Flavor Challenges and Solutions for High Protein Functional Foods and Beverages

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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

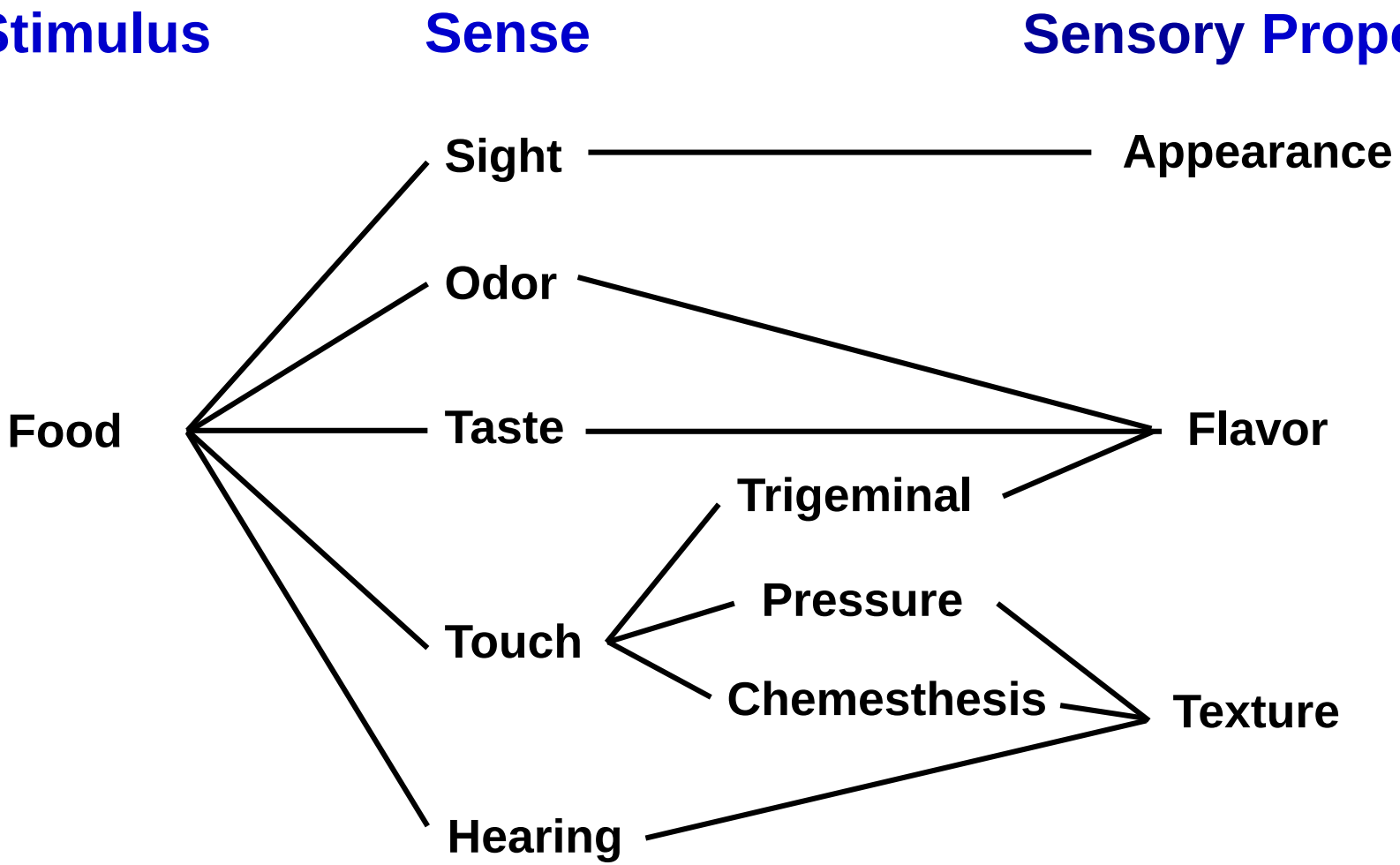
Significance of Flavor

- **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

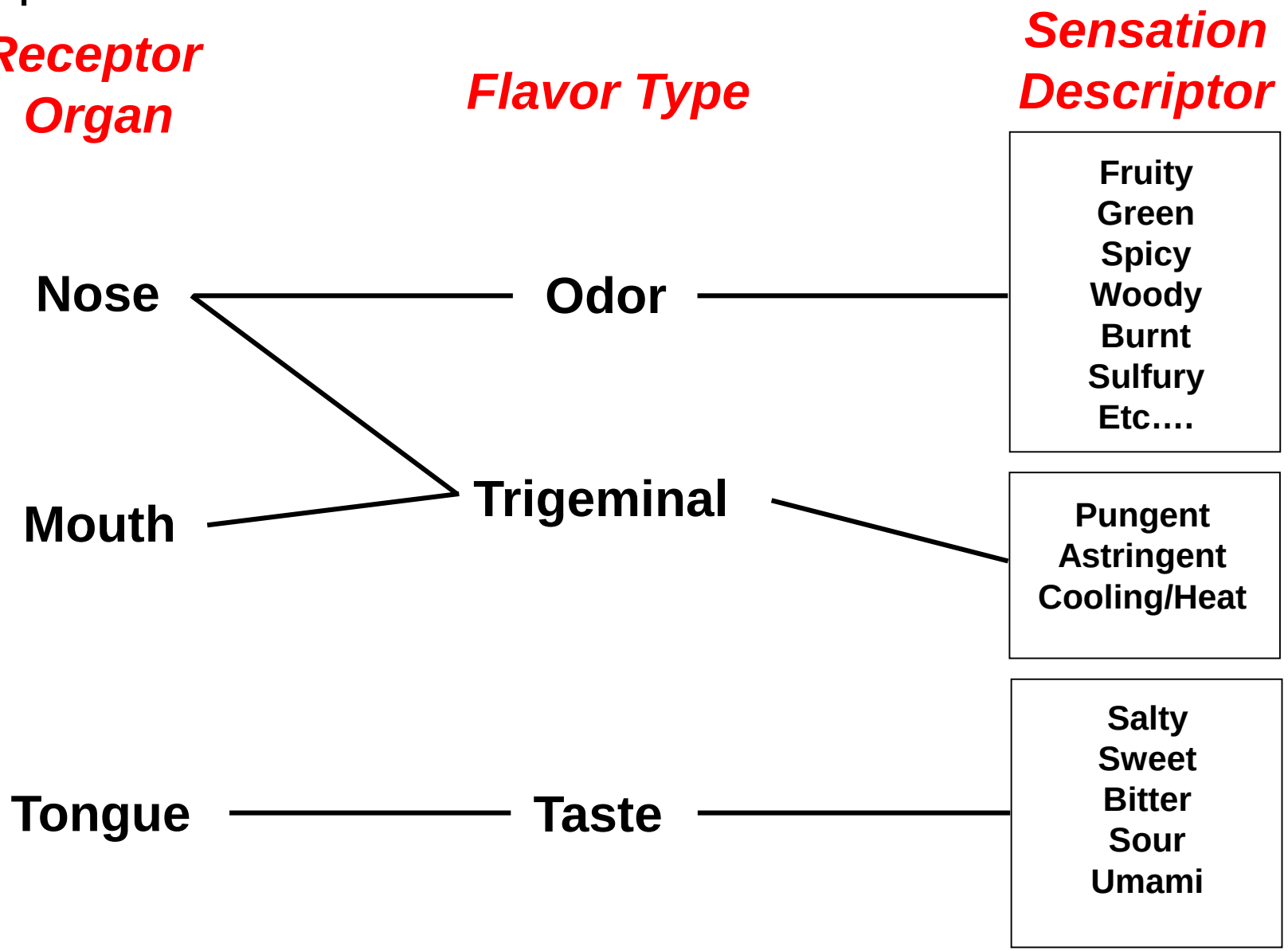
What is Flavor?

- **Sensation (Smell/Taste/Mouthfeel)**
  - **Flavor perception**
- **Stimuli**
  - **Chemicals causing sensation**

Senses and Sensory Properties



‘Flavor’ Sensations



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)**

Breslin, P.A.S. 2001. Human gustation and flavour. Flavour Fragr. J. 16: 439-456.

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**

Cadwallader, K.R. 2015. Flavor challenges in functional beverages. In *Handbook of Functional Beverages in Human Health.* Shahidi, F. , Alasalvar, C. (Eds.). CRC Press Taylor & Francis Group.

