Types of *micro-organisms* used in food production

- **Bacteria**
  - Lactic acid bacteria
  - Cyanobacteria (also known as blue-green algae)
- **Fungi**
  - Yeasts
  - Moulds
- **Algae**
  - Green algae
What is fungi?

• They are living things, neither a plant nor an animal
• Fungi can be single celled or very complex multicellular organisms
• Fungi grow by absorbing nutrients from their surroundings
• Multicellular filamentous moulds and macroscopic filamentous fungi develop **fruiting bodies** to produce **spores** for reproduction
What is fungi?

• 3 major groups of fungi:
  – **Multicellular filamentous moulds**
    • moulds are made up of very fine threads known as *hyphae*
    • they grow by forming a network of threads called a *mycelium*
  – **Macroscopic filamentous fungi**
    • also grow by producing a mycelium
    • differ to moulds that they produce visible fruiting bodies (commonly known as mushrooms) that hold spores
  – **Single celled microscopic yeasts**
    • they are made up of only individual cells
    • they reproduce by budding
What is algae?

• Algae are a group of organisms that use **photosynthesis** to produce food
  – They are different from plants that their cells are not clearly organised into different tissues with different functions
  – All **green algae** contain a pigment called **chlorophyll**
  – In addition to chlorophyll, some algae may have photosynthetic pigments in red, blue and brown as well

• Algae range from microscopic (microalgae) to large seaweeds (macroalgae)
  – Algae can be single-celled, filaments or multicellular
  – Green algae, red algae and brown algae are common microalgae
  – The green microalgae are one of the major sources of nutritional products
Use of micro-organisms in food production

• Production of fermented food, e.g.
  – Bacteria are used as the starter culture in the production of cheese and yoghurt
  – Mould is used in cheese ripening
  – Yeast is used in making bread and wine
  – Bacteria, mould and yeast are used in making soya sauce

• Added to enhance nutritional value of food, e.g.
  – Bacteria as probiotics

• Used as food sources directly, e.g.
  – Black moss is a kind of blue-green algae
  – Chlorella and seaweed are green algae
  – Mycoprotein (i.e. protein from fungi) is the common ingredient in all Quorn products
Production of fermented food

• What is fermentation?
  – Fermentation is a natural process in which micro-organisms turn sugar into alcohol and carbon dioxide
    • Micro-organisms used for making fermented foods are called “starters”
  – Benefits of food fermentation:
    • Develop flavours, aromas and textures of food, e.g.
      – improvement of flavour and aromas (e.g. from coffee beans to coffee, from grapes to wine)
    • Extend the shelf life of food, e.g.
      – from milk to yoghurt and cheese
    • Improve the nutritional value of the product, e.g.
      – improved digestibility (e.g. from wheat to bread)
      – synthesis of probiotic compounds (e.g from milk to yoghurt)
## Examples of fermented food

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>Cheese</td>
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<tr>
<td></td>
<td>Yoghurt</td>
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<tr>
<td>Meats</td>
<td>Sausages (e.g. Salami)</td>
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<tr>
<td></td>
<td>Chinese ham</td>
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<tr>
<td>Grains</td>
<td>Yeast bread</td>
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<tr>
<td></td>
<td>Beer and sake</td>
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<tr>
<td></td>
<td>Chinese rice wine and rice vinegar</td>
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<tr>
<td>Plants</td>
<td>Szechuan pickled vegetables</td>
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<tr>
<td></td>
<td>Pickled Chinese mustard</td>
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<tr>
<td></td>
<td>Kimchi</td>
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<tr>
<td></td>
<td>Sauerkraut</td>
</tr>
<tr>
<td></td>
<td>Oolong tea, red tea, black tea</td>
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<tr>
<td>Legumes</td>
<td>Fermented bean curd, bean paste</td>
</tr>
<tr>
<td></td>
<td>Miso, soya sauce</td>
</tr>
<tr>
<td>Fruits</td>
<td>Wine, vinegar</td>
</tr>
<tr>
<td>Fish and shell fish</td>
<td>Fermented fish, fish sauce</td>
</tr>
<tr>
<td></td>
<td>Shrimp paste</td>
</tr>
</tbody>
</table>
Functions of bacteria in the production of fermented foods

• Bacteria are used to make a wide range of products
• The most important bacteria in food production is the *Lactobacillus* bacteria species, also known as lactic acid bacteria

• Lactic acid bacteria
  – Lactic acid bacteria is a group of bacteria that can decompose lactose (a form of sugar) in milk products to lactic acid
Functions of **bacteria** in the production of fermented foods

