Flavor Challenges and Solutions for High Protein Functional Foods and Beverages

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Protein Trends and Technologies Seminar 2015
May 5-6, 2015 • Oak Brook, Illinois, USA
Overview

- Flavor and Flavor Quality
- Flavor Problem with Functional Foods/Beverages
- Flavor Consequences of Proteins and Other Ingredients
- Product Considerations
- Finding a Flavoring Solution
- Final Recommendations
Significance of Flavor

- **Cultural aspects**
  - food (flavor) acceptance linked to cultural experience

- **Emotional aspects**
  - aroma perception linked to memory and emotion

- **Nutritional aspects**
  - flavor is an important determinant of food acceptance and diet
What is Flavor?

- Sensation (Smell/Taste/Mouthfeel)
  - Flavor perception

- Stimuli
  - Chemicals causing sensation
Senses and Sensory Properties

Stimulus  Sense  Sensory Property

Food  

Sight  Appearance

Odor

Taste  Flavor

Touch  Trigeminal

Hearing  Pressure

Chemesthesis  Texture
‘Flavor’ Sensations

Receptor Organ

Nose
Mouth
Tongue

Flavor Type

Odor
Trigeminal
Taste

Sensation Descriptor

Fruity
Green
Spicy
Woody
Burnt
Sulfury
Etc….

Pungent
Astringent
Cooling/Heat

Salty
Sweet
Bitter
Sour
Umami
Dimensions of Flavor

- Qualitative – recognized attribute (e.g. salty, vanilla)
- Intensity – dose/response behavior
- Temporal Aspects – time/intensity. Especially important in taste (e.g., clean vs. lingering aftertastes)
- Spatial – locale of stimulation/perception
- Hedonics – like or dislike
- Interactions with Other Modalities (appearance, texture)

What defines flavor quality?

Desirable Sensory Attributes

- Immediate impact of identifying flavor (e.g. vanilla / chocolate)
- Rapid development of a balanced, full-bodied flavor
- Compatible mouthfeel and texture
- Lack of off-flavors
- Minimal (brief) aftertaste

Many functional foods and beverages have ‘harsh’ flavors including off-odors, bitter tastes and undesirable mouthfeel properties (e.g. astringency).

Many lack any inherent positive flavors.

Functional foods are viewed as members of a particular food category rather than the “functional food” category.

The “If it tastes bad, it’s good for you” concept doesn’t apply to functional foods and beverages.


Taste vs. Perceived Health Benefits

Frequency distribution of consumer acceptance of functional foods:

A = accept functional foods if they taste good.

B = accept functional foods if they taste worse than conventional substitute foods

Flavor Consequences of Protein Ingredients
Undesirable flavors from protein ingredients

- **Inherent off-flavors (potent odorants)**
  - low concentrations (ppb)/high flavor impact
  - enzyme-derived volatiles
  - protein degradation volatiles

- **Reaction-derived flavors (during processing/storage)**
  - lipid oxidation
  - Maillard reaction (during thermal processing)
  - misc. chemical breakdown (e.g. vitamins)
Flavor of Soy Protein

- Odor (aroma) components
  - mainly aldehydes, ketones, alcohols
  - *green*, *beany*, and *cereal* notes

- Bitter / astringent components
  - oxidation products (e.g. oxidized lecithin)
  - phenolic acids (e.g. phytate)
  - polyphenols (isoflavones/saponins)

Dairy Proteins

**TABLE 1.**

INITIAL MILK POWDER AND DRIED DAIRY INGREDIENTS LANGUAGE

<table>
<thead>
<tr>
<th>Aromatics</th>
<th>Dairy Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked/sulfurous</td>
<td></td>
</tr>
<tr>
<td>Caramelized/sweet</td>
<td></td>
</tr>
<tr>
<td>Aromatic/vanillin</td>
<td></td>
</tr>
<tr>
<td>Heated butter</td>
<td></td>
</tr>
<tr>
<td>Cereal/grassy</td>
<td></td>
</tr>
<tr>
<td>Animal/mucilage/</td>
<td></td>
</tr>
<tr>
<td>Wet dog/barny</td>
<td></td>
</tr>
<tr>
<td>Brothy/potato-like</td>
<td></td>
</tr>
<tr>
<td>Fried fatty/painty</td>
<td></td>
</tr>
<tr>
<td>Fishy</td>
<td></td>
</tr>
<tr>
<td>Mushroom/metallic</td>
<td></td>
</tr>
<tr>
<td>Cardboard/papery</td>
<td></td>
</tr>
<tr>
<td>Burnt/charcoal</td>
<td></td>
</tr>
<tr>
<td>Vitamin/rubbery</td>
<td></td>
</tr>
<tr>
<td>Diacetyl</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tastes</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Salty</td>
<td></td>
</tr>
<tr>
<td>Sour</td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td></td>
</tr>
<tr>
<td>Bitter</td>
<td></td>
</tr>
<tr>
<td>Umami</td>
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</tr>
</tbody>
</table>

