What is behind cereal flavour: Case studies on linking sensory and instrumental data

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Outline of presentation

- Benefits of wholegrain products
- Formation and modification of flavour of cereal products
- Relating perceived flavour and flavour-active chemical compounds
- Case studies
  1. Stability of oats
  2. Milling fractionation of rye: Flavour and bioactivity
  3. Tailoring cereal flavour by bioprocessing
  4. Enzyme-aided flavour boosting
WHY WHOLE GRAIN?
Rye and oat are consumed as whole grain

- Raw material for health-beneficial foods
- Decreases risk to several diseases, e.g. diabetes, cardiovascular diseases and many cancers
  - High fibre content, low fat content
  - Good source of starch, valuable proteins, high vitamin and mineral content
  - Several phytochemicals: lignans, plant sterols, alk(en)ylresorcinols (in rye), avenanthramides (in oats), phenolic acids; Most phenolic compounds bioactive & influence perceived flavour

Consumer-originated product development of cereal products

- Flavour & texture of cereal products must appeal to consumers and meet their expectations
- Desired flavour & texture to be ACTIVELY DESIGNED instead of just measuring sensory profiles of products
- Flavour & texture of cereal foods to be adjusted by DIFFERENT PROCESSING TECHNIQUES to produce ideal products
Formation and modification of flavour of cereal products

- Flavour of native grain is rather mild and bland
- Grain must be processed prior to use in human consumption
- Cereal flavour forms in processing

Flavour formation in cereal products

What is 'cereal-like' flavour?

- Rye-like flavour = Flavour of rye bread?
- Oat-like flavour = Flavour of oat porridge?

All cereal have their characteristic flavour

- Oat flavour different from rye flavour

Variety of grain, season and cultivation area influence flavour

- Oat cultivar Veli has sweeter, more oat-like flavour than cv. Lisbeth
Tailoring desired flavour & texture to cereal products

- Mechanical milling fractionation of the grain
- Sourdough fermentation & baking
- Germination (malting) & drying
- Heat treatment: Extrusion, puffing in autoclave, IR-roasting …
- Enzymatic flavour-boosting

- Fermentation & germination increase amounts of health-beneficial phenolic compounds, concurrently influencing considerably perceived flavour
- Heat-treatment important step for tailoring perceived flavour (Maillard reaction)

Perception of flavour (odour & taste; mouthfeel)
Perceived flavour is influenced by:
1. Flavour-active compounds of grain: aldehydes, alcohols, ketones, phenolic compounds
2. Flavour precursors in grain: amino acids, sugars, fatty acids, phenolic compounds

Flavour-active compounds influence perceived flavour of a product, but...

- Specific odour/taste thresholds of the chemical compounds
- All chemical compounds are not responsible for flavour sensation
- Synergistic or suppressive effects of compounds
- Individual differences in sensitivity of odour/flavour perception

In addition to volatile compounds, several non-volatile components affect the perceived flavour.
PLS regression - Relating perceived flavour and flavour-active chemical compounds by multivariate statistics

Sensory assessment by descriptive profiling

GC/MS quantification of e.g. volatile compounds

Perceived flavour and volatile compounds analysed separately

Impact of flavour-active compounds to flavour of germinated, heat-treated oat: Roasted, nutty, sweet flavour, crisp texture results when drying at 85°C
GC-Olfactometry

GC analysis combined with simultaneous odour perception

Flavour extraction by SPME (compound-specific fibres)

<table>
<thead>
<tr>
<th>No.</th>
<th>Compound</th>
<th>Description</th>
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<tbody>
<tr>
<td>9.6</td>
<td>(sweet)</td>
<td></td>
</tr>
<tr>
<td>10.2</td>
<td>3-methyl-2-pentanol, ethyl lactate</td>
<td>sweet, citrus, green fruits</td>
</tr>
<tr>
<td>11.1</td>
<td>4-pentyl-2-methyl-3-decanone</td>
<td>sweet, lamb, game, orange</td>
</tr>
<tr>
<td>11.4</td>
<td>terphenyl butane</td>
<td>(solvent)</td>
</tr>
<tr>
<td>11.5</td>
<td>3-methylpyrazine</td>
<td></td>
</tr>
<tr>
<td>12.6</td>
<td>furfural</td>
<td></td>
</tr>
<tr>
<td>12.6</td>
<td>furfural</td>
<td>sweet, unripe, pruny, rancid</td>
</tr>
<tr>
<td>12.7</td>
<td>furfural</td>
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<tr>
<td>13</td>
<td>2-heptanone</td>
<td>sweet, unripe, pruny, rancid</td>
</tr>
<tr>
<td>13.3</td>
<td>2-heptanone</td>
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</tr>
<tr>
<td>13.4</td>
<td>hexanal</td>
<td></td>
</tr>
</tbody>
</table>

Piece of GC-Olfactometry chromatogram of a cereal product
CASE 1 - Stability of oat

- Rancid and bitter flavour develops easily in oat during storage due to its high fat content.
- Germination-drying process can be used to adjust effectively the perceived flavour and to increase the flavour stability.

