Practical Application of Sensory-Directed Flavor Analysis of Foods

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Overview of Today’s Talk

- Flavor
- Rationale for Flavor Analysis
- Sensory-Directed Flavor Analysis
- Bridging the Gap Between Sensory and Analytical Flavor – e.g. Cheese
Flavor is a multi-sensory experience.
Flavor

- Olfaction (aroma or odor) plays the predominant and characterizing role in food flavor quality, including recognition and overall food acceptance (Spence, 2015).

- **Flavor** is THE main determinant or driver consumer acceptance

- Therefore, there is need for the measurement of flavoring (aroma) substances in foods.

Need for Flavor Analysis

- Development of new and improved products.
  - process/ingredient optimization
  - optimization/evaluation of storage conditions
  - shelf-life testing

- Determine source of off-flavors or taints
Quality assurance or grading of products
  ◆ fingerprinting of products (raw materials or finished products)
  ◆ assurance of “naturalness” of products

Basic/Applied Research
  ◆ physiological structure-function relationship
  ◆ physical chemistry: flavor-matrix interactions
  ◆ relating sensory attributes of a food to its (complex) chemical composition [e.g. relating the sensory aroma profile to the volatile and nonvolatile flavor composition]
Flavor Analysis

Natural source e.g. fruit

Isolation

Flavor Extract

Separation

Characterization

= 

OH
Volatile Composition of a Complex System

- **low to trace levels**
  - parts-per-million to parts-per-trillion

- **water-soluble to fat-soluble**
  - log $P$ value
    - maltol: 0.02
    - diacetyl: 0.8
    - hexanal: 1.8

- **wide range of volatility**
  - b.p. (°C)
    - methanethiol: 6
    - haxanal: 120
    - vanillin: 285

- **low Impact to high impact**
  - Odor threshold
    - decanoic acid: 10 ppm
    - hexanal: 4.5 ppb
    - β-damascenone: 2 pptr
Aroma Analysis

Isolation of aroma components

Separation/Characterization of aroma components (GC, GC-MS, GCO)

Identification and Quantification

Choice of extraction method depends on . . .

- Information desired (objective)
- Sample matrix
- Stability and concentration of analytes
- Capability (limitations) of chosen instrumental techniques

Gas chromatographic methods are most often used, but liquid chromatography (HPLC) may be useful for unstable/labile compounds.

Compounds are usually identified by their mass spectra and GC retention indices.

GC areas used to estimate concentration.
Limitations of traditional volatile compound analysis (GC-MS)

- Not all detectable (instrumental) volatile compounds are equally important (or necessarily participate) in the flavor (aroma) of a food.

- Instruments cannot measure the sensory attributes (odor/intensity) of a volatile compound.

- Limitations overcome by combining instrumental and sensory techniques.
Gas Chromatography-Olfactometry

- For locating and characterization of odorants in a complex mixture of volatile compounds
Sensory-Directed Flavor Analysis

- Application of sensory analysis to help guide and interpret the findings from instrumental analysis
- Gas chromatography-olfactometry (GCO)
- Rigorous GC-MS qualitative and quantitative analysis
- Sensory comparison of ‘synthetic’ flavor systems (models) to actual food system
Examples: Relating Cheddar Cheese Flavor to its Volatile Chemical Constituents
Relating chemical analyses results to perceived (sensory) flavor in Cheese

Why Important?

- Accurate communication
  - between research groups (analytical versus sensory)
    - better understanding of what drives liking
    - potential marketing issues
Cheddar cheese flavor

- Results from correct balance/concentration of a wide range of sapid and aromatic compounds “Component Balance Theory”

- Numerous biochemical pathways involved in flavor development.

- Over 110 volatile components identified
Relating chemical analyses results to perceived (sensory) flavor . . . .

How to accomplish?

- Develop sensory tool (flavor lexicon) for precise description and rating of ‘all’ flavor attributes
- Employ GC-olfactometry based methods to identify potential key odorant(s) responsible for each attribute
- Conduct simple model or spiking sensory studies to verify relationship(s) between odorant and flavor attribute

  e.g. 2-mercapto-2-methypentan-4-one

  “Catty”
Cheddar flavor lexicon . . . .

