An introduction to beer flavour

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Overview

- How do we sense flavour?
- Beer flavour overview
- The importance of beer flavour
- Why sensory?
- Managing a sensory panel
At the end of this session you should be able to

- List the main contributions made by raw materials, yeast and processing to the flavour of beer
- Name the main flavour compounds associated with the flavour of fresh beer
- Name the main flavour defects associated with beer
- Name the process parameters you can control to optimize the flavour of beer
So how do we sense flavour?
Sensory perception

- Sight
- Hearing
- Touch
- Smell
- Taste
Sensory perception

Sense of smell

- Humans can detect over 10,000 compounds
- Odour molecules sensed by olfactory receptors – Orthonasal and Retronasal
- We sense smells at a molecular level
- We can discriminate closely related molecules
- We can classify based on impression ie fruit/sulphury etc.
Sense of smell

- Blindness and sensitivity varies by person
- Variation to sensitivity can be up to 10,000 fold
- Detection rates vary greatly! Femtograms to Grams
- The particular compound and variety of compounds varies by person
Smell

We remember smells in a completely different way than we remember other sensory memories.
Taste

- Sweet
- Salt
- Bitter
- Sour
- Umami
- Emerging: Fat

Areas of Six Tastes on the Tongue
We sense taste through our taste buds that are located on:
- Roof of the mouth
- Tongue
- Cavity behind the mouth and nose
- And elsewhere....
Factors affecting taste

- Health
- Medication
- Personal Hygiene (mouthwash)
- Smoking
- Age
- Sex
- Genetic variations
Sensing of texture/pain

- Known as the trigeminal sense
- Neither taste nor aroma
- Attributes detected:
  - metallic
  - astringency
  - carbonation
  - mouthfeel
  - chalkiness
Beer flavour
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
Beer Styles

6 SUBSTYLES OF IPA JUST CAUSE YOU OVERHOPPED OTHER STYLES

WTF
Most lager beers have between 15 and 25 positive flavour characters.

Typically 7 – 10 main flavour characters.

Examples include:

- Malty-biscuity | Grainty | DMS
- Bitter | Spicy hop | Floral hop
- Isoamyl acetate | Ethyl acetate
Most craft ales have between 30 and 40 positive flavour characters

Typically 15 – 20 main flavour characters

- Burnt sugar | Caramel | Chocolate
- Bitter | Citrus hop | Damascenone
- Isoamyl acetate | Ethyl acetate | 4-Vinyl guaiacol
What constitutes a beer flavour specification?

- List all flavours that must be present in the beer
- Define their target intensity
- Define the significance and consumer impact of non-conformances in intensity
- List all potential defect flavours
- Define the significance and consumer impact of non-conformances in intensity
Example flavour specification
Managing beer flavour

▲ There’s a time and a place for every flavour – with exceptions
▲ Positive and negative attributes are equally important. Too much of a good thing isn’t good.
▲ What makes my beer different?
▲ What are my specifications and allowable variances?
Origins of fresh beer flavour

- Water
- Malt
- Adjuncts
- Brewing salts
- Acids
- Hops
- Fruits
- Spices
- Herbs
- Yeast
# 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>Worthy</td>
<td>Formed during wort boiling</td>
</tr>
<tr>
<td>Dimethyl 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 kilning</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>
Positive flavour in some types of beer - off-flavour in other beer types

Derived from precursors in malt

Dimethyl sulphide from $\text{S}$-methyl methionine

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
# 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 converted to iso-alpha-acids in prior to delivery to the brewery or 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
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
- Can also be produced by contaminant wild yeasts
- Flavour intensity increases as beer pH value is reduced
- Flavour threshold 3 mg/l
Lightstruck

- 3-methyl-2-butene-1-thiol
- Formed by exposure to light
- ‘Sunburn for beer’
- Initiates a reactions involving bitter acids and sulphur compounds
- flavour threshold 4-30 ng/l
## Flavours from Yeast

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Flavour</th>
<th>Origins</th>
</tr>
</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>
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
Acetic

- Positive flavour in some beers – off-flavour in most beer types
- Produced by all yeast
- Concentration depends on yeast strain and growth
- Can also be produced by contaminant bacteria
- Flavour threshold 90 mg/l
Diacetyl

- Positive flavour in some beers - off flavour in other beer types
- Precursor is produced by yeast during fermentation
- 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
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 - off-flavour at high concentration
- Produced by yeast during fermentation
- Concentration depends on yeast strain and fermentation conditions
- Especially dependent on yeast health and yeast generation number
- Used to gauge yeast health
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
Phenolic - 4-vinyl guaiacol

- 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
 Phenolic – 4-ethyl phenol

- Positive character in some beer styles
  - off-flavour in most styles
- Produced by *Brettanomyces* yeasts
- Occasionally produced by LAB
- Indicative of contamination in most beer styles
- Flavour threshold 300 µg/l
Origins of off-flavours

- Moulds
- Yeasts
- Bacteria
- Enzymic
- Chemical
- Non-enzymic
Some compounds can cause product recalls when present at <10 ng/l in the final product.
# flavour defects

<table>
<thead>
<tr>
<th>Chemical</th>
<th>flavour</th>
<th>Origins</th>
</tr>
</thead>
<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>2,4,6-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>
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
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
**Musty**

- 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
Metallic

▲ 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
## 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.
Compounds found in stale beer

- Unsaturated carbonyl compounds play a big part in development of stale flavours in lager beer
- These have:
  - Very low flavour thresholds
  - Unpleasant aromas and flavours

For example: *trans*-2-Nonenal
Papery

- *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 suppressed by sulphur dioxide
- Flavour threshold *ca* 50 ng/l
Current views on flavour stability
- One slice of a complicated situation!

Oxidation of precursors in malt, mash, wort and beer

Release of ‘stale carbonyls’ from proteins during beer storage

Binding of ‘stale carbonyls’ to wort proteins

Uptake and reduction by yeast

Oxidation of precursors in malt, mash, wort and beer

loss of reducing power

further oxidative degradation to ‘stale carbonyls’

carbonyls bound as flavour-inactive SO₂ adducts

‘unmasking’ of stale flavours by loss of SO₂

enhancement of the flavour of stale carbonyls by 2-FEE

Oxidation

Stale flavour
So why do sensory training?

- Cost effective
- Objective results
- Build a sensory profile of your beer beers
- Better judges
Management of taste panels

- Recruitment and selection of assessors
- Training and coaching of assessors
- Management and administration of taste sessions
- Analysis and reporting of test results
- Managing taster welfare
Thanks to Amaey J. Mundkur and Dr. Bill Simpson
Questions?
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