Functional properties of food

• Every ingredient used in a recipe has a specific function, e.g.
  – Starch (flour) is mainly used to thicken mixtures
  – Sugars are used to add flavour and help with the browning of foods
  – Eggs can function as an emulsifier, foaming agent and thickener
  – Fats and oils play roles in food aeration, shortening and emulsions
Functional properties of food

- Starch
  - Gelatinisation
  - Gelation
  - Dextrinisation

- Protein
  - Coagulation/denaturation
  - Foaming
  - Browning
  - Emulsification

- Fats
  - Aeration
  - Emulsification
  - Shortening
Colloidal dispersion

- Substances can either be dissolved, dispersed, or suspended in water depending on their particle size and solubility
  - Small molecules such as salts, sugars, etc. dissolve in water to form a solution
  - Molecules that are too big (between 1 and 100nm, e.g. cellulose, cooked starch, etc.) to form true solution may be dispersed in water to form a colloidal dispersion
  - Particles that are larger than 100nm (e.g. uncooked starch) are too large to form a colloidal dispersion; they form a suspension when mixed with water
Food colloidal systems

• A colloidal system consists of 2 separate phases:
  – Dispersed phase
    • the phase that is disrupted or finely divided within the emulsion
  – Continuous phase (or dispersion medium)
    • the phase or medium in which the dispersed phase is suspended
Food colloidal systems

• Colloidal systems in food include:

<table>
<thead>
<tr>
<th>Colloidal system</th>
<th>Dispersed phase</th>
<th>Continuous phase</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion</td>
<td>Liquid</td>
<td>Liquid</td>
<td>Milk</td>
</tr>
<tr>
<td>Foam</td>
<td>Gas</td>
<td>Liquid</td>
<td>Whipped cream, whipped egg white</td>
</tr>
<tr>
<td>Sol</td>
<td>Solid</td>
<td>Liquid</td>
<td>Starch suspension in water (due to gelatinisation)</td>
</tr>
<tr>
<td>Gel</td>
<td>Liquid</td>
<td>Solid</td>
<td>Jelly, jam</td>
</tr>
</tbody>
</table>
Starch

- Polysaccharides are complex carbohydrates formed from hundreds of glucose molecules
- Starch is a complex carbohydrate
Starch

- Starch is made up of **amylose** (linear) and **amylopectin** (branched), both are long chains of glucose (simple sugar).

![Starch structure diagram](image-url)
Starch

- Starch is found in very small “packets” called granules.
- Starch usually contains more amylopectin than amylose.
- The amount and proportions of amylose and amylopectin found in starches vary according to the starch’s plant source.
- The properties of starch depend on amounts of each component.

A starch granule: [Diagram showing AF starch granule with amylose and amylopectin labeled]
Starch

• Starches are derived from seeds and roots of various plants

• Starch can be found in:
  – Roots, e.g.
    • potato
    • arrowroot
    • tapioca
  – Cereal, e.g.
    • corn
    • wheat
    • rice
Effect of cooking on starch

• **Gelatinisation**
  – When starch is *heated with water*, the starch granules soften and swell, then absorb water, causing some to rupture and release the compounds inside
  – Gelatinisation increases the volume and gumminess of many foods, e.g.
    • pasta, rice, oats, most sauces, soups and puddings have different texture before and after cooking
    • The rigid structure of a batter or dough is contributed by gelatinisation of starch
  – The gelatinised starch mixture becomes thicken and transparent

• **Dextrinisation**
  – Dextrin is formed when foods containing starch are subject to *dry heat*
  – It turns the food brown and becomes sweeter
Gelatinisation

• When starch granules are heated in a liquid, they absorb the liquid, swell and rupture and finally increase in viscosity (stickiness). Finally, the mixture is thickened. The process is called **gelatinisation**

• This occurs because:
  
  – when starch is mixed with cold water, it does not dissolve but form a **suspension** (i.e. a solid held in a liquid)
  
  – as the suspension is heated (60°C), starch granules absorb the water, soften and swell
  
  – as more heat is applied (80°C), the starch granules break open, causing the mixture to thicken
Gelatinisation

1. Liquid
   Starch

2. Starch granules become swollen

3. Starch granules are broken up

4. The liquid thickens and gelatinises
Gelatinisation

• The mixture must be stirred as it is being heated to prevent lumps forming and also helps to ensure uniform consistency

