Protein Functionality

Classification

Protein must interact with other components of the food system

- Hydration properties
  - Water absorption/retention; Wettability; Swelling; Adhesion, Dispersibility, Solubility, Viscosity
- Protein-Protein Interactions
  - Gelation, Dough/fiber formation
- Surface properties
  - Emulsification, Foaming

Water binding

- Factors influencing hydration
  - Protein concentration
  - pH
  - T
  - Ionic strength
  - Other compounds

Solubility

- Extraction and Purification
- Good Index for potential applications of proteins
  - Degree of insolubility
  - Impaired ability for gelation, emulsification and foaming
  - Important in food beverages
- Markedly and irreversibly reduced when heating is involved
- Main advantage
  - Permits rapid and extensive dispersion
  - Facilitates protein diffusion

Viscosity

- Reflects its resistance to flow
- Main factor influencing viscosity behavior
  - Apparent diameter of the dispersed molecules
  - Diameter depends on:
    - Intrinsic characteristics of protein
    - Protein-solvent interactions
    - Protein-protein interactions

Viscosity

- Shear thinning
  - Progressive orientation of molecules in direction of flow
  - Deformation of protein hydration sphere
  - Rupture of H- and other weak bonds
    - Dissociation of protein aggregates or networks
- Apparent diameter of particles in direction of flow is reduced
- The viscosity coefficient increases exponentially with protein concentration
- Important for optimization of operations
  - Pumping, mixing, heating, cooling, spray drying

Gelation

- A gel is a continuous network of macroscopic dimensions immersed in a liquid medium exhibiting no steady-state flow
- Denatured proteins
- Thermal treatment is required
  - Protein unfolding
  - Water binding
  - Protein-protein interactions
  - Water immobilization

Gelation

- Bound Water
  - Small portion tightly bound to proteins
  - Majority of water is capillary water
  - 3D network must be formed to entrain water
- Factors affecting gel formation
  - °T
  - Protein concentration
  - pH
  - Salt concentration
  - Ca^{++}
  - Free [sulfhydryl]
  - Protein hydrophobicity

Gelation

- Protein network
  - Balance between protein-protein and protein-solvent interactions
  - Attractive and repulsive forces
  - Hydrophobic interactions (enhanced by high T)
  - Electrostatic interactions (Ca++ bridges)
  - H-bonding (enhanced by cooling)
  - Disulfide cross-links

Emulsification

- Thermodynamically unstable mixtures of immiscible liquids
- Protein stabilized emulsions
  - Diffuse to interface
  - Unfold
  - Expose hydrophobic groups
  - Interact with lipid
- Adsorb at interface and contributes to the physical and rheological properties to prevent droplet coalescence

Emulsification

- Factors important for protein stabilized emulsions
  - Rate of diffusion
  - Solubility
  - Viscosity
  - Protein flexibility
  - Net charge
  - Protein hydrophobicity

Emulsification

- pI
  - protein sparingly soluble
  - No stabilizing repulsive surface charge
  - Adopt a compact structure with high viscoelasticity
    - Prevent unfolding and adsorption at interface
    - Stabilize already adsorbed protein film against surface deformation or desorption
  - Enhanced hydrophobic interactions
  - Conflicting
    - Optimal at pI (gelatin, egg white)
    - Optimal away from pI (soy prot, peanut prot, whey prot, caseins, BSA)

Emulsification

- Temperature
  - Heating (60 C)
    - Lowers viscosity
    - Favors hydrophobic interactions
- Concentration
  - Higher conc favors
    - rate of diffusion
    - formation protein film

Emulsification

- Most important attribute
  - Ability to diffuse towards and adsorb at the oil/water interface
- Flexible proteins
  - Unfold
  - Establish hydrophobic interactions
  - Produce adsorbed films
- Caseinates:
  - High solubility, random coil, high hydrophobicity and separation of hydrophobic and hydrophilic regions

Foaming

- Dispersions of gas bubbles in a continuous liquid or semisolid phase that contains a soluble surfactant
- Factors affecting foam formation and stability
  - Solubility (good foaming capacity and stability)
  - Surface viscosity (stabilizing, insoluble particles)
  - pI (improves stability, intramolecular attractions increase thickness and rigidity of film)
  - Good foam performances at extreme pH
    - Increase viscosity

