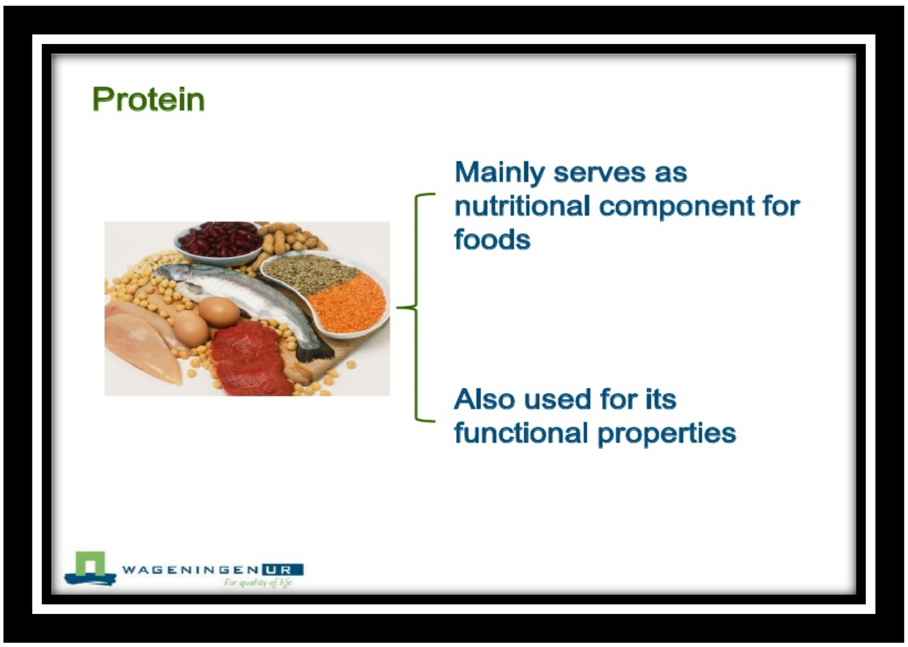
CC 12.,unit 4 (part 2) Food chemistry

Functional properties of proteins

Introduction

Proteins are the macromolecules which play a fundamental role not only in sustaining life, but also in foods derived from plants and animals. In addition to their contribution to the nutritional properties of foods through provision of amino acids that are essential to human growth and maintenance, proteins impart the structural basis for various functional properties of foods.



Source reference: proteins www.slideshare.net

Proteins are the principal structural and functional components of many food systems; e.g., meat, cheese, gelatin, egg white and many cereal products.

In addition, proteins are used to fabricate and facilitate the engineering of new foods such as protein beverages and extruded foods.

The applications depend upon the physicochemical properties of protein ingredients, collectively referred to as the functional properties.

Proteins as dry powders, have very limited appeal to potential users or consumers. To facilitate their use in foods and their conversion to desirable ingredients they must possess appropriate functional properties following interactions with other food components; e.g., water, carbohydrates or lipids, during processing.

Functional properties of proteins are those physicochemical properties which affect their behavior in food systems during preparation, processing, storage, and consumption, and also contribute to the quality and organoleptic attributes of food systems.

Therefore, functional properties of proteins can be studied under following sub topics:

- Introduction to functional properties
- Organoleptic properties
- Protein hydration
- Solubility of proteins
- Gelation
- Binding
- Emulsifying&Foaming properties
- Other properties- Sedimentation, Denaturation &Amphoterism
- Conclusion

Introduction to functional properties

"Functionality" of food proteins is defined as "those physical and chemical properties which affect the behavior of proteins in food systems during processing, storage, preparation and consumption".

Food preferences by human beings are based primarily on sensory attributes such as texture, flavor, color, and appearance. The sensory attributes of a food are the net effect of complex interactions among various minor and major components of the food.