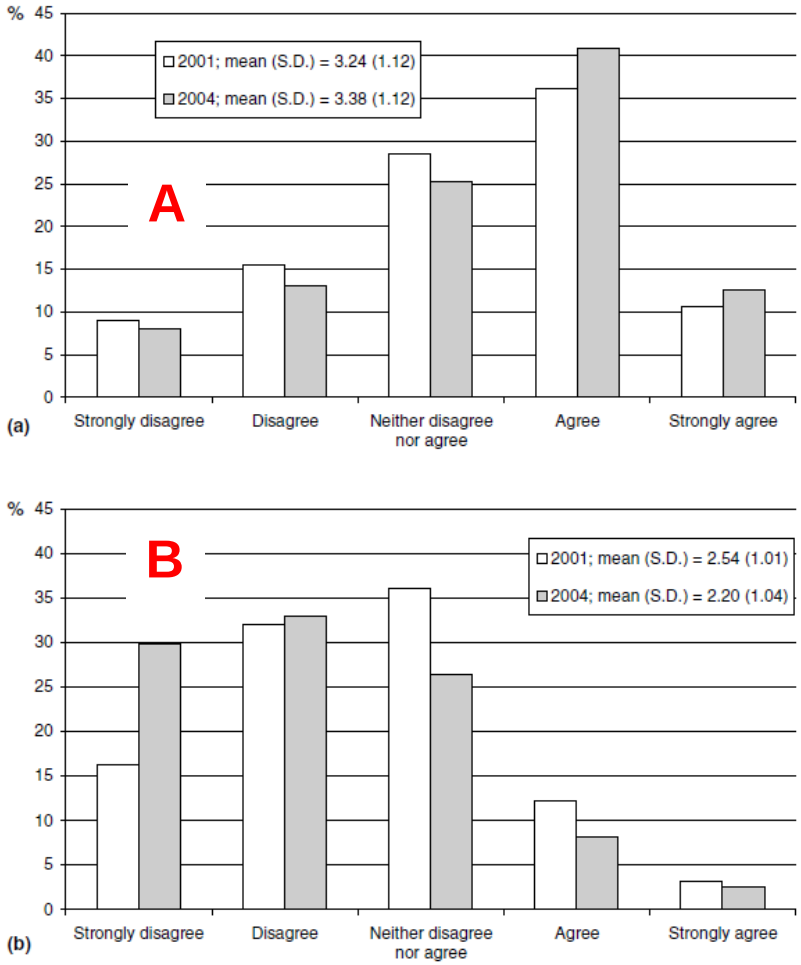
Flavor Issues/Functional Foods

- **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.**

Verbeke, W. 2006. Functional foods: Consumer willingness to compromise on taste for health? Food Qual. Pref. 17: 126-131.

Siro, I., Kapolna, E., Kapolna, B., Lugasi, A. 2008. Functional food: Product development, marketing and consumer acceptance - A review. Appetite 51: 456-467.

Taste vs. Perceived Health Benefits



Frequency distribution of consumer acceptance of functional foods:

2001 **2004**

A = accept functional foods if they taste good.

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

Verbeke, W. 2006. Functional foods: Consumer willingness to compromise on taste for health? Food Qual. Pref. 17: 126-131.

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)**

MacLeod, G. and Ames, J. 1988. Soy flavor and its improvement. CRC Critical Reviews in Food Science and Nutrition 27: 219-401.

Dairy Proteins

TABLE 1.
INITIAL MILK POWDER AND DRIED DAIRY INGREDIENTS LANGUAGE

Aromatics
Cooked/sulfurous
Caramelized/sweet aromatic/vanillin
Heated butter
Cereal/grassy
Animal/mucilage/wet dog/barny
Brothy/potato-like
Fried fatty/painty/fishy
Mushroom/metallic
Cardboard/papery
Burnt/charcoal
Vitamin/rubbery
Diacetyl