- Language has definitions and references for each term
- Scale includes intensity anchors
  - Additional descriptors
  - Subdivisions of basic descriptors
Additional Descriptors and Subdivision of basic terms provide additional specificity

- Other descriptors
  - oxidized
  - yeasty
  - moldy/earthy/bell pepper
  - methyl ketone
  - animal/wet dog
  - fecal
  - waxy, crayon
  - caramelized
  - rosy/floral
  - astringent
  - burn/prickle

- Subdivided terms
  Examples:
  - Sulfur: overall sulfur, egg-like, match-like
  - Brothy: beefy, chicken, mushroom
Example II: “Nutty” flavor in Cheddar

- Two NUTTY and two NON NUTTY cheeses were selected from 40 blocks (9 mo. – 3.5 years)
- Cheeses profiled by descriptive sensory analysis
- Cheeses evaluated by instrumental-sensory based techniques (comparative AEDA)
- Additional sensory analyses performed to confirm roles of identified compounds in characteristic flavor notes.

Descriptive Sensory Evaluation of NUTTY (N) and NON NUTTY (NN) Cheeses – selected descriptors

- cooked
- milkfat/lactone
- brothy
- nutty
- sulfur

Bar chart showing the comparison of N1, N2, NN1, and NN2 samples in terms of the selected descriptors.
Comparison of headspace components of N and NN cheeses by GCO of decreasing dynamic headspace volumes (GCO-DHS)

- One NUTTY (N3) and two NON NUTTY (NN3, NN4) cheeses

- Conditions (off-line)
  - 10 g grated cheese
  - 40°C, 20 min (preheat)
  - Tenax TA 60/80 trap
  - 50 mL/min N₂ flow
  - thermal desorption, TDS2 (Gerstel)

- GCO-DHS was achieved by varying headspace purge times (25, 5 or 1 min) or volumes (1250, 250, or 50 mL)
## AEDA results – “Nutty” Cheddar

<table>
<thead>
<tr>
<th>Odorant</th>
<th>Odor Property</th>
<th>FD Factor* (Intensity)</th>
</tr>
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<tbody>
<tr>
<td>Dimethylsulfide</td>
<td>cut cabbage, corn</td>
<td>5 (1) 5 (1) 25 (3)</td>
</tr>
<tr>
<td>2-methylpropanal</td>
<td>dark chocolate, malty</td>
<td>- - 5 (3) 25 (3)</td>
</tr>
<tr>
<td>2-/3-methylbutanal</td>
<td>dark chocolate, malty</td>
<td>25 (1) 25 (1) 25 (4)</td>
</tr>
<tr>
<td>Diacetyl</td>
<td>buttery</td>
<td>25 (1) 25 (1) 25 (3)</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>fruity, bubble gum</td>
<td>25 (3) 25 (1) 25 (3)</td>
</tr>
<tr>
<td>Ethyl hexanoate</td>
<td>fruity, berry-like</td>
<td>1 (2) 5(1) 25 (3)</td>
</tr>
<tr>
<td>1-Octen-3-one</td>
<td>mushroom</td>
<td>25 (2) 25 (1) 25 (3)</td>
</tr>
<tr>
<td>Dimethyltrisulfide</td>
<td>sulfurous, cabbage</td>
<td>25 (2) 25 (1) 25 (4)</td>
</tr>
<tr>
<td>Methionial</td>
<td>potato</td>
<td>25 (2) 25 (2) 25 (4)</td>
</tr>
</tbody>
</table>

*FD-factor: highest purge volume tested divided by lowest purge volume in which odorant was last detected by GCO*
Strecker Aldehydes and “Nutty” flavor

Relationship between 2-methylbutanal concentration and "nutty" intensity

Relationship between 3-methylbutanal concentration and "nutty" intensity

Thresholds (in water)
- 2-MP (1 ppb)
- 2-MB (1 ppb)
- 3-MB (0.35 ppb)
e.g. Flavor Profile of British Farmhouse Cheddar Cheese

- descriptions: aromatics associated with barns and stock trailers
- reference: p-cresol, Band-aid, phenol
Results of gas chromatography-olfactometry (GCO) and Aroma Extract Dilution Analysis (AEDA) (Table 2) showed 2-isopropyl-3-methoxypyrazine and p-cresol to be responsible for cowy/barny and earthy/bell pepper flavors, respectively.

Additional sensory testing (dose-response) confirmed result.
Conclusions

- Application of combined instrumental-sensory tools, such as GCO, makes it possible to link single odorants or combinations to descriptive sensory terms.

- Ultimately, researchers will be able to relate sensory flavor quality (attributes that drive liking or disliking) with the chemistry and technology of production.