Fats and oils

• **Lipids** is a general term for both fats and oils
  – Fats are lipids that are solid at room temperature while oils are lipids that are liquid at room temperature
• Fats and oils are made up of carbon, hydrogen and oxygen
• Fats and oils are composed of **fatty acids** and **glycerol**
  – Three fatty acids combine with one glycerol to form a triglyceride
  – Fat found in foods is made up of triglycerides
Fats and oils

- Fatty acids may be saturated or unsaturated
- **Saturated fatty acids**
  - Each carbon atom in the fatty acid is combined with two hydrogen atoms
  - They are called “saturated” as they contain all hydrogen atoms which is chemically possible for them to have
  - Saturated fatty acids usually have higher melting points and are solid at room temperature, e.g.
    - lard and butter
    - margarine (produced from hydrogenation of vegetable oils)
      - hydrogenation is the process of adding hydrogen to polyunsaturated fatty acids to change oils into solid fats
Fats and oils

- **Unsaturated fatty acids**
  - Food having a lot of unsaturated fatty acids are usually soft or in liquid form at room temperature and have a lower melting point, e.g. olive oil
  - **Monounsaturated fatty acids** have one pair of carbon atoms (with only one hydrogen atom attached) so they are capable of taking one more hydrogen atom
  - **Polyunsaturated fatty acids** have two or more pairs of carbon atoms, which are capable of taking up more hydrogen atoms

![Chemical structures](image)
Surface tension

• Surface tension is formed when there is an attractive force among the molecules of a liquid
• Water has a high surface tension as the force required to pull water molecules apart to expand the surface or to spread is high
  – Water tends to form droplets rather than spreading evenly as a thin film when water is put on a clean surface
• The term “surface tension” is used when a liquid is surrounded by a gas (e.g. water droplets surrounded by air)
• The term “interfacial tension” is used when the surface is between two liquids. (e.g. water and oil)
Emulsification

• An emulsion contains droplets of one liquid dispersed in another, the two liquids being immiscible
  – Immiscible liquids do not mix together, e.g. oil floats on the surface of water when mixed

• An emulsion consists of:
  – a **continuous phase**
    • the phase or medium in which the dispersed phase is suspended
  – a **dispersed phase**
    • the phase that is disrupted or finely divided within the emulsion

![Formation of oil-in-water emulsion](image)
Emulsification

- **An emulsifier**
  - The emulsifier is present at the interface between the dispersed phase and the continuous phase and keeps them apart.
  - They are molecules that have two different ends:
    - a hydrophilic (water-loving) end that associates with water but not with oils
    - a hydrophobic (water-hating) end that associates with oils but not with water
Emulsification

• Functions of an emulsifier:
  – Facilitate emulsion formation
    • adsorbs at the interface between two immiscible liquids such as oil and water
    • lowers the interfacial tension between two liquids so that one liquid can spread more easily around the other
  – Promotes emulsion stability
    • forms a stable, coherent interfacial film which prevents coalescence of the dispersed emulsion droplets

Diagram to illustrate what may happen after two droplets in an emulsion collide
Emulsification

- **Common food emulsifiers**
  - Egg yolks used in mayonnaise and hollandaise sauces
  - Casein proteins in milk and butter
  - Fine particles of ground dry mustard used in sauces and salad dressings

- **Proteins** such as egg yolk are good emulsifiers
  - Proteins contain both hydrophobic and hydrophilic sections in the same molecule
  - Proteins denature and then adsorb at the interface and interact to form a stable interfacial film

![Diagram of protein adsorption at the interface of oil and water]
Emulsification

• 2 types of food emulsion
  – Oil-in-water (o/w) emulsion
    • oil droplets are dispersed in water, e.g.
      – milk
      – cream
      – mayonnaise
      – salad dressings
  – Water-in-oil (w/o) emulsion
    • droplets of water are dispersed in oil, e.g.
      – butter
      – margarine
Factors affecting stability of emulsions

- **Emulsifier**
  - Good emulsifiers can form stable interfacial films produce stable emulsions

- **Droplet size**
  - Larger droplets are more likely to coalesce, e.g.
    - large oil droplets tend to rise to the surface
    - large oil droplets cause the emulsion to break

Effects of the size of oil droplets on stability of oil-in-water emulsion
Factors affecting stability of emulsions

• **Use of acidic ingredients**
  – Reduce the stability of the interfacial film

• **Viscosity of the emulsion**
  – If the emulsion is thick, the molecules within the system have less movement and take longer for the 2 phases to separate
  – Thickeners such as gums, pectin or gelatin can be added to emulsions to increase the viscosity of the system
Factors affecting stability of emulsions

• **Temperature**
  – Most emulsions are broken under freezing conditions
    • the formation of ice crystals disrupts the interfacial films
  – Heating disrupts emulsions
    • when the emulsion is warmed, the oil droplets become more fluid and coalescence is more likely to occur