Tastes
Salty
Sour
Sweet
Bitter
umami

Feeling factors
astringent

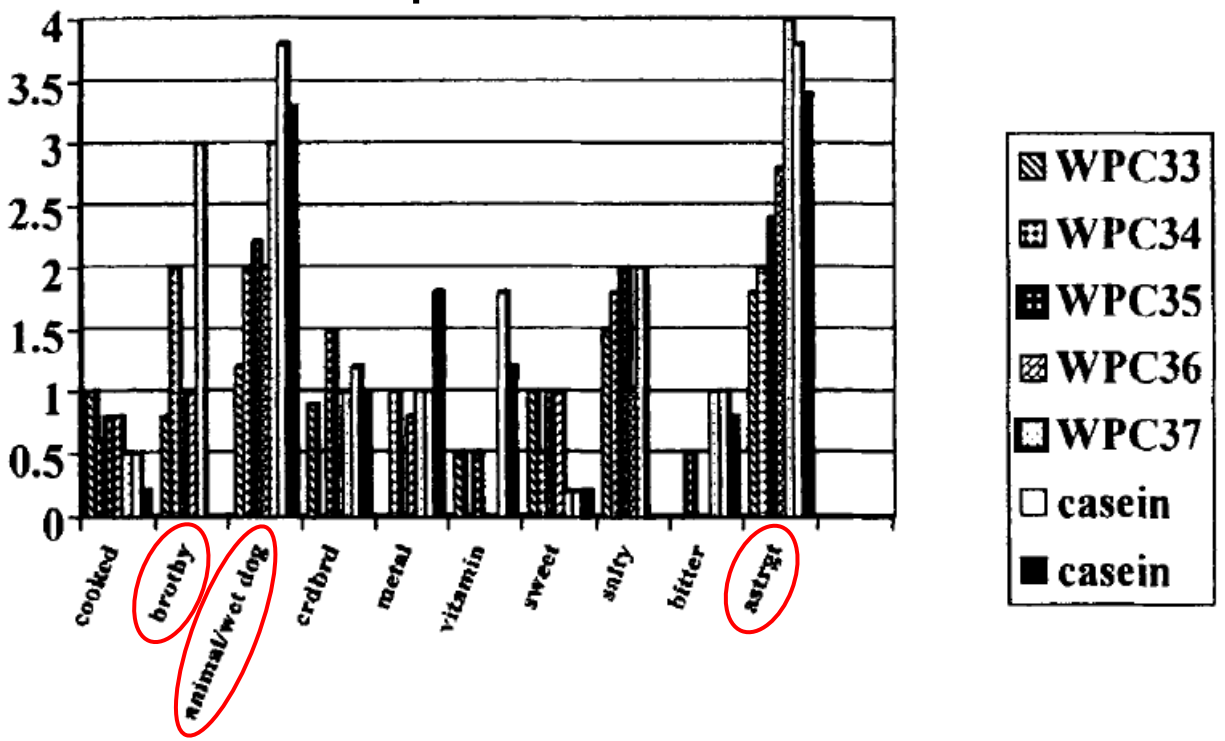


FIG. 4. ATTRIBUTES AND INTENSITIES OF CASEINATES AND WHEY PROTEIN CONCENTRATES

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

Drake, M.A., Karagul-Yuceer, Y., Cadwallader, K.R., Civille, G.V., and Tong, P.S. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. J. Sensory Studies 18: 199-216.

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*

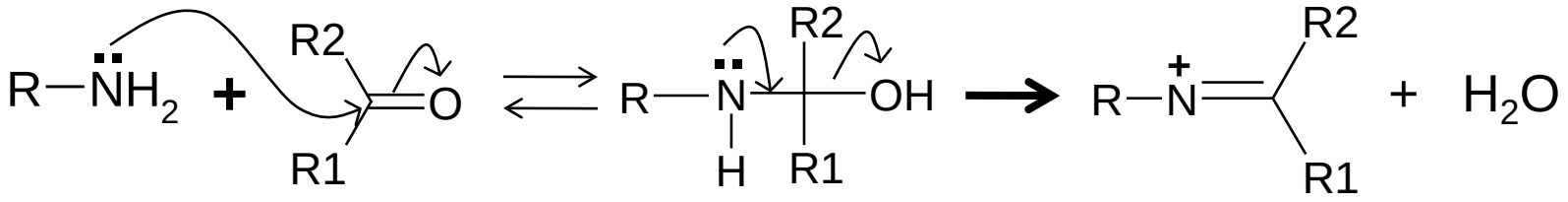
- **Protein degradation as a source of off-flavors**
- **Persistence of off-flavors**
  - **difficult to remove bound off-flavors from proteins (SPC, SPI, WPC, WPI, Caseins)**
- **Removing bound flavors**
  - **membrane processing (deflavoring)**
  - **protein hydrolysis**
- **Flavor consequence I**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

Suppavorasatit, I. and Cadwallader, K.R. 2010. Flavor-soy protein interactions. In *Chemistry, Texture and Flavor of Soy.* Cadwallader, K.R. and Chang, S.K.C. (Eds.). ACS Symposium Series 1059, American Chemical Society, Washington, DC, pp. 339-359.

