Introduction

When food is consumed, the interaction of taste, odor and textural feeling provides an overall sensation which is best defined by “flavor”.

What is flavor?

- **In the past**
  Aroma, taste & chemesthetic responses (tongue, mouth, lips, throat, olfactory region)

- **Now**
  Complex interaction of taste, smell, appearance, feeling, exposure, etc.

- Flavor results from compounds that are divided into two broad classes:
  - those responsible for taste and
  - those responsible for odors.
- There are compounds which provide both sensations.
- Compounds responsible for taste are generally nonvolatile at room temperature. They interact only with taste receptors located in the taste buds of the tongue.
- Taste buds enable humans to sense sweetness, sourness, saltiness, and bitterness, and these sensations contribute to the taste component of flavor.

Nonspecific or trigeminal neural responses also provide important contributions to flavor perception through detection of pungency, cooling, umami, or delicious attributes, as well as other chemically induced sensations that are incompletely understood.

**Taste**

- **Sweet**
  - i.e. polyhydroxy compound, saccharin
  - i.e. NaCl (Sodium chloride)

- **Sour**
  - i.e. acetic acid, lactic acid

- **Salty**
  - i.e. NaCl (Sodium chloride)
  - LiCl (Lithium chloride)

- **Bitter**
  - i.e. lean meat
  - → creatine
  - Coffee, cocoa → caffeine
Sweetness

- Sweetness is found in many types of molecules (not just sugars), and relative sweetness is normally compared to sucrose
- Natural sugars – sucrose (1.0); glucose (0.76); fructose (1.52)
- Also artificial sweeteners – sodium cyclamate (30); acesulpham-K (140); aspartame (200); saccharin (350); 1-n-propoxy-2-amino-4-nitrobenzene (4000)

Relative Sweetness of Sugars and Other Sweeteners

<table>
<thead>
<tr>
<th>Compound</th>
<th>Relative Sweetness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>1</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.27</td>
</tr>
<tr>
<td>Maltose</td>
<td>0.6</td>
</tr>
<tr>
<td>Sorbitol</td>
<td>0.6</td>
</tr>
<tr>
<td>Galactose</td>
<td>0.6</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.5–0.7</td>
</tr>
<tr>
<td>Mannitol</td>
<td>0.7</td>
</tr>
<tr>
<td>Glycerol</td>
<td>0.8</td>
</tr>
<tr>
<td>Fructose</td>
<td>1.1–1.5</td>
</tr>
<tr>
<td>Cyclamate</td>
<td>30–80</td>
</tr>
<tr>
<td>Glycyrrhizin</td>
<td>50</td>
</tr>
<tr>
<td>Aspartyl-phenylalanine ester</td>
<td>100–200</td>
</tr>
<tr>
<td>Stevioside</td>
<td>300</td>
</tr>
<tr>
<td>Neohesperidin dihydrochalcone</td>
<td>300</td>
</tr>
<tr>
<td>Saccharin</td>
<td>500–700</td>
</tr>
<tr>
<td>Neohesperidin dihydrochalcone</td>
<td>1000–1500</td>
</tr>
</tbody>
</table>

**Sourness**
- Sourness assumed to be linked with acidic solutions
- However, the presence of unionized organic acids (i.e. RCO₂H) is more important for the taste of sourness
  - *citric, malic, tartaric (grape), isocitric, oxalic, acetic, lactic acid*

- **In foods:**
  - Sourness of vinegar due to acetic acid, but also adds importantly to aroma, such as with fish and chips
  - Lactic acid in pickled foods such as sauerkraut comes from bacterial fermentation of the sugars in the vegetables
  - Sodium lactate is used in salt and vinegar flavoured crisps

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**Salty Taste**
- The salty taste is best exhibited by sodium chloride.
- The taste of salts depends on the nature of both cation and anion.
- As the molecular weight of either cation or anion—or both—increases, salts are likely to taste bitter.
- The lead and beryllium salts of acetic acid have a sweet taste.

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**Bitterness**
- Several classes of compounds exhibit bitterness
- Taste buds at back of tongue responsive to:
  - *group 1 and 2 halide salts*
  - certain phenolics
- KBr is both salty and bitter
  - *Halide salts with the sum of their ionic diameters > KBr are bitter, if the sum is less then they are salty*

<table>
<thead>
<tr>
<th>Taste</th>
<th>Salts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salty</td>
<td>LiCl, LiBr, LiI, NaNO₂, NaCI, NaBr, NaI, KNO₂, KCl</td>
</tr>
<tr>
<td>Salty and bitter</td>
<td>KBr, NH₄Cl</td>
</tr>
<tr>
<td>Bitter</td>
<td>CsCl, CsBr, KI, MgSO₄₂</td>
</tr>
<tr>
<td>Sweet</td>
<td>Lead acetate,¹ beryllium acetate¹</td>
</tr>
</tbody>
</table>

¹Extremely toxic

- The current trend of reducing sodium intake in the diet has resulted in the formulation of low-sodium or reduced-sodium foods.
- Sodium chloride enhances mouthfeel, sweetness, balance, and saltiness, and also masks or decreases off-notes.
- Salt substitutes based on potassium chloride do not enhance mouthfeel or balance and increase bitter or metallic off-notes.

NaCl (0.556) < KBr (0.658 nm) < KI (0.706) < MgCl₂ (0.850)
**Bitterness**

- Many plants contain molecules which we perceive as very bitter
  - Nicotine, atropine, emetine
  - *Quinine* - a flavor component of tonic water and bitter lemon
- **Role in plants unknown**, but many have undesired pharmacological properties
- Quinine antiplasmodial agent used to prevent and cure malaria by consumption of tonic waters

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**Phenolics: Seville oranges**

- Phenolics in the form of flavanoids are source of bitterness in citrus fruits.
  - Naringin is a bitter sugar-flavanone conjugate found in Seville oranges. Its bitterness is detected at 1:50,000 dilution.