• **Shaking**
  – Violent shaking disrupts emulsions, e.g.
    • cream is converted to butter by churning
Example of emulsification

Mayonnaise

- The main ingredients of mayonnaise are oil (the dispersed phase), vinegar (the continuous phase) and egg yolk.
- Egg yolk contains **lecithin** which acts as an effective emulsifier.
- The lecithin holds the oil and water (i.e. vinegar) together and stops them from separating out.
Example of emulsification

Milk and butter

- Milk is an emulsion with fat globules (particles) dispersed in an aqueous (watery) environment
- The fat droplets of milk do not coalesce as they are stabilised by a milk fat globule membrane (a protein)
- About 80% of the milk proteins is casein protein
- Caseins are not soluble in water and exist as small particles
- Caseins act as an emulsifier in milk and butter
  - caseins contain both hydrophobic and hydrophilic sections so they can also adsorb at the oil-water interface to form a stable film which prevents coalescence of emulsion droplets
Example of emulsification

Milk and butter

- Butter is a concentrated form of milk produced through churning of pasteurised cream
  - Butter contains 80-82% of milk fat
- Churning breaks the fat globule membrane so that the emulsion is broken and the fat coalesces
- Churning turns the original oil-in-water emulsion in milk to a water-in-oil emulsion and butter is made
Foaming

- Foams are dispersion of a gas in a dispersing medium
  - Dispersed phase: gas
  - Continuous phase: liquid

- **Foaming agents**, similar to emulsifiers, are able to adsorb at the interface to reduce interfacial tension and form a stable interfacial film that resists rupture, e.g.
  - Egg white proteins are good foaming agents (similar to emulsifier) and are used in food products such as meringues, angel cake and other baked food
  - Gelatine (e.g. marshmallows)
  - Milk proteins (e.g. whipped cream)
Formation of foams

• The formation of foam is accomplished by providing energy (by whipping) to counteract the surface tension of the liquid and to stretch the fluid into thin films encompassing gas bubbles

• The protein-containing liquid should have a relatively low surface tension
  – Low surface tension is essential to foam formation and stability
  – If the surface tension is high, the formation of foam will be difficult because of the resistance to spreading
  – A foam formed with a liquid of high surface tension collapses very quickly as a result of the tendency to coalesce
Formation of foams

• The liquid should have low vapour pressure so that it will not evaporate quickly
  – When the liquid surrounding a gas bubble evaporates, nothing is left to retain the gas that had been trapped in the liquid
Examples of foaming

Egg foams

• Egg foams are used in making meringue, soufflés, angel cake, sponge cake, chiffon cake, etc.
Examples of foaming

Egg foams

- Egg proteins have good foaming qualities because of their low surface tension and low vapour pressure
  - Egg albumen can be spread into thin films over a large surface area, and air can be incorporated into the bubbles created by beating of the egg proteins
  - Some proteins denatured during beating contributes to stability of the foam
Factors influencing the stability of egg foam

• Extent of beating
  – If the white is not well beaten
    • the foam will be coarse, low in volume and watery
    • the bubbles will burst and the foam collapses due to insufficient coagulation
  – If the white is over beaten
    • over-coagulation will occur and the egg protein (which is stretched to hold the air bubbles and produce the foam) becomes thin and breaks, and the foam collapses
Factors influencing the stability of egg foam

Stages of beating egg white

- **Foamy stage**
  - transparent, coarse, fluid foam

- **Soft peak stage**
  - tips of the peaks just bend over
  - the foam has elasticity and is stable to maintain a good volume

- **Stiff peak stage**
  - the peaks stand up straight

- **Dry stage**
  - the foam is overbeaten
  - so stiff that they become brittle and break apart
Factors influencing the stability of egg foam

• **Sugar and acidic ingredients, e.g. cream of tartar or lemon juice**
  – Stabilise foams
  – Sugar delays foam formation because they slow down the denaturation of egg proteins, therefore, should be added at a later stage

• **Thickening agents**
  – Gums and other thickening agents are added to increase the viscosity of the continuous phase
Factors influencing the stability of egg foam

• **Fats**
  – Fat delays the formation of egg foams and has a negative impact on the volume of egg foam, e.g.
    • adding fat to sponge cake mixture
    • contamination of the egg whites with a trace of yolk (the fat compounds in the yolk interfere with the alignment of protein around air cells)

• **Temperature**
  – Egg at room temperature can be beaten easily into a foam of fine texture
  – Chilled egg are more viscous and difficult to beat, requiring more beating to form a foam of lesser volume and coarser texture
Examples of foaming