Flavor Binding to Proteins

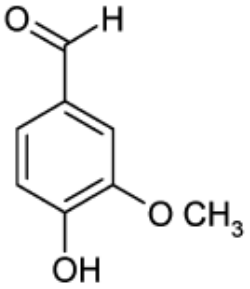
- **Mainly hydrophobic or hydrogen bonding**

- **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**

Flavor Fade (Vanillin)



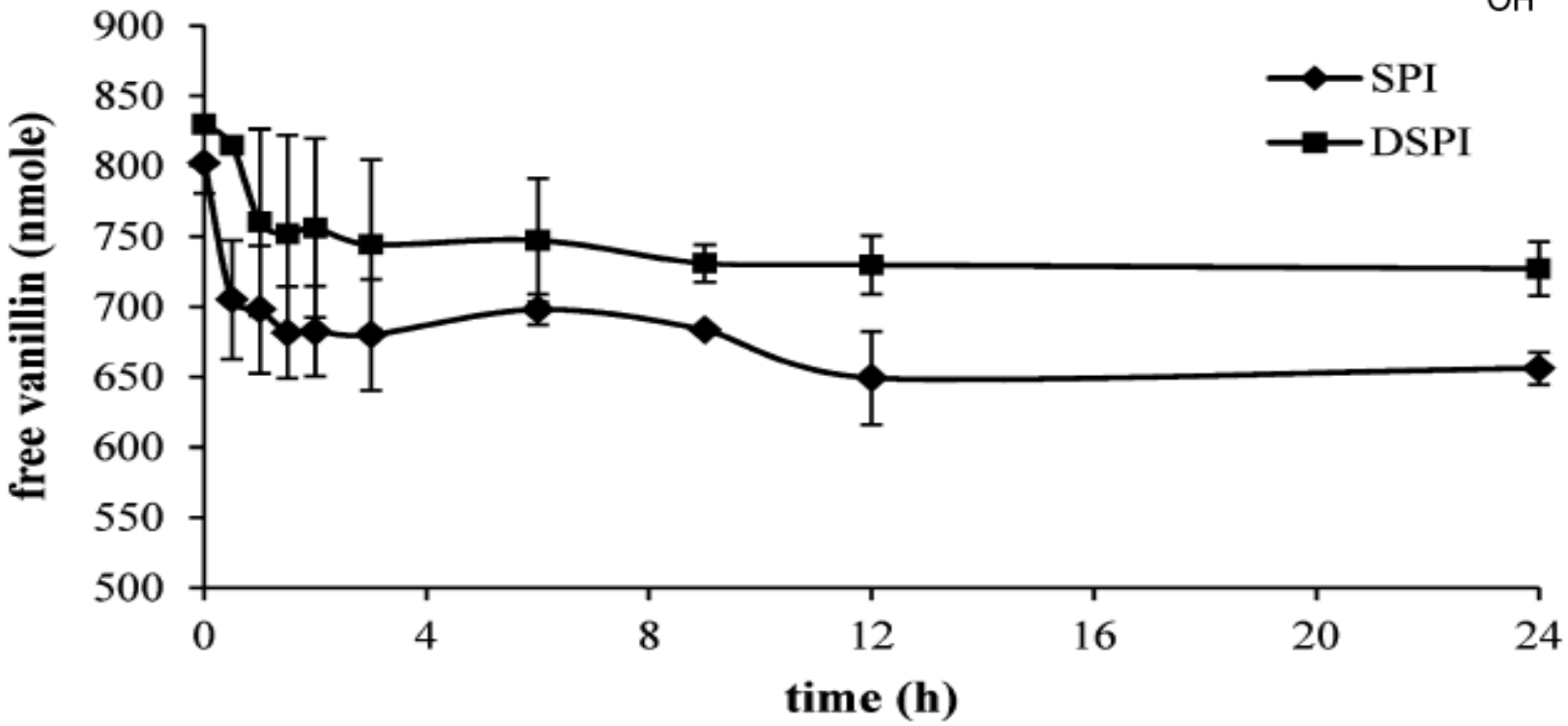


Figure 2. Equilibration curves for binding of vanillin with soy protein isolate (SPI) and deamidated soy protein isolate (DSPI) at 25 °C.