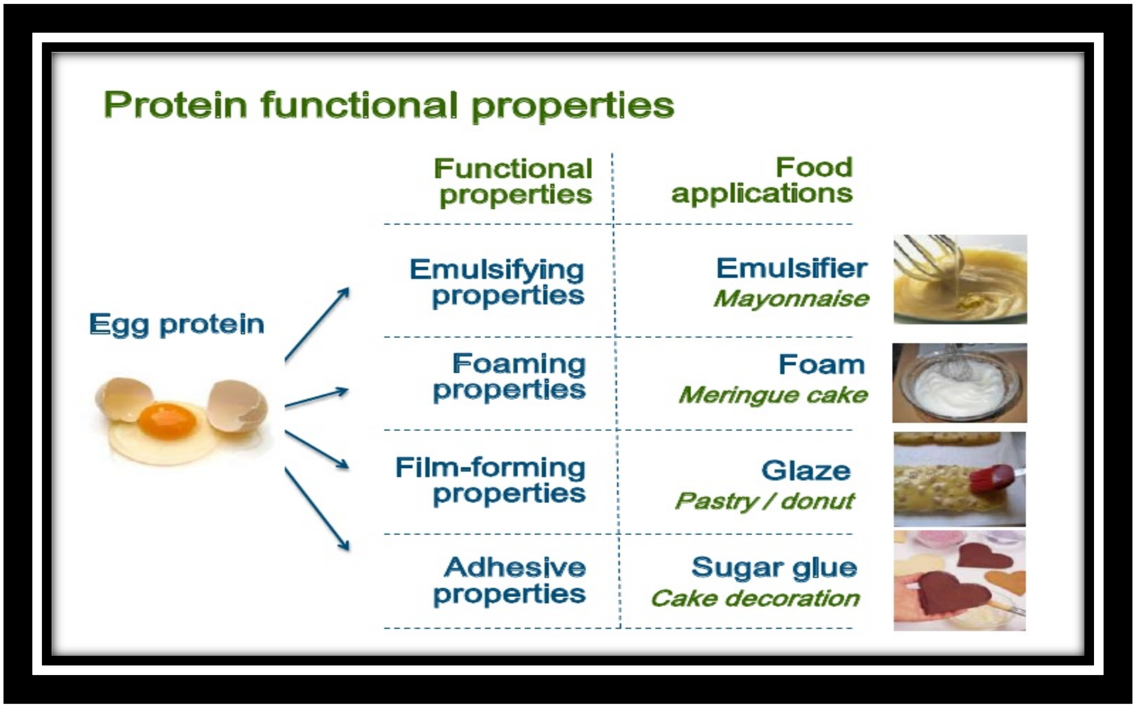
Proteins generally have a great influence on the sensory attributes of foods.
For example

1) The sensory properties of bakery products are related to the viscoelastic and dough-forming properties of wheat gluten.

2) The textural and succulence characteristics of meat products are largely dependent on muscle proteins (actin, myosin, and several water-soluble meat proteins).
3) The textural and curd-forming properties of dairy products are due to the unique colloidal structure of casein micelles; and
4) Thestructure of cakes and the whipping properties of dessert products depend on the properties of egg-white proteins.

The physical and chemical properties that govern protein functionality include size, shape, amino acid composition and sequence, net charge and distribution of charges, hydrophobicity/hydrophilicity ratio, secondary, tertiary, and quaternary structures, molecular flexibility/rigidity and ability to interact/react with other components.

The general functional properties of proteins is as shown on the screen



Source reference: Proteins - functional properties,2012

The various functional properties of proteins can be viewed as manifestations of three molecular aspects of proteins:

(a) Hydrodynamic properties
(b) Protein-protein interactions
(c) Protein surface-related properties.

The functional properties such as Viscosity (thickening), gelation, and texturization are related to the hydrodynamic properties of proteins, which depend on size,shape, and molecular flexibility.

Properties such as wettability, dispersibility, solubility, foaming, emulsification, and fat and flavor binding are related to the chemical and topo-graphical properties of the protein surface.

Functional roles of food proteins in food systems is as shown on screen (table)

Organoleptic properties

The organoleptic or sensory properties of proteins include color, flavor, taste & odor. The sensory attributes of foods are achieved by complex interactions among various functional ingredients.

Protein hydration

Water is an essential constituent of foods. The rheological and textural properties of foods depend on the interaction of water with other food constituents, especially with macromolecules, such as proteins and polysaccharides.

Water modifies the physicochemical properties of proteins. Water molecules bind to several groups in proteins. These include charged groups, backbone peptide groups, amide groups, and nonpolar residues.

Many functional properties of proteins, such as dispersibility, wettability, swelling, solubility, thickening/viscosity, water-holding capacity, gelation, coagulation, emulsification, and foaming depend on water-protein interactions.

Now lets us know about water binding & water holding capacity of proteins

The water binding capacity of proteins is defined as grams of water bound per gram of protein when a dry protein powder is equilibrated with water vapor at 90–95% relative humidity. The water binding capacities is also called hydration capacity.

Whereas, Water-holding capacity refers to the ability of the protein to imbibe water and retain it against gravitational force within a protein matrix, such as protein gels.