**FIG. 4. ATTRIBUTES AND INTENSITIES OF CASEINATES AND WHEY PROTEIN CONCENTRATES**

Cooked - cooked flavor, animal/wet dog - animal/wet dog, brothy - potato/brothy, cardboard - cardboard, metal - mushroom/metallic, vitamin - vitamin, sweet - sweet taste, salty - salty taste, bitter - bitter, astringent - astringent. For complete references, see Table 2.

Other Proteins

- Pea Protein
  - early/soil, green (grassy), beany

- Rice (Bran) Protein
  - rancid, smoky

- Egg Protein
  - sulfurous

- Protein Blends
  - ?
Must Consider Flavor Potential of Other Functional Ingredients

- Vitamins
  - B1 (thiamin) - meaty (medicinal/vitamin) note

- Minerals
  - metallic tastes, chalkiness (calcium)

- Amino acids
  - bitter, sweet or umami

- Phytochemicals/extracts, omega-3-fatty acids
Bitter/Astringent Functional Ingredients

- Naringen/limonin (citrus) – bitter
- Peptides – bitter
- Caffeine (coffee) – bitter
- Catechins (tea) – bitter/astringent
- Tannins (cranberry) – astringent
- Isoflavones/saponins (soy) – bitter/astringent
- Plant extracts – bitter/astringent and off-odors/tastes
Flavor and Proteins: Practical Considerations

- Protein degradation as a source of off-flavors
- Persistence of off-flavors
  - difficult to remove bound off-flavors from proteins (SPC, SPI, WPC, WPI, Caseins)
- Removing bound flavors
  - membrane processing (deflavoring)
  - protein hydrolysis
- Flavor consequence I
  - Off-flavor carried (released) into final product
- Flavor consequence II
  - Flavor fade/imbalance - caused by selective binding of added flavorings

Flavor Binding to Proteins

- Mainly hydrophobic or hydrogen bonding

- Covalent bonding possible
  - e.g. Schiff base formation (irreversible) – reaction of aldehydes with amino groups of proteins

- Binding affinity/capacity depends on environmental conditions
  - pH, temperature, moisture/water activity, salt, degree of protein denaturation / hydrolysis
Figure 2. Equilibration curves for binding of vanillin with soy protein isolate (SPI) and deamidated soy protein isolate (DSPI) at 25 °C.
Flavor - Food Matrix Interactions

- Flavor partitioning, diffusion and mass transfer
  - e.g., low fat versus full fat products
  - fat modulates flavor release

- Flavor stability, retention/release
  - storage, packaging interactions
  - encapsulated flavors

- Flavor binding
  - e.g., flavor - protein interactions
  - leads to flavor loss (fade) and imbalanced flavor
Thermal Process Induced Flavor Changes

- Ultra-High Temperature (UHT) processing can cause flavor changes.

Product Form and Function

Bars/Cereals

- Low moisture/low water activity
  - moisture migration concerns
  - texture concerns
  - possible phase changes

- No or mild thermal process

- Immobile flavor system

- Ambient storage/long shelf-life

- Possibility of using encapsulated ingredients (vitamin/minerals, harsh ingredients/omega-3-FA)
  - will reduce off-flavor potential

Beverages

- High moisture
  - spoilage concerns
  - viscosity/consistency concerns

- pH restrictions (protein solubility)

- Severe thermal process (UHT)

- Integrated/mobile flavor system

- Ambient or refrigerated storage
  - variable shelf-life

- Difficult to use encapsulated ingredients
  - complexation (cyclodextrins) of some components possible
Approaches:

- Reduction / removal of off-flavors in ingredients
- New / improved processing methods which minimize formation of off-flavors or reduce off-flavors (as a result of a process).
  - reduced time / temperature treatment in processing with flash cooling to evaporate or “flash off” highly volatile off-odors
  - create physical barriers to reduce off-flavor impact
- Better flavoring solutions: addition of masking agents / specially formulated flavorings
What are masking agents?