Suppavorasatit, I., Lee, S.-Y. and Cadwallader, K.R. 2013. Effect of enzymatic protein deamidation on protein solubility and flavor binding properties of soymilk. J. Food Sci. 78: C1-C7.

Flavor - Food Matrix Interactions

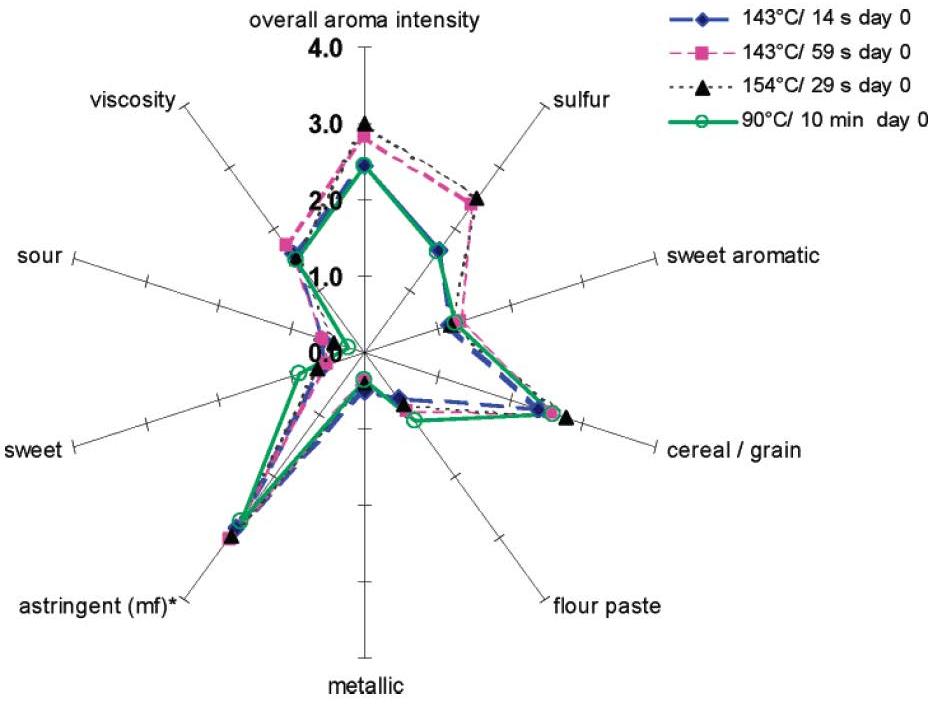
- **Flavor partitioning, diffusion and mass transfer**
  - **e.g., low fat versus full fat products**
  - **fat modulates flavor release**

- **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.**



Lozano, P.R., Drake, M.A., Benitez, D. and Cadwallader, K.R. 2007. Instrumental and sensory characterization of heat-induced odorants in aseptically packaged soy milk. J. Agric. Food Chem. 55: 3018-3050.

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

Developing a Flavor Solution

- **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**

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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