The hydration capacity of a protein is related to its amino acid composition - greater the number of charged residues, greater is the hydration capacity.

Several environmental factors, such as pH, ionic strength, type of salts, temperature, and protein conformation, influence the water binding capacity of proteins.
Proteins exhibit the least hydration at their isoelectric pH, where enhanced protein-protein interactions result in minimal interaction with water. Above and below the isoelectric pH, because of the increase in the net charge and repulsive forces, proteins swell and bind more water.

In food applications, the water-holding capacity of a protein preparation is more important than the water binding capacity.
Studies have shown that the water-holding capacity of proteins is positively correlated with water binding capacity. The ability of protein to entrap water is associated with juiciness and tenderness of meat products and desirable textural properties of bakery and other gel-type products.

Solubility of proteins

Protein solubility is variable and is influenced by the number of polar and apolar groups and their arrangement along the molecule.

Generally, proteins are soluble only in strongpolar solvents such as water, glycerol, formamide,dimethylformamide or formic acid.

In less polar solvent such as ethanol, proteins are rarely soluble (e.g,prolamines).
The solubility in water is dependent on pH and on salt concentration.

Effect of pH: At low ionic strengths, the solubility rises with increase in ionic strength.
Effect of salt concentration: Protein solubility is decreased (“salting out” effect) at higher salt concentrations due to the ion hydration tendency of the salts.

At low concentrations they increase the solubility ("salting in" effect) by suppressing the electrostatic protein-protein interaction (binding forces).

The solubility of a protein is the thermodynamic manifestation of the equilibrium between protein-protein and protein-solvent interactions.

Protein-Protein + Solvent-Solvent = Protein-Solvent

The major interactions that influence the solubility characteristics of proteins are hydrophobic and ionic in nature.

Hydrophobic interactions promote protein-protein interactions and result in decreased solubility, whereas ionic interactions promote protein-water interactions and result in increased solubility.

Based on solubility characteristics, proteins are classified into four categories.

1) ***Albumins*** are those that are soluble in water at pH 6.6 (e.g., serum albumin, ovalbumin, and α-lactalbumin)

2) ***Globulins*** are those that are soluble in dilute salt solutions at pH 7.0 (e.g., glycinin, phaseolin, and β-lactoglobulin)

3) ***Glutelins*** are those that are soluble only in acid (pH 2) and alkaline (pH 12) solutions (e.g., wheat glutelins) and

4) ***Prolamines*** are those soluble in 70% ethanol (e.g., zein and gliadins).

Both prolamines andglutelins are highly hydrophobic proteins.

Generally solubility of proteins is influenced by several solution conditions, such as pH, ionic strength, temperature, and the presence of organic solvents.

Gelation

A gel is an intermediate phase between a solid and a liquid. Technically, it is defined as "a substantially diluted system which exhibits no steady state flow".

It is made up of polymers cross-linked via either covalent or noncovalent bonds to form a network that is capable of entrapping water and other low-molecular-weight substances.

Protein gelation refers to transformation of a protein from the “sol” state to a “gel-like” state. This transformation is facilitated by heat, enzymes, or divalent cations under appropriate conditions. All these agents induce formation of a network structure.

Most food protein gels are prepared by heating a protein solution. In this mode of gelation, the protein in a sol state is first transformed into a “progel” state by denaturation.

The progel state is usually a viscous liquid state in which some degree of protein polymerization has already occurred. This step causes unfolding of the protein and exposure of a critical number of functional groups, such as hydrogen bonding and hydrophobic groups, so that the second stage, formation of a protein network, can occur.
Proteins form two types of gels, namely, coagulum (opaque) gels and translucent gels. The type of gel formed by a protein is dependent on its molecular properties and solution conditions.

Binding properties of proteins

Proteins can hold together a combination of ingredients. When heated, proteins coagulate so that the product is unbroken (ex: cakes, burgers).

Proteins themselves are odorless. However, they can bind flavor compounds, and thus affect the sensory properties of foods.

Several proteins, especially oilseed proteins and whey protein concentrates, carry undesirable flavors, which limits their usefulness in food applications.

These off flavors are due mainly to aldehydes, ketones, and alcohols generated by oxidation of unsaturated fatty acids. Upon formation, these carbonyl compounds bind to proteins and impart characteristic off flavors.The binding affinity of some of these carbonyls is so strong that they resist even solvent extraction.

The flavor-binding property of proteins also has desirable aspects, because they can be used as flavor carriers or flavor modifiers in fabricated foods.
This is particularly useful in meat analogues containing plant proteins, where successful simulation of a meat-like flavor is essential for consumer acceptance.