- Act to neutralize undesirable aromatics & tastes
  - bitterness
  - aftertastes
  - off-odors (e.g. rancid/vitamin/scorched/terpenes)
  - . . . . without imparting any characteristic flavors

- Should be applied before overlaying ‘base’ with added flavoring (mask first/flavor later)
  - Helps prevent over flavoring of product
  - Better enables use of ‘natural’ flavors
The art and science of masking

Masking (the science)

**Suppression**

Odor (aromatics) suppression
- Perceived intensity of odorant mixture less than individual components (*mixture suppression*)

Bitterness suppression
- Sodium salts
- Glycine
- Sucrose and natural/artificial high intensity sweeteners *mutual suppression*


Taste Inhibition (Taste Blockers)

Bitterness inhibition
- e.g. phosphatitic acid, adenosine monophosphate (AMP), riboflavin-binding protein (chicken egg)
- e.g. various proprietary agents/technologies

Sweetness inhibition
- e.g. Lactisol

Flavor Potentiation (Enhancement)
- MSG and 5’-nucleotides (IMP/GMP)
- Salt enhances sweetness perception
- ‘Sweet aromatics’ often enhance sweet taste perception (“halo effect”)
Flavor Modulation

Fat - important in flavor modulation & release

• Full-fat versus fat-free

• Fat replacers / bulking agents
  - May impact flavor release and mouthfeel
  • e.g. polydextrose

Modifiers

Texture, mouthfeel

• e.g. pectin – provides lubricity, creaminess, fullness
Counteraction versus Masking

Counteraction
- reduction of off-flavor with off-flavor still predominant

Masking
- addition of flavor which becomes predominant while also suppressing off-flavor

Three phases of flavor-flavor interaction

A. Enhancement (hyper-additive)
B. Additive
C. Suppression (sub-additive)

“Physical Masking”

- Develop physical barriers that minimize perception of bitterness and astringency
  - Inclusion complexation (cyclodextrins)*
  - Physical separation - bars (encapsulates/coatings)
  - Emulsions (micro/nano-emulsions) - beverages
  - Modify viscosity (add soluble fiber/gums) - beverages
  - Change pH (phenolic compounds are less bitter/astringent at neutral pH)
The final product

A balance between art and science
Obtaining masking agents

- Available from most flavor houses
  - proprietary or patented technology
  - may be custom blended to meet requirement
  - try several to find one that works in specific product application

- Depending on R & D capability
  - provide base to supplier for custom formulation
  - trial-and-error (added benefit of proprietary product formulation) – select from numerous off the shelf products
Partnering with a Flavor House

- Involve them early in the process
  - greatly reduces development time

- Provide the composition of your product
  - protein, moisture, gums/stabilizers, pH, water activity
  - minor components that could impact flavor
    - vitamins, minerals, phytochemicals
  - levels of sugar, high-intensity sweeteners

- Inform them of any process and/or storage variables,
  - thermal process (e.g., UHT) conditions
  - packaging and storage considerations
Do “Masking Agents” Actually Work?

- Soy protein isolate (aqueous suspension) was chosen as the “beverage” matrix.

- Three masking agents (chosen from over 12 commercial products) were tested in the SPI matrix.

- Descriptive sensory analysis was used to rate specific sensory attributes (aroma, aromatics, and tastes).

Mean Intensity Ratings for Aroma Attributes for Hydrated SPI, Alone (Control) or Treated with Three Different Masking Agents

Different letter denotes significant difference of the samples within attributes
Flavoring a ‘masked’ product

- Use a flavoring that complements residual or lingering aromatics and tastes
  - a.k.a. assimilation masking
    - e.g. coffee/chocolate flavors – expect bitterness
  - look for synergies (aromatic vs. taste compound)

- Shelf-life issues: consider flavor changes that may occur over time
  - flavor fade caused by binding of flavors to proteins
  - reformulate flavor to account for selective flavor binding (flavor rebalancing)
Flavoring Considerations for High Protein Functional Foods

- Products have intermediate pH (not sour/tart)
  - Citrus, berry, grape, etc. flavors are not generally a viable option.

- Neutral fruit flavors
  - Mango, papaya, banana, peach

- Dairy and indulgent flavors
  - Cream, vanilla, chocolate, fudge, coffee/mocha, peanut butter, coconut, cookies & crème, etc.

- Subtle flavors are challenging
Final Recommendations

- Flavoring of a high-protein specialty foods and beverages is a big challenge

  - Products carry off-flavors and may selectively bind (e.g. high protein products) added flavorings
  - Be aware of off-flavor ‘potential’ of all ingredients
  - Apply masking agents to the complete ‘base’ before adding flavorings
  - Use complementary flavoring strategies for finished product