**Phenolics: beer**

- Before the fermentation stage of the brewing process, the flowers of the hop plant, *Humulus lupulus*, are added to the wort
- Hops are added to add both flavour & bitterness
  - The humulones or α-acids
  - Iso α-acids
- The humulones are converted to the more soluble and more bitter iso α-acids in the boil

**Nonspecific Sensations**

- **Umami**
- **Pungency**
  - i.e. Peppermint, Spearmint, wintergreen → l-isomer of menthol; camphor
- **Astringency**
  - i.e. Tea leaves & red wines → polyphenols tannin; unripe bananas
- **Cooling**
  - i.e. L-menthol
Umami

- Water soluble, non-volatile taste components
- Monosodium glutamate, MSG, umami$_1$
  - Levels of 10-35 mg/100 g meat
- Inosine monophosphate (IMP) umami$_2$
  - Levels of 1-200 mg/100 g
  - Also, but less important, guanosine monophosphate, GMP (0-10 mg/100 g)
AROMA

- Aroma substances are volatile compounds which are perceived by the odor receptor sites of the smell organ, i.e. the olfactory tissue of the nasal cavity.
- They reach the receptors when drawn in through the nose (orthonasal detection) and via the throat after being released by chewing (retronasal detection).

AROMA

- Exceedingly complex - a given food aroma may consist of several 100 volatiles
- Exceedingly sensitive - nose $10^{-17}$ g of some odorants

Aroma Formation

- Vegetables
  Flavor formed after cellular disruption

- Fruits
  Flavor formed during ripening
**Onion**

\[
\text{H}_3\text{N} - \text{COOH} \\
\text{CH} \\
\text{CH}_2 \rightarrow 4\text{(RSOH)} \rightarrow \text{R-S-S-R} \\
\text{S-O} \\
\text{R} \\
\text{R-SH} \\
\text{R-S-R} \\
\text{CYSTEINE SULFOXIDE} \rightarrow \text{R-S-S-R} \\
\text{R-S-S-S-R}
\]

**FRUIT FLAVOR**

- Aliphatic amino acids → alcohols + acids → Esters (fruity)
- Aromatic amino acids → aromatic aldehydes (spicy)
- Fat → free fatty acids → acids + alcohols → Esters
- Terpenes (glycosidically bound)

**Vegetable radish**

\[
\text{HS-S=CH-CH-C-S-GLUCOSE} \\
\downarrow \text{N-OSO}_3 \\
\text{S} \\
(R-C_\text{N}-O-\text{SO}_3) \text{UNSTABLE} \\
\downarrow \\
\text{ISOThIOCYANATES + NITRILES} \\
\text{SULFIDES, ETC}
\]
FACTORS INFLUENCING FLAVOR

- **Genetics**
  A. Different precursors
  B. Different enzyme systems

  Example:
  *Onions* - 5 fold variation in flavor intensity
  *Orange* (var. Mandarine ≠ Florida ≠ California)

- **Environments**
  A. Soil
    i.e. Carrots
    - *California* - most flavor, most sweet, least harsh
    - *Florida* - low in sweetness, low in flavor
    - *Texas* - most harsh/rough, otherwise moderate
  B. Rainfall
    - High rainfall - large, abundant produce, little flavor
      e.g. Onions → 4 x difference in aroma on low water vs high water
  C. Temperature
    Generally large temperature extremes (stress) → ↑ flavor

- **Maturity**
  - Pick fruit early and allow to ripen away from plant → **Climacteric Fruits**
    i.e. Avocado, banana, mango – ok
  - Otherwise → **Non Climacteric Fruits** - no!
    i.e. Peaches, tomato - total flavor imbalance

- **Post harvest storage**
  A. Temperature - banana
    - Temp. < 5 C - no banana flavor
    - Temp. 10 - 12 C - 60% reduction in flavor
    - Temp. > 27 C - high levels of ethanol & ethyl acetate
  B. Controlled Atmosphere Storage
    Storage equipped with specific air composition of CO₂ & O₂
    5% CO₂ + 2% O₂ → No flavor
  C. Humidity
    Apples - low humidity flavor imbalance
FLAVOR ANIMAL PRODUCTS

- Diets
  - can get major flavor influence

- Aging
  - Beef, lamb, mutton

FLAVOR FORMED DURING PROCESSING

- NONENZYMATIC BROWNING/NEB (The Maillard Reaction)
  - Characteristic flavor of many baked, fried, or otherwise thermally processed foods

Flavor formation of NEB reaction

Amino acids + reducing sugars

↓

Complex

↓

Fragmentation of complex

↓

Recombination to form flavor

Factors: pH, Water activity, Oxidation/reduction state, Temperature, Time

Meatiness

- Many volatile aromas present in meats
  - Over 650 identified in beef
  - Most common are hydrocarbons (18%) and non cyclic sulfur compounds (11%)

Maillard breakdown of S-containing amino acids

ROASTED MEAT FLAVOURS
**Caramelization**
- acid / base catalysed (organic acids / water) • any sugar – here glucose

\[
sugar \xrightarrow{\text{high temps}} \text{brown pigments} \xrightarrow{\text{flavours}}
\]

**LIPID OXIDATION**

- Potential in most foods containing fat or oil.

Factors influence lipid oxidation:
- Unsaturated fatty acids
- Water activity
- Antioxidants
- Temperature
- Catalysts

**FERMENTATION**

1. *Primary products* - acids, alcohols, aldehydes
   - Examples: some cheeses, yoghurt, beer

2. *Secondary products* - ketones, esters, amino acids
   - Examples: aged cheeses

THANK YOU