In order for a protein to function as a good flavor carrier, it should bind flavors tightly, retain them during processing, and release them during mastication of food in the mouth.
However, proteins do not bind all flavor compounds with equal affinity. This leads to uneven and disproportionate retention of some flavors and undesirable losses during processing.

Emulsifying& Foaming properties

Emulsions are disperse systems of one or more immiscible liquids. They are stabilized by **emulsifiers** – compounds which form interface films and thus prevent the disperse phases from flowing together.

Proteins are amphiphilic molecules, and they migrate spontaneously to an air-water interface or an oil-water interface. This spontaneous migration of proteins from a bulk liquid to an interface indicates that the free energy of proteins is lower at the interface than it is in the bulk aqueous phase.

Protein-stabilized foams andemulsions are more stable than those prepared with low-molecular-weight surfactants, and because of this, proteins are extensively used in food applications.

Although all proteins are amphiphilic, they differ significantly in their surface-active properties.The differences in surface activity are related primarily to differences in protein conformation.

The conformational factors of importance include stability/flexibility of the polypeptide chain, ease of adaptability to changes in the environment, and distribution pattern of hydrophilic andhydrophobic groups on the protein surface.

All of these conformational factors are inter-dependent, and they collectively have a large influence on the surface activity of proteins.

Desirable surface-active proteins should have three attributes:

(a) Ability to rapidly adsorb to an interface,
(b)Ability to rapidly unfold and reorient at an interface, and
(c) Ability to interact with the neighboring molecules and form a strong cohesive, viscoeleastic film that can withstand thermal and mechanical motions.

- **Functional role in foods**

Several natural and processed foods, such as milk, egg yolk, coconut milk, soy milk, butter, margarine, mayonnaise, spreads, salad dressings, frozen desserts, frankfurter, sausage, and cakes, are emulsion-type products where proteins play an important role as an emulsifier.

In natural milk, the fat globules are stabilized by a membrane composed of lipoproteins. When milk is homogenized, the lipoprotein membrane is replaced by a protein film comprised of casein micelles and whey proteins.

Homogenized milk is more stable against creaming than is natural milk because the casein micelle-whey protein film is stronger than the natural lipoprotein membrane.

The emulsifying properties of food proteins are evaluated by several methods such as size distribution of oil droplets formed, emulsifying activity, emulsion capacity, and emulsion stability.

The properties of protein-stabilized emulsions are affected by several factors. These include intrinsic factors & extrinsic factors.
Intrinsic factors: These include pH, ionicstrength, temperature, presence of low-molecular-weight surfactants, sugars, oil-phase volume, type of protein, and the melting point of the oil used.

Extrinsicfactors: These include type of equipment, rate of energy input, and rate of shear.

Foaming properties of proteins

Foams consist of an aqueous continuous phase and a gaseous (air) dispersed phase. The foaming property of a protein refers to its ability to form a thin tenacious film at gas-liquid interfaces so that large quantities of gas bubbles can be incorporated and stabilized.
Foams are dispersions of gases in liquids. Proteins stabilize by forming flexible, cohesive films around the gas bubbles. During impact, the protein is adsorbed at the interface via hydrophobic areas; this is followed by partial unfolding (surface denaturation).

The reduction of surface tension caused by protein adsorption facilitates the formation of new interfaces and further gas bubbles. The partially unfolded proteins associate while forming stabilizing films.

The ideal foam-forming and foamstabilizing protein is characterized by a low molecular weight, high surface hydrophobicity, good solubility, a small net charge in terms of the pH of the food, and easy denaturability.

Protein-stabilized foams are formed by bubbling, whipping, or shaking a protein solution.

Foaming properties of proteins are evaluated by***foaming capacity& foaming stability.***

Foaming capacity: Foaming capacity or foam ability of proteins refers to the amount of interfacial area that can be created by the protein. It can be expressed in several ways, such asor *foaming power* (or foam expansion) or*overrun*(or steady-state foam value).

$$FP = \frac{\text{volume of gas incorporated}}{\text{volume of liquid}} \times 100$$

$$\text{Overrun} = \frac{\text{volume of foam} - \text{volume of initial liquid}}{\text{volume of initial liquid}} \times 100$$

- **Functional role in foods**

In several processed foods, proteins function as foam forming and foam-stabilizing components, for example in baked goods, sweets, desserts, whipped cream, ice cream, cakes, meringue, bread, souffles, mousses, and marshmallow.