Foaming

- Salts
  - NaCl reduces stability
  - Ca ions improve stability
- Sugars
  - Depress foam expansion but improves stability
    - Increase viscosity
  - Lipids
    - Impair foaming performances
    - Surface-active polar lipids interfere with adsorbed proteins

Foaming

- Protein concentration
  - Increases stability more than foam volume
  - Smaller bubbles and stiffer foams
- Duration and intensity of stirring
  - Adequate unfolding and adsorption
- Moderate Temperature
  - Increase overrun but decrease stability
  - Impair foaming capacity: air expansion, decreased viscosity, bubble rupture, foam colapse

Foaming

- Foam formation:
  - Diffusion of soluble proteins
    - Unfold
    - Concentrate
    - Lower interfacial tension
  - Flexible proteins (caseins)
  - Mild heating, denaturing agents or partial proteolysis: unfold
  - Correlation between surface hydrophobicity and lowered surface and interfacial tensions

Foaming

- Foam stability
  - High MW globular produce thick adsorbed films
  - Aggregation of partially unfolded proteins
    - Hydrophobic, H, electrostatic
  - Adsorb strongly at interface via hydrophobic interactions
  - Move from a region of low interfacial tension to a region of high interfacial tension, dragging with them underlying water molecules
    - Restoring initial thickness of the lamella
  - Polar side chains interact with water within the lamella and reduce drainage

Flavor Binding

- Little impact on flavor
- Contribute to flavor by
  - Bound molecules
  - Absorption
  - Breakdown products
  - Chemical reactions

Dough formation

- Unique property of gluten (gliadins and glutenins)
  - Form strong cohesive and viscoelastic paste or dough when mixed and kneaded with water
- Other components in wheat
  - Starch granules, pentosans, lipids, and soluble proteins
  - Contribute to dough network and final texture

Dough formation

- Gliadins and Glutenins
  - Composition and large molecular size
  - Low content of ionizable Aas $\Rightarrow$
  - Rich in glutamine (>33%) and hydroxyl amino acids
    - Water adsorption
    - Cohesion-adsorption
      - Apolar Aas $\Rightarrow$ hydrophobic interactions $\Rightarrow$ binding of lipids and glycolipids
  - Formation of disulfide cross-links

Dough formation

- Hydrated bread is mixed and kneaded
  - Unfolding of gluten proteins
  - Hydrophobic interactions and disulfide cross-links
  - 3D viscoelastic protein network
    - Thin membranes or films
    - Entrap starch granules and other components
  - Glutenins responsible for elasticity, cohesiveness and mixing tolerance of dough
  - Gliadins facilitate fluidity, extensibility and expansion
    - Contribute to bread-loaf volume

Dough formation

- Proper balance
  - Excessive cohesion
    - inhibits expansion of trapped CO_2 bubbles during fermentation
    - rise of dough and
    - presence of open air cells in bread crumb
  - Excessive extensibility
    - Weak and permeable films
    - Poor retention of CO_2
    - Dough collapse

Dough formation

- Baking does not induce additional denaturation
- Gluten proteins play major role in retaining moisture during baking
  - Soft crumb
- Add foreign proteins into formulation
  - Compatibility
  - Use heat denatured soy, whey or milk proteins
  - Addition of polar lipids or synthetic surfactants help
    - Glycolipids in gluten-dough network

Functionality in various foods

Food	Functionality
Beverages	Solubility at different pH, heat stability, viscosity
Soups, sauces	Viscosity, emulsification, water retention
Dough formation, baked products	Formation of a matrix and film with viscoelastic properties, cohesion, heat denaturation, gelation, water absorption, emulsification, foaming, browning
Dairy products	Emulsification, fat retention, viscosity, foaming, gelation, coagulation
Egg substitutes	Foaming, gelation
Meat products	Emulsification, gelation, cohesion, water and fat absorption and retention
Meat extenders (texturized vegetable protein)	Water and fat absorption and retention, insolubility, hardness chewiness, cohesion, heat denaturation
Coatings	Cohesion, adhesion
Confectionary products (chocolate milk)	Dispersibility, emulsification