raw materials to smoke</td>
</tr>
<tr>
<td>1-Napthol</td>
<td>Mothballs</td>
<td>Pesticide residues</td>
</tr>
<tr>
<td>4-Ethyl phenol</td>
<td>Band aid</td>
<td>Produced by speciality yeast</td>
</tr>
</tbody>
</table>
## Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Off-flavour</td>
<td>Flavour generated within the product by chemical or biological reactions</td>
</tr>
<tr>
<td>Taint</td>
<td>Flavour contributed to the product from an external source <em>via</em> a ‘vector’</td>
</tr>
</tbody>
</table>
Consumer impact

1. “It’s different”
2. “It’s not quite right”
3. “I’m not sure I like this”
4. “There’s something wrong here”
5. “I’m worried”
6. “Help!”
Origins of off-flavours

- Microbiological
  - Bacteria
  - Yeasts
- Enzymic
- Chemical
- Non-enzymic
- Moulds
Taint ‘vectors’

- Ingredients
- Water
  - Product water
  - Process water
- Gases
  - Environmental air
  - Process gases
- Packaging materials
- Environment
Taint in beer

Contributed to beer through contamination with caustic cleaning agents (such as NaOH)

Beer sodium content and colour are also increased

Only ‘trace’ concentrations of cleaning agents are needed to spoil beer flavour
Butyric

- Off-flavour in beer
- Produced by bacteria in mashing or in sugar syrup
- Flavour not obvious in wort but appears after fermentation
- Can also be produced by contaminant bacteria – *Bacillus* and *Clostridium* spp
- Flavour intensity increases as beer pH value is reduced
- Flavour threshold 3 mg/l
Bromophenol

- Taint in beer
- Contributed to beer through contaminated packaging materials
- Bromophenols are common environmental contaminants as they are used as fire retardents
- Especially associated with recycled wood and cardboard
- Flavour threshold 100 ng/l
Chlorophenol

- Taint in beer
- Contributed to beer through contaminated water and water treatment media, and reaction with cleaning agents
- Originates through reactions between chlorine and phenolic compounds
- Flavour threshold 300 ng/l
Taint in beer

Contributed to beer through contaminated raw materials, filter aids, processing aids, or packaging materials

2,4,6-Trichloroanisole

Originates through conversion of environmental chlorophenols to chloroanisoles by moulds

‘Cork taint’ in wine

Flavour threshold 10 – 500 ng/l
Taint in beer

Contributed to beer through contamination with metal ions, either from raw materials or corrosion of brewery equipment

Iron, copper and manganese can all give metallic flavours

Detected by ‘trigeminal’ sense and by odour

Flavour thresholds in the region of 0.05 – 0.3 mg/l
Why is beer flavour unstable?
Where do flavour life problems come from?

- Design of the product
- Poor quality raw materials
- Production in the brewery
- Handling in distribution
- Handling in the market
## Different flavours form at different times

<table>
<thead>
<tr>
<th>Age of beer</th>
<th>Compounds formed</th>
<th>Flavour impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4 weeks</td>
<td><em>trans,trans</em>-2,4-Heptadienal, methional</td>
<td>Rancid oil, mashed potato</td>
</tr>
<tr>
<td>4 – 12 weeks</td>
<td><em>trans</em>-2-Nonenal, 3-methylbutanal, acetaldehyde</td>
<td>Papery, grainy, acetaldehyde</td>
</tr>
<tr>
<td>6 – 18 weeks</td>
<td>β-Damascenone, dimethyl trisulphide</td>
<td>Black tea, onion</td>
</tr>
<tr>
<td>8 – 20 weeks</td>
<td>Various Maillard reaction products</td>
<td>Caramel, sweet</td>
</tr>
<tr>
<td>10 – 50 weeks</td>
<td>Various quinones, oxidized polyphenols, 2-furfuryl ethyl ether</td>
<td>Leathery, astringent, ‘old beer’</td>
</tr>
<tr>
<td>&gt;20 weeks</td>
<td>Various acetals</td>
<td>Sherry, winey, ‘oxidized’</td>
</tr>
</tbody>
</table>

Sulphur dioxide is lost a constant rate during storage impacting perception of other beer flavours.
trans-2-Nonenal
Produced by breakdown of malt-derived lipids - binds to malt proteins during wort boiling
Released from protein during storage of packaged beer
Beer pH controls rate of release – yeast controls the beer pH value
Flavour supressed by sulphur dioxide
Flavour threshold ca 50 ng/l
NSBCo. Mountain Weiss draught

- WB06 Weiss yeast
- Low to no hop character – 10 IBU
- >50% malted wheat breadiness
- Yeast derived flavours
  - Yeast phenol – 4 Vinyl guaiacol – spicy, clove
  - Fruity esters – iso amyl acetate
Positive character in some beer styles - off-flavour in lager beer

Produced by *Saccharomyces* and *Brettanomyces* yeasts

These yeasts possess the **PAD** gene which codes for production of phenyl acrylate decarboxylase

Low levels can be produced from malt-derived precursors in the brewhouse

Flavour threshold 0.3 mg/l
Isoamyl acetate

Positive flavour in beer – off-flavour at high concentration

Produced by yeast during fermentation

Concentration depends on yeast strain, wort quality and fermentation conditions

Especially dependent on wort clarity, dissolved oxygen and fermenter depth

Flavour threshold 1.1 mg/l