• Factors influencing gelatinisation
  – Types of starch
  – Water
  – Temperature
  – Stirring
  – Addition of other ingredients, such as sugar, fat / protein, acid
Factors influencing gelatinisation

• Types of Starch
  – Starch from different sources varies in the thickening ability
    • starch with more amylopectin usually has higher thickening ability
    • root starches are usually more effective than cereal starches
    • potato starch (生粉) is the most effective as a thickening agent
    • wheat is the least effective starch as a thickening agent
### Factors influencing gelatinisation

- **Types of Starch**

<table>
<thead>
<tr>
<th>Starch</th>
<th>% amylose</th>
<th>% amylopectin</th>
<th>Comparative amount needed to achieve designated viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Root/tuber</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>20</td>
<td>80</td>
<td>1.96</td>
</tr>
<tr>
<td>Tapioca</td>
<td>17</td>
<td>83</td>
<td>3.54</td>
</tr>
<tr>
<td><strong>Cereal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>22</td>
<td>78</td>
<td>5.49</td>
</tr>
<tr>
<td>Wheat</td>
<td>26</td>
<td>74</td>
<td>6.44</td>
</tr>
<tr>
<td>Corn</td>
<td>28</td>
<td>72</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Comparative thickening ability of selected starches
Factors influencing gelatinisation

• Water
  – Sufficient water is needed to be absorbed by starch
  – When preparing starchy foods such as grains or pasta, more water should be used to allow for evaporation and volume expansion of the food

• Temperature
  – Gelatinisation temperature varies with different types of starch
  – Heating beyond the gelatinisation temperature decreases viscosity
Factors influencing gelatinisation

- Peak viscosity: The starch granules are swollen
- Loss of viscosity: Continue heating causes rupturing of starch granules
- Different starches reach their maximum viscosity at different temperatures
Factors influencing gelatinisation

• Stirring
  – Stirring gently is essential to create a smooth, gelatinised sauce
    • to prevent lumps from forming
    • to ensure uniform consistency
  – Vigorous stirring causes the starch granules to rupture prematurely, resulting in a slippery starch paste

• Sugar
  – Sugar competes with starch for water
  – Delays gelatinisation and the final temperature required to achieve gelatinisation is raised
Factors influencing gelatinisation

- Fat/protein (e.g. fat and protein in meat drippings used to produce gravy)
  - Delays gelatinisation by coating the starch and preventing it from absorbing water
  - Less granular swelling and resulting in a decreased viscosity of the starch paste
Factors influencing gelatinisation

• Acid, e.g. lemon juice, wine, and vinegar
  – The combination of acid and heat causes the breakdown (hydrolysis) of starch molecules into slightly smaller molecules
  – Hydrolysis of the starch molecules cause the resulting gelatinised starch paste to be thinner
  – The effect of acid can be minimised by e.g.
    • when thickening fruit juice for a pie filling, a rapid heating rate will minimise the effect of acid on starch and result in a thicker product
    • the acid should be added after gelatinisation is completed so that the thinning caused by acid will be avoided
Examples of gelatinisation

Risotto

Blancmange

Starch is used to thicken soups (湯羹) and sauces
Dextrinisation

- **Dextrinisation** is the breakdown of starch molecules to smaller, sweeter-tasting molecules (dextrins) by dry heat such as baking or toasting
  - Gives the toasted bread and the crust of cakes and biscuits a golden colour and crisp texture

- **Dextrins:**
  - Composed entirely of glucose units linked together
  - The chain length is distinctly shorter than starch
  - Dextrins are more soluble and easier to be digested than starch, and they have less thickening ability
  - Dextrins are also produced when starch is broken down by enzymes in saliva
Examples of dextrinisation

**Toasting bread**
- Browning occurs on the surface of bread when it is toasted
- Toasting break down amylose and amylopectin in starch
- The resulting dextrins cause toast to taste sweeter than the original bread
- The browning of toasted bread are also results of caramelisation and Maillard browning reaction of sugars

**Formation of brown crust on baked potatoes**
Dextrinisation and other browning reactions in food

- **Dextrinisation**
  - the browning of *starchy* food when cooked in *dry heat*, e.g.
    - toasting bread, baked goods, brown gravies and sauces, etc.

