Proteins (part I)

Explaining the observed phenomena of proteins and linking it to the chemistry behind it.

In contrast to Lipids and carbs, Nitrogen and Sulfur are present in proteins and distinguish them from other biopolymers.
Proteins are the providers of essential and non-essential amino acids, which are required for the formation of tissues and DNA processes. Some enzymes are lost and degraded in digestion and need to be reconstituted.
Some proteins are used in energy if not stored and in cases of fasting. Proteins are essential for structural components of the body (hair, nails, bones...).
Meat is an expensive product given the high demand on meat that has been going on for a while.

The chemistry of proteins:

Amino acids have an amino end and an acid group; the AA molecule is chiral and exists most commonly in as L-amino acids (amino group to the right, R-group to the bottom)
-Polar R-groups: Affinity for water, A-Polar R-groups: Affinity for fat

- **In foam**, apolar groups hydrophibically are directed towards the air bubble contrary to the polar groups which are directed towards the invert sugar or the aqueous medium around the air bubble
- **In emulsions**, the apolar side chains of the protein are turned to the oily inside of the oil droplet suspended in water, the aqueous phase has the protein's polar side chains turned: Acting as Emulsifiers

The construction of Proteins:
Occurs by **linking the hydroxyl group of an amino acid to the amino group** of another, **water is removed**, condensation occurs, peptide linkages are formed.
All R groups in proteins are rotating; the rest is the fixed protein backbone

Primary structures in Amino Acid: Are the amino acid structures and their linkages (Ser-Hist-Leu-Val-...-Lys). Only peptide bonds exist.

Secondary structures (ALPHA HELIXES and BETA PLEATED SHEETS)
Alpha helix: Polypeptide chain is stabilized into a helix structure with **Hydrogen and Peptide bonds between the peptide linkages** to stabilize and maintain the folded structure in an efficient manner. The alpha helix is the structure for fibrous proteins.

Tertiary Structure: polypeptides (secondary structures) are then folded and compacted into globular shapes. The folded product is **due to polarity** (Polar side chains are turned outwards for their hydrophilic properties and apolar side chains are turned inwards): **Ionic bonds, Hydrophobic, Disulfide-Covalent, and Hydrogen bonds** are formed allowing a folded structure to be held together.

Quaternary Structure: Hydrogen bonds connect the folded amino acids together

Denaturation:

The Unfolding of a protein due to circumstances

Even the destruction of one type of bonds (secondary valence go first), is enough to denature/ neutralize the enzyme, no peptide linkages are broken

Causes

Chemical

Acids: add **H+ bonds and binds to the Carboxylate**, previous ionic interaction lost

Alkalis: add **HO^-** which **deprotonates NH_3^+,** which becomes NH_2 (previous ionic interaction lost**)**

NaCl has a high affinity to water which literally (to dehydrate the present water), which is sufficient for hydrophobic bonds to break. **Na^+ and Cl^- ions also bind** to both the carboxylate and the amine groups, preventing their interaction together.

Alcohol breaks hydrogen bonds and performs dehydration, by forming its own H-bonds and by breaking hydrophobic bonds

Physical

Heat breaks Hydrophobic, Hydrogen, Ionic, and covalent bonds (which require the highest temperatures and more time to break).

Beating and whipping move proteins around unfolding them in an aqueous medium where the proteins produce coats for bubbles that contain Air/Hydrophobic material (with hydrophobic side chains interacting with each other and the hydrophilic ones to the outside, in the aqueous layer).

Effects

-Better digestibility and increase in biological value: due to the breakage of the tertiary structure, making peptide bonds more available for hydrolysis by proteolytic enzymes
-Enzymatic activity is lowered or lost due to loss of active sites
-Exposure of reactive groups (previously hidden by the folds of the structure): cabbage like taste due to exposure of SH groups
-Sensory Properties: decrease in solubility, increase in viscosity, texture, and color...
Exposing Protein in water to Heat produces a gel whereby the Ionic and Hydrogen bonds between proteins are broken allowing for water and sugar to enter

Proteins of Meat (part II)

The degree of formation of Actomyosin affects the tenderness of meat.

- **Myofibrillar Proteins (56% of total proteins)**

Made up of two major fractions: actin and myosin. Interaction between actin and myosin is responsible for contraction and relaxation of muscle tissues. ATP, calcium, magnesium and temperature influence process

Actin + Myosin $\underset{\text{Relaxation}}{\overset{\text{Contraction}}{\rightleftharpoons}}$ Actomyosin

Reversible under appropriate conditions, Irreversible formation of Actomyosin occurs during rigor mortis (stiffness of dead tissue).

- **Connective Tissue Proteins (11% of total proteins)**

Collagen: Main constituent of skin, bones and connective tissues. There is high content of proline, hydroxyproline and glycine, almost devoid of tryptophan. Collagen molecules are rod-shaped and consist of three-stranded helices. Easily denatured by heat [T ~ 64 ^{o}C], which is why Gelatin is made by soaking collagen in hot water containing acids or Alkalis for varying intervals of time

- **Sarcoplasmic Proteins (33% of total proteins)**

These are mainly enzymes of the sarcoplasm and myoglobin (which is responsible for the red color of meat). The difference in the concentration of myoglobin is responsible for differences in the color of meat.
Given the fact that the Heme complex of the Myoglobin holds oxygen therefore, maintenance of the red color of raw meat is dependent on the supply of oxygen and reducing compounds (saturation of oxy-myoglobin is what preserves the bright red color of commercially sold meat)

Changes of Meat upon cooking

Achieving a desirable color and aroma while completely eliminating pathogenic MO and the larvae of parasitic worms.