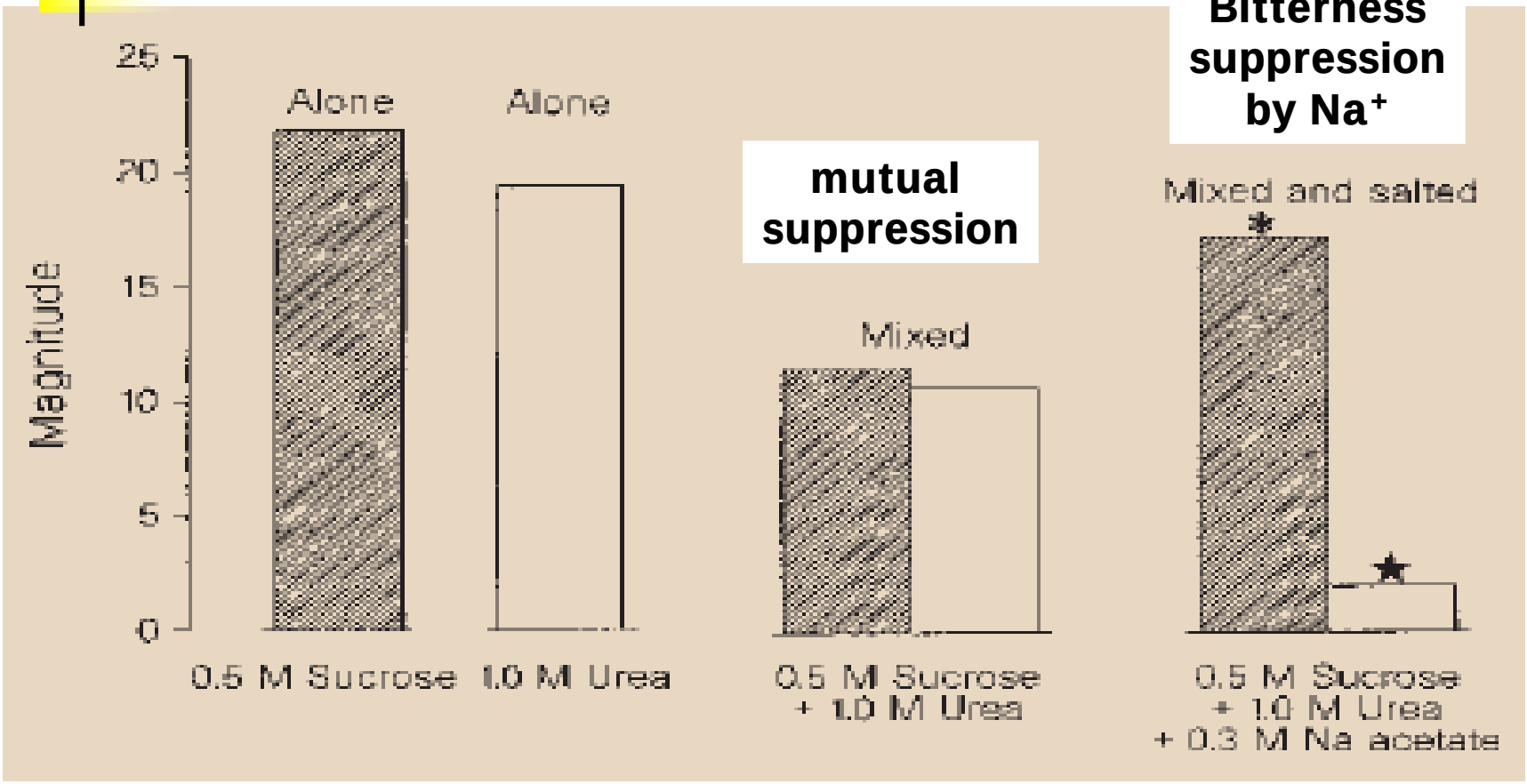
  Odor (aromatics) suppression

  - **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***

Bitterness/Sweetness Suppression



Breslin, P.A.S. and Beauchamp, G.K. 1995. Suppression of bitterness by sodium: Variation among bitter taste stimuli. Chem. Senses 20: 609-623.

Breslin, P.A.S. and Beauchamp, G.K. 1997. Salt enhances flavour by suppressing bitterness. Nature 387: 563

Mennella, J.A. et al. 2015. “A spoonful of sugar helps the medicine go down”: Bitter masking by sucrose among children and adults. Chem. Senses 40: 17-25.

Masking

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")

Masking

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

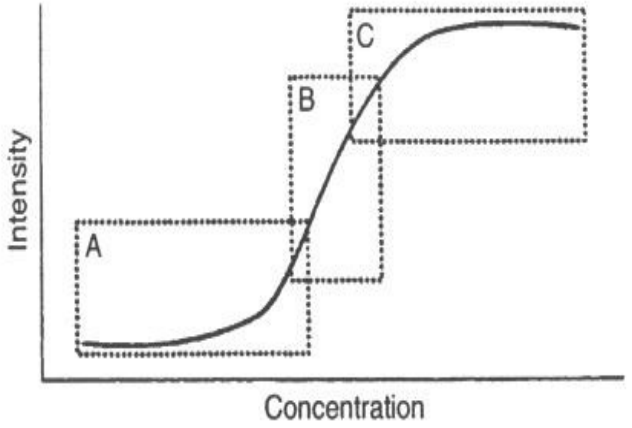
- **addition of flavor which becomes predominant while also suppressing off-flavor**

Three phases of flavor-flavor interaction

A. **Enhancement (hyper-additive)**

B. **Additive**

C. **Suppression (sub-additive)**



Breslin, P.A.S. 2001. Human gustation and flavour. Flavour Fragr. J. 16: 439-456.