- **Carmelisation**
  - the browning of *sugar* when heated in *both dry heat and moist heat*, e.g.
    - browning on top of the dessert, e.g. crème caramel
    - browning of biscuits, cakes and other baked products

- **Maillard Reaction**
  - the browning of food due to the reaction between *sugars and proteins* when they are heated, e.g.
    - browning in toasted bread
    - roasting coffee
Enzymatic browning

When fruits or vegetables are peeled or cut, the plant tissue releases some enzymes which in the presence of oxygen from the air, goes into chemical reactions of plant compounds to give brown pigments.

- Plant compounds (Polyphenol)
- Enzymes from plant tissues (Polyphenol oxidase)
- Brown pigment (Melanin)
Proteins

- Proteins are made up of **amino acids**
  - Every amino acid contains a central carbon atom which is attached to
    - a carboxyl group (COOH)
    - an amino group (NH$_2$)
    - a hydrogen atom (H) and
    - a side chain (R group, specific to the particular amino acid)
  - There are more than 20 different amino acids in proteins
    - Their properties depend on the nature of the side chains (R groups)
Proteins

• All proteins are made up of many amino acids joined by peptide bonds
  – A dipeptide contains two amino acids joined by a peptide bond
  – A polypeptide contains many amino acids joined by peptide bonds

• Shape and function of a protein are determined by its particular amino acid sequence
Protein structure and conformation

• 4 levels of protein structure:

• **Primary structure**
  – It is the specific sequence of amino acids joined by peptide bonds
  – The sequence of amino acids determine the form or shape of higher protein structure

• **Secondary structure**
  – It is the 3-dimensional organisation of segments of polypeptide chain
Protein structure and conformation

• Tertiary structure
  – It is the 3-dimensional organisation of the complete protein chain
  – It refers to the spatial arrangement of a protein chain rather than a detail look at a small section of it
  – Two types of protein tertiary structure:
    • Fibrous proteins: the protein chains are extended, forming rods or fibers, e.g.
      – collagen (connective tissue protein)
      – actin, myosin (proteins for muscle contraction)
    • Globular proteins: compact molecules and are spherical in shape
      – myoglobin (proteins for carrying oxygen to the muscle)
      – whey proteins and caseins (milk proteins)
Protein structure and conformation

• **Quaternary structure**
  – It refers to the association of protein chains (which may or may not be identical), e.g.
    • actomyosin system of muscles: the complex formed by actin and myosin
    • the casein micelles of milk: the casein fractions associate with each other to form a spherical structure

Quaternary structure: Association of 2 or more polypeptide chains
Denaturation/ Coagulation

- **Denaturation**
  - When proteins are subjected to heat, pH extremes, alcohol or mechanical actions (e.g. beating or whipping), they undergo denaturation
  - It is an irreversible process in which the structure of protein is disrupted, resulting in partial or complete loss of function

  ![Diagram of denaturation process](image)

  - **Brought by:**
    - Heat
    - pH
    - Mechanical disturbances
    - Salts

Denaturation of proteins

Native state → Denaturation → Denaturated state
Denaturation/Coagulation

- **Coagulation**
  - Denaturation can result in coagulation, which is the clotting or curdling of protein molecules into a relatively insoluble protein mass.

Denaturation and coagulation of proteins
Factors affecting coagulation

• Effects of added ingredients:
  – Sugar
    • Sugar delays the protein denaturation, e.g.
      – in the preparation of meringues, sugar should be added after the egg white has denatured
      – smaller foam will be formed if sugar is added early
    • Sugar increases the temperature required for coagulation
  – Salt
    • Salt promotes denaturation and coagulation by lowering the coagulation temperature, e.g.
      – in cheese making, salt is added to curd to increase firmness
  – Addition of rennin
    • Rennet is the enzyme used to coagulate milk proteins, e.g.
      – in making of cheese, rennin is used together with bacterial starter culture to form curds
Factors affecting coagulation

- **Acid**
  - coagulation occurs more readily under acidic conditions
  - the use of acidic ingredients e.g. tomato or vinegar, lower the temperature for coagulation e.g.
    - fermentation of lactose to lactic acid by bacteria in milk helps the production of cheese and yoghurt
    - gluconodeltalactone is added to soya milk to make soya bean curd