The uniquetextural properties and mouthfeel of these products stem from the dispersed tiny air bubbles.

Several environmental factors such as pH, salts, sugars, protein concentration, lipids etc; affect the foam formation & stability.

Other properties of proteins

Under this subtopic we ‘ll be learning about other important properties of proteins which are as follows;

- **Sedimentation: Sedimentation** is the tendencyfor particles in suspension to settle out of the fluid in which they are entrapped and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them.

  These forces can be due to gravity, centrifugal acceleration, or electromagnetism.

Sedimentation of proteins is carried out to separate them or purify them. Several thousand proteins have been purified in active form on the basis of ***solubility, size, charge,& specific binding affinity***.

Usually, protein mixtures are subjected to a series of separations, each based on a different property to yield a pure protein.

At each step in the purification, the preparation is assayed and the protein concentration is determined. Substantial quantities of purified proteins are needed to fully elucidate their three-dimensional structures and their mechanisms of action.

A variety of separation techniques are used to purify proteins which include salting out, dialysis, gel filtration chromatography, ion exchange chromatography, affinity chromatography, high pressure liquid chromatography, gel electrophoresis, etc.

- **Denaturation:**Denaturation is a phenomenon that involves transformation of a well-defined, folded structure of a protein, formed under physiological conditions, to an unfolded state under non physiological conditions.

The native structure of a protein is the net result of various attractive and repulsive interactions emanating from variousintramolecular forces as well as interaction of various protein groups with surrounding solvent water. However, native structure islargely the product of the protein's environment.

Any change in its environment, such as pH, ionic strength,temperature, solvent composition, etc., will force the molecule to assume a new equilibrium structure.

Subtle changes instructure, which do not drastically alter the molecular architecture of the protein, are usually regarded as “conformationaladaptability,” whereas major changes in the secondary, tertiary, and quaternary structures without cleavage of backbone peptidebonds are regarded as “denaturation.”

Many biologically active proteins lose their activity upon denaturation. In the case of food proteins, denaturation usually causes insolublization and loss of some functional properties.

In some instances, however, protein denaturation is desirable. Example thermaldenaturation of trypsin inhibitors in legumes markedly improves digestibility and biological availability of legume proteins whenconsumed by some animal species.

Partially denatured proteins are more digestible and have better foaming and emulsifying properties than native proteins. Thermal denaturation is also a prerequisite for heat-induced gelation of food proteins.

- **Amphoterism:** The ability of a chemical to behave both as an acid or base is called amphoterism& the substance is called amphoteric substance. These substances act as acids in presence of base &viceversa.
  Examples of amphoteric sustances include water, amino acids, and proteins.

Proteins are amphoteric polyelectrolytes, i.e. they possess both acidic and basic properties. The acid-basic properties of amino acids are primary due to occurrence of α-amino and α-carboxyl groups (i.e. acid-base pairs) in them.

The amphoterism of proteins is due to the acid-base groups of side-chain radicals of protein-constituting amino acids.

Conclusion

Proteins represent a most important class of functional ingredients because they possess a range of dynamic functional properties.

The functional properties of food proteins affect behavior in food systems and influence the quality attributes-structure, texture, mouth-feel, and flavor of the final product.

Therefore, knowledge of the physicochemical characteristics required for particular use is very important.

They show versatility during processing, they can form networks and structures and they provide essential amino acids, that is, they fulfill functional and nutritional requirements. In addition, they interact with other components and improve quality attributes of foods.

The functional properties of proteins are often affected by protein solubility, and those most affected are thickening, foaming, emulsifying, and gelling. Insoluble proteins have very limited uses in food.

Function	Mechanism	Food	Protein type
Solubility	hydrophilicity	beverages	Whey proteins
Viscosity	Water binding , hydrodynamic size and shape	Soups, gravies, and salad dressings, desserts	Gelatin
Water binding	Hydrogen bonding, ionic hydration	Meat sausages, cakes, and breads	Muscle proteins, egg Proteins
Gelation	Water entrapment and immobilization, network formation	Meats, gels, cakes, bakeries, cheese	Muscle proteins, egg and milk proteins
Emulsification	Adsorption and film formation at interfaces	Sausages, soup, cakes, dressing s	Muscle proteins, egg proteins, milk proteins
Foaming	Interfacial adsorption and film formation	Whipped toppings, ice cream, cakes, desserts	Egg proteins, milk Proteins
Fat and flavor binding	Hydrophobic bonding, entrapment	Low-fat bakery products, doughnuts	Milk proteins, egg proteins, cereal proteins