“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

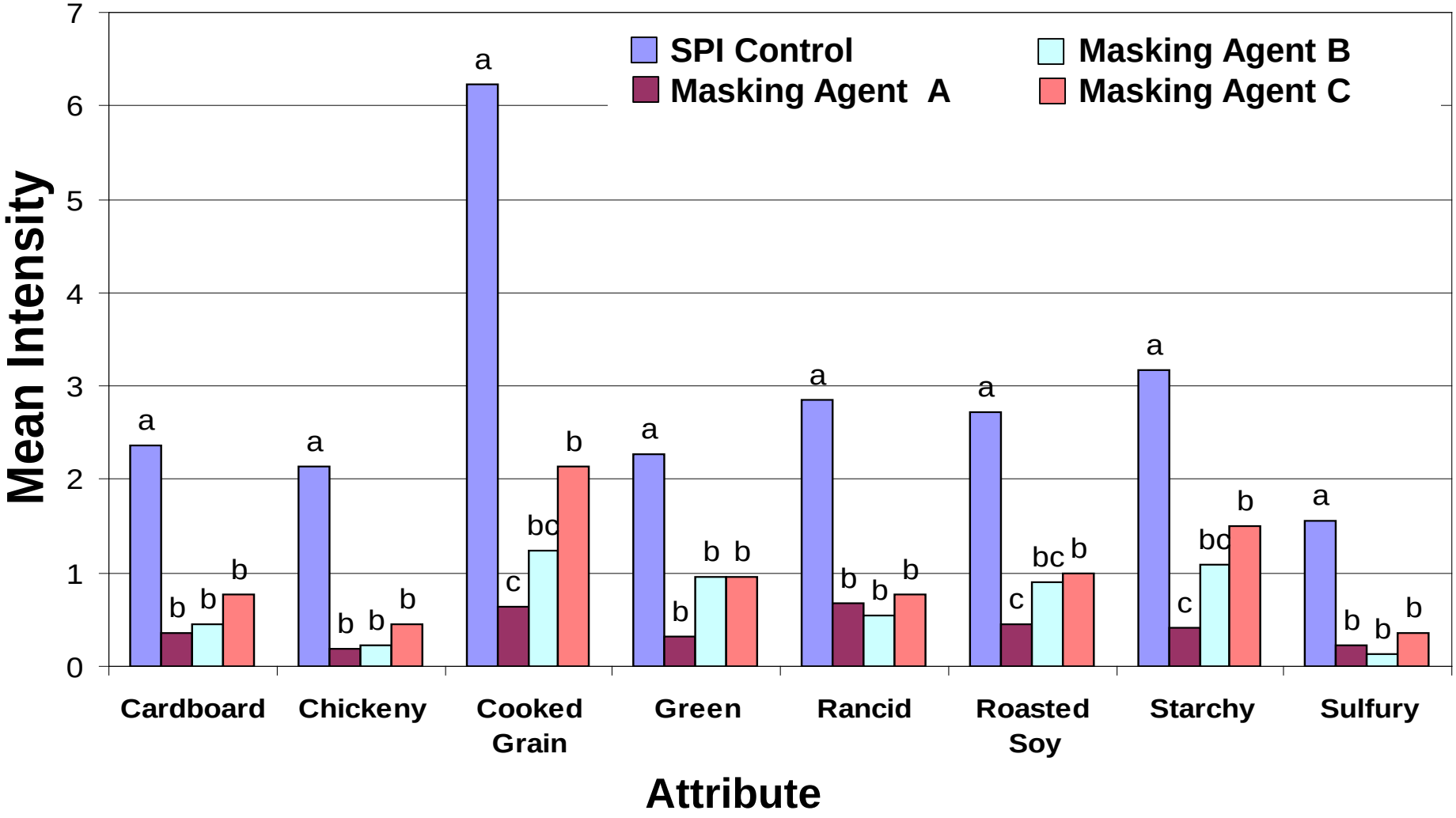
- **Involve them early in the process**
  - **greatly reduces development time**
- **Provide the composition of your product**
  - **protein, moisture, gums/stabilizers, pH, water activi**
  - **minor components that could impact flavor**
    - **vitamins, minerals, phytochemicals**
  - **levels of sugar, 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).**

Muether, A.T. MS Thesis, University of Illinois, May 2006.

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**