- **Mechanical action**
  - Whisking of egg whites cause coagulation of protein
  - Protein molecules unfold and form a reinforcing network round the air bubbles to stabilise the foam, e.g.
    - production of meringues and soufflés
Examples of coagulation

Coagulation of proteins in egg foaming

• Formation of egg foam depends on denaturing the protein found in eggs through mechanical disruption
• Egg whites become stiff when they are whipped
• Once the foam is formed, sugar is added to beaten egg whites to stabilise the delicate denatured proteins
  – Therefore, sugar is often added near the end of whipping, just before the egg whites have reached their optimal consistency

Coagulation of egg proteins in the formation of egg foams
Examples of coagulation

Coagulated eggs are used to coat products to protect them when they are fried

• Fried foods are dipped in egg and breadcrumbs or in batter that contains egg, before frying
• The egg protein coagulates in the hot oil, seals and protects the food inside as it cooks, e.g.
  – Fried fish and chicken
  – Tempura

Fried chicken

Tempura
Examples of coagulation

Egg whites and yolks coagulate at different temperature

• Cooked egg showing thickened, opaque and coagulated egg white
• Egg white begins to coagulate at 60°C
  – It changes from transparent to white colour
• Egg yolk coagulates at around 62°C-70°C
• This difference allows egg to be cooked when their whites are firm but the yolks remain soft
• An egg may be cooked at 61°C for an hour but still have a soft yolk
Examples of coagulation

Coagulation of milk in making ginger milk curd (薑汁撞奶)

• Ginger milk curd is a Chinese style dessert made of ginger, milk and sugar
• Coagulation of milk is an essential step in the making of the curd
• Ginger contains a protease enzyme (known as zingibain) that catalyse the denaturation of the milk to form the milk curd

Making of ginger milk curd

Ginger juice + Milk → Ginger protease → Ginger milk curd

preferably from old ginger
preferably with high protein content
Examples of coagulation

Coagulation of gluten proteins in flours

• Flours are used in making pasta, breads and baked products

• When water is added to flour, the wheat proteins called gliadins and glutenins, joined together and make a stretchy, elastic substance called gluten

Development of gluten in flours
Examples of coagulation

Coagulation of gluten proteins in flours

- Gluten can be stretched into fairly thin strands in batters and doughs
- Denatured gluten is responsible for much of the structure of baked products
  - When dough is heated, the gluten “network” is stretched by bubbles of gas produced in the dough by raising agents (e.g. yeast)
  - These bubbles of gas make the dough “rise”
  - The gluten proteins coagulate in the heat to produce a stable “risen” product
Examples of coagulation

Coagulation of gluten proteins in flours

- Fats and sugar delay gluten development and reduce the strength of gluten
  - Fats
    - Fat coats on the surface of gluten reduces its interaction with water
  - Sugar
    - sugar competes with flour proteins for water in the mixture
    - the competition results in reduced hydration of flour proteins and slower development of gluten

Fat coat on the surface of gluten reduce the interaction of water
Examples of coagulation

Effects of heat on meat and poultry when they are cooked

• Meat is the edible flesh of animals
• Meat (and poultry) is made of bundles of muscle fibres which contain two proteins called actin and myosin
• If the muscle fibres are big, the meat will tend to be tough
  – Meat from older animals or from parts of the animal that have done a lot of work (the legs and neck) tends to be tough
• Muscle fibres are bound together by connective tissue which is made of two proteins called collagen and elastin
  – Collagen is mostly responsible for making meat or poultry tough
Examples of coagulation

Effects of heat on meat and poultry when they are cooked

• As the meat is heated (~60°C), the proteins in the muscle fibres (actin and myosin) denature and the texture becomes firmer and the meat shrinks
  – denaturation of collagen squeezes the meat fibers and causes the release of water
  – the melting of fat during cooking also cause the meat to shrink

• Overcooked meat tends to be dry and tough because the protein coagulates, water is squeezed out, and the muscle fibers toughen

• Meat can be tenderised by marinating (soaking) in acid (e.g. vinegar or lemon juice) due to protein denaturation
Examples of coagulation

Effects of heat on meat and poultry when they are cooked

• The colour of meat is caused by a protein called myoglobin and some haemoglobin from blood
• During cooking, the myoglobin changes from red to brown due to protein denaturation