CASE 1 - Relating perceived flavour and flavour-active volatile compounds of stored oat

- Graph showing the relationship between X-loading weights and Y-loadings for various compounds like Pentanal, n-Butylfuran, Pentylfuran, Heptanal, 1-Pentanol, 1-Hexanol, Phenyl acetate, Methylbutanal, 3-Pentanone, Methylpropanal, 2-Heptanone, 2-Ethylfuran, Belzaldehyde, Dimethylsulphide, 3-Hexanone, Dimethylsulphide, and Germinated-0.
CASE 1 - Stability of oat

• Musty, earthy odour and bitter, rancid flavour in stored, deteriorated oat; these attributes closely correlate with free fatty acids and volatile compounds related to lipid oxidation
• However, phenolic compounds and volatile compounds derived from protein degradation are related to favourable roasted flavour

CASE 2 - Milling fractionation of rye: Flavour and bioactivity

• In mechanical milling fractionation rye kernel is separated into fractions, each of them having their characteristic flavour
CASE 2 - Flavour of milling fractionationated rye grain

Flavour components unevenly distributed to different layers of rye grain

- **Endosperm**: Mild flavour
- **Bran**: Strong, bitter flavour
- **Shorts**: Rye-like flavour without bitterness

Between mild-tasting innermost part and bitter-tasting outer bran fraction, rye-like flavour without bitterness is observed. This shorts fraction contains significant amounts of health-beneficial, nonvolatile phenolic compounds (phenolic acids, alk(en)ylresorcinols and lignans), which may have input to perceived flavour.

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**CASE 2 - Flavour and bioactivity of fractionationated rye: Flavour vs. Free phenolic acids**

![Flavour vs. Free phenolic acids diagram](image)

- **X-loading Weights and Y-loadings**
  - **CEREAL FLAVOUR**
  - **Bitterness**
  - **GERM/LIKE FLAVOUR**
  - **Syringic acid**
  - **Vanillic acid**
  - **Syringic acid**
  - **Veratric acid**
  - **Sinapic acid**
  - **Ferulic acid**

**Axes**: PC2 vs. PC1

**Explained Variance (%)**
- X-expl: 81%, 14%
- Y-expl: 55%, 15%

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Heinö R-L, et al. LWT 2003a
CASE 2 - Flavour and bioactivity of fractionationated rye: Flavour vs. Alk(en)ylresorcinols

CASE 2 - Flavour and bioactivity of fractionationated rye: Flavour vs. Lignans
CASE 3 - Tailoring cereal flavour by bioprocessing

- Different volatile compounds evaporate from same raw material depending on the applied bioprocessing technique
- Thus, sourdough fermented, germinated and milled rye extrudates deviate from each other both in their sensory attributes and their volatile compounds

Pretreatment - milling (M), germination (G) or sourdough fermentation (S) - dominates flavour of extruded (E) rye

Heiniö et al. LWT 2003b
CASE 4 - Enzyme-aided flavour boosting

- Enzymatic treatment is a new approach for modifying flavour
- Intensive, bitter flavour of rye may be caused by small peptides and phenolic compounds, and can be studied by enzyme-aided processing
- Bitterness could be blocked by
  A - Breakdown/polymerisation of compounds influencing harmfully on flavour
  B - Formation of flavour-beneficial flavour precursors, e.g. for Maillard reaction

Sensory assessment of enzyme-boosted rye

Sensory profiles of rye-water suspensions with high enzyme dosages (n=2 x 9)

Most intense bitterness in rye-water suspensions caused by protease
CASE 4 - Enzyme-aided flavour boosting
Perceived bitterness

Bitterness of flour and cracker after Corolase additions (n=2 x 9-10)

CASE 4 - Enzyme-aided flavour boosting
Bitterness, soluble proteins and total phenolics

Bitterness (−5 ... 5)

Soluble protein (mg/ml)

Total phenolics (g/l)

Soluble protein

Total phenolics
Conclusions

• Cereal flavour influenced by volatile and phenolic compounds, amino acids, sugars and fatty acids
• Tools for relating perceived flavour and flavous-active chemical compounds: PLS regression & GC-olfactometry
• Flavour of native grain is mild -> Processing required: milling, fractionation, sourdough fermentation & baking, germination, heat and enzymatic treatments

New tools for developing novel, palatable, health-beneficial breakfast & snack applications from cereal