Color

Browning of meat is due to

- **Changes in Myoglobin:** denaturation of globin due to oxygen release under heat into a greyish-brown structure.
- **Maillard browning**: as a reaction between free amino acids in proteins and sugars which results in brown polymers.

Tenderness

- **Conversion of Collagen to Gelatin**: due to heating at a temperature range of **65-70°C**, increasing the tenderness of meat.
- **Denaturation of Myofibrillar proteins**: **actin** denatures **at 70-80°C** while **myosin** denatures **at 55°C** which leads to the toughening and to a decrease of the water-holding capacity of the cooked meat
- **Loss of most water associated with meat proteins: at 75-80°C**

Achieving cooked meat with adequate tenderness means cooking in the "maximum tenderness region" which falls between 65 and 70°C for Myofibrillar proteins to adequately toughen while the collagen adequately tenders.

MILK

Proteins of Milk

Acidifying milk to a pH of 4.6 separates the milk into **Foam, Whey, and Casein**
A typical Heterogeneous Complex of proteins consists of **three Casein micelle arrangements, bound together by Ca^{2+} ions, that hold fat, lactose, and whey proteins inside.**

Casein:

Gives milk its characteristic white appearance (milk is yellowish green without it). Made up of different protein fractions (β, αS and κ, are arranged in a micelle as αS+β)

Whey Proteins include:

- **β-Lactoglobulin**: **largest component** of Whey Proteins with the highest Molecular Weight, containing most Cysteine (-SH) groups in milk. When milk is overly heated –SH groups release a cabbage-y scent
- **α-Lactoglobulin**: one of two proteins required for the **lactose synthetase enzyme**
- **Immunoglobulins**: Antibodies
- **Bovine Serum Albumin**: identical to that in blood.
- **Enzymes:** lipases, phosphatases, oxidases…

Curd Formation: Cheese Making:

A. Primary phase of curd production

1- Heating of Milk and pasteurization
2- Temperature lowered to 40-45 (rennet's optimal temp)
3- Rennet (extracted from animal stomachs) added. *The end point is tested by sensation where the texture changes, and the thick milk is solidified. As whey, it's as solid as possible.*
   κ–casein is the protective layer of the micelle, which has its peptide linkages broken by the Rennet (the micelle is insensitive to the Calcium in milk)
   κ–casein falls off the micelle, which becomes vulnerable to Calcium
   Ca^{2+} bridges with the unprotected casein micelle forming a continuous phase (curd)
   Curd traps fat, lactose, and whey proteins inside.
4- The curd is then cut into small cubes (the cutting releases the lactose and the whey protein) and the end point of cheese is only fat trapped.

B. Further processing of curd to cheese

1- **Cheesecloth** is then used to filter the curd protein from the whey. Curd is compressed in the cheesecloth into **Baladi cheese:** hand pressed curd, the most primitive.
2- **Calcium Chloride ($CaCl_2$)** speeds up the bridging process: Faster curding.
3- **Whey** taken is grouped and **Citric Acid** is added. The mixture is boiled, whey proteins denature and flocculate, what's produced is grouped and sold as **Qarishe** which may be sold as is or pressed into **Double crème cheese**.
4- **Curd:**
   A- Pressing and 10% brine addition makes **Akkawi**
   B- Addition of **Whey** at **high temperature** (boiling for 30-45 minutes) turns

the cheese block rubbery into **Halloum**
C- Small cut pieces **boiled in water** to fuse, they become a rubber mass which is extracted when hot and braided and dropped in Brine (so it can keep for longer and it becomes saltier)

*A variety of **Starters (cultures)** are added to cheese to produce a variety of cheeses some of which are matured (for a variety of times) drastically changes texture.*

Oilseed Proteins: are residues left after oil extraction from Oilseed.
They contain several anti-nutritional factors:
-Proteins: Hemagglutinins, which are Trypsin Inhibitors
-Carbohydrates: Oligosaccharides, which produce Flatus
-Tannins: Phytic Acid, which complex with Calcium, Magnesium, Iron, and Zinc

Soy mince (40-50% protein) is upgraded for human use, given that soybean is highly cultivated in the US

1- Stirred with aqueous alcohol: oligosaccharides blend into the aqueous alcohol area for extraction
2- The soybean concentrate (70% proteins) is produced and can be cultivated into **textured vegetable protein**
3- The concentrate can also be solubilized (soaked) in a highly alkaline solution, which dissolves the protein
4- The solution is then precipitated in acidic conditions (pH lowered quickly from 10-11 to 4-4.5). Where the protein (which is already denatured in the alkali phase) coagulates in the low pH.
5- The soy protein is washed and the isolate (>90% protein) is then cultivated into **Spun Vegetable Protein** (used as Tofu in animal-free cheeses and meats).

(Soy proteins lower cholesterol and increase estrogen production and the treatment of osteoporosis)

Textured Vegetable Proteins: concentrate 70% protein and water is blended into a dough and extruded via Pressure difference (high to low) producing a rope of soy concentrate (Cut, dried, and sold)

Spun Vegetable Proteins: isolate spun into an acid bath, this causes coagulation (which produces fine threads similar to meat fiber) they are twisted into meat like structures.