- Cream is made from milk, it is made up of:
  - milk fat, protein, milk sugar (lactose), minerals and vitamins (particularly vitamin A)
- Cream is an emulsion of fat in water
- There should be at least 30% fat content, otherwise, the cream cannot be whipped into a foam
  - the fat globules trap the whisked air to create the foam
Examples of foaming

Cream foams

• When cream is whipped, it changes from a liquid to a foam
  – Air is beaten into the cream, which makes bubbles in the cream
  – The protein in the cream denatures and surrounds the air bubbles. This protects the bubbles so that they do not burst and lose the air (they are stabilised)
  – The fat globules stick to the protected bubbles and make it thicker
Factors influencing the stability of cream foams

• **Fats**
  – The principle component contributing to the formation of cream foam
  – The foam is stabilised by the aggregation of very small fat particles in the films of liquid that form the confining walls of the air bubbles

• **Temperature**
  – The stability of whipped cream is excellent if the cream is kept chilled
Factors influencing the stability of cream foams

• **Sugar**
  – Keep fat from clumping within the films surrounding the air bubbles
  – Additional beating is required if sugar is added before the desired end point

• **Extent of beating**
  – Cream is an oil-in-water emulsion
  – Overbeating of whipped cream causes reversal to a water-in-oil emulsion and form clumps of butter
The process of trapping air in a mixture is called **aeration**.

Aerating makes a mixture lighter.

**Fats, eggs and sugar** are used for aerating.

**Ways of adding air to mixtures**:
- Whisking whole egg and egg whites, e.g. meringues, soufflés, sponge cake
- Folding and rolling of flour dough e.g. flaky pastry
- Beating mixtures e.g. batters
- Sieving flour
- Creaming fat and sugar together
Aeration

- **Creaming** is the vigorous mixing of fat and sugar to create an air-in-fat foam
- **Beating** is the very vigorous agitation to trap air
- **Folding** is the gentle motion of adding air to mixture or flour dough
Aeration in baking

- **Air** is used as a raising agent in cake, batter and dough to make food products light and risen.
- Air in the mixture expands when heated.
- **Steam** and/or **carbon dioxide** in the mixture diffuses into the expanded air space and enlarging it:
  - Steam is produced during baking from liquid ingredients.
  - Carbon dioxide is chemically produced from baking soda/baking powder, or biologically produced by yeast.
**Aeration in food preparation**

- Egg white and/or egg foams are usually folded into a batter to increase the amount of air that is available for leavening the mixture
  - Egg protein (albumin) can stretch as it is whisked or beaten on its own or with other ingredients
  - The trapped air adds lightness to foods such as mousses and soufflés, and pushes baked mixtures to rise
- Examples:
  - beaten egg or egg white is added to fat, sugar and flour to trap air
  - egg white is beaten with sugar to trap air to form a stiff foam in making meringue
Shortening

• Fats are used to make cakes, biscuits and pastries
• **Shortening** is the ability of fats to shorten gluten strands (the structural protein network in wheat-containing cake mixture, batters and dough)
• This gives the baked mixture a tender and melt-in-the-mouth texture because the fat has shortened the tougher gluten strands
Shortening

• How it works?
  – The fat covers the flour particles with a waterproof layer, which stops the gluten in the flour from forming long strands
    • the protein in flour produces gluten when mixed with water and kneaded
    • gluten is elastic and stretchy
    • when less water is absorbed by flour, less gluten is produced and so the mixture is “shortened”
Factors influencing shortening ability of fats

• Plasticity
  – It is the ability of a fat to spread into thin films and its ability to surround air and make large number of bubbles when the fat is creamed or beaten
  – The plasticity of fats depends on their melting points
    • fats do not melt at fixed temperatures but over a range
    • the degree of unsaturation determines the melting point of fats
    • fats with more saturated fatty acids have higher melting points
Factors influencing shortening ability of fats

– An ideal fat should be soft enough to spread easily, but not so fluid that it runs out of the mixture

  • Saturated fatty acids with carbon chains are hydrophobic and are repelled by water
  
  • Unsaturated fatty acids with double bonds and carbonyl group of free fatty acids are hydrophilic have an attraction for water

  – Unsaturated fatty acids molecules align themselves along the interface and block the passage of water
Factors influencing shortening ability of fats

• Types of fat
  – Oils with high content of polyunsaturated fats
    • Coat flour particles more thoroughly
    • Yield a tenderer and crumbly product than other types of fats
  – Fats with high content of saturated fatty acids (e.g. butter, margarine, lard, shortenings)
    • Cover less surface area of flour particles and produce a less tender, but flaky pastry
Factors influencing shortening ability of fats

- Butter and margarine have shortening potential less than lard, shortenings, or oil that contains 100% fat
  - butter and margarine contain water and/or milk (20%) in addition to a variety of fat (80%)
  - water in butter and margarine hydrates the starch in flour
  - extra water also means extra toughness as a result of increased gluten development