- Used as the **starter cultures** in e.g.,
  - production of cultured dairy products such as cheese and yoghurt from milk
  - production of fermented meat products such as salami and pepperoni
  - production of pickled vegetables such as sauerkraut and kimchi from cabbage
Functions of **moulds** in the production of fermented foods

- Moulds are used to produce specific flavours and textures in several food products, e.g.
  - The moulds *Aspergillus oryzae* and *Aspergillus sojae* are used in the production of **soya sauce** and **miso**
  - The mould *Penicillium* is used in the production of **cheese**
    - Roquefort, Stilton, Gorgonzola and Danish Blue are examples of cheeses made by the *Penicillium* mould
Functions of **yeasts** in the production of fermented foods

• Through fermentation, yeasts are used to make bread, alcoholic drinks and vinegar

• *Saccharomyces cerevisiae* is a very important type of yeasts in food industry as a starter for producing fermented foods
EXAMPLES OF FERMENTED FOODS
Cheese

- Cheese is a *cultured milk product* which is rich in casein (a milk protein) and milk fat
- There are many different types of cheeses
  - Cheeses are differentiated according to their
    - flavour
    - texture
    - type of milk
    - salts & seasoning added
    - type of bacteria & mould species used in *ripening*
How is cheese made?

- Standard cheese processing is as follows:
  - Cheese is made from the milk of cows, sheep, goats and buffalo
  - Milk is heated to the required temperature for pasteurisation and then cooled
  - **Starter culture** is added to the cooled milk
  - The **lactic acid bacteria** change the lactose in the milk into lactic acid
  - The lactic acid helps to coagulate the protein in the milk
How is cheese made?

- Coagulation is the conversion of a liquid into solid.

  ![Diagram](image.png)

  **Diagrammatic representation of milk coagulation**

- **Rennet** is added
  - Rennet is a general term for enzymes used to coagulate milk.
  - Rennet coagulate the milk protein **casein** into solid curds (coagulated proteins)
    - casein is the main protein in cheese.
How is cheese made?

- The curds are cut into smaller pieces to release the liquid (whey)
- The cheese is packed and pressed to remove any remaining whey
  - Whey is a by-product of cheese production
- Salt is added for flavour and as a preservative
How is cheese made?

- Most cheese undergo further microbial process called ripening.
- The action of *bacteria / moulds* and enzymes in the cheese develop the colour, texture and flavour of the final cheese.
- Ripening should take place in a controlled environment.
  - Different cheeses required different temperature and humidity.
  - Ripening may take from weeks to years depending on type of cheese.
  - The longer the ripening period, the stronger the taste developed.
Examples of cheese ripened by bacteria

- *Lactobacillus* bacteria is used in the ripening of Cheddar cheese
- Cheddar cheese is the most widely eaten cheese in the world

Ingredients:
- Pasteurised cow’s milk, salt, starter culture, microbial rennet

Cheddar cheese
Examples of cheese ripened by bacteria

- Propionic acid bacteria is used in the ripening of Swiss cheese
- The bacteria convert acetic acid to propionic acid and carbon dioxide

\[
\text{Acetic acid} \xrightarrow{\text{Propionic acid bacteria}} \text{Propionic acid} + \text{Carbon dioxide}
\]

- The carbon dioxide gives the Swiss cheeses their characteristic “holes”
Examples of cheese ripened by moulds

• Natural moulds attracted by the wet and protein rich surface form the rind which acts as a barrier against unwanted bacteria and allow the cheeses to mature

• In blue cheeses such as Stilton, *Penicillium Roqueforti* grows throughout the cheese

Use of *Penicillium Roqueforti* (a type of mould) to make Blue Stilton cheese
Use of moulds in cheese ripening

- *Penicillium camemberti* is associated with surface-ripened soft cheeses such as Camembert and Brie.

Use of *Penicillium camemberti* (a type of mould) to make Danish Brie cheese.
Yoghurt

• Yoghurt is a cultured milk product
• The starter culture for traditional yoghurt is a mixture of equal quantities of *Lactobacillus* and *Streptococcus* bacteria

Ingredients:
Fresh milk, modified corn starch, *Lactobacillus Bulgaricus & Streptococcus Thermophilus*

Use of *Lactobacillus* and *Streptococcus* bacteria in yoghurt
Yoghurt

• The bacteria helps to lower the pH value of the yoghurt:
  – helping to preserve the yoghurt
    • a low pH can stop the growth of undesirable micro-organisms
  – coagulating milk proteins, giving the yoghurt its texture
  – The preferred pH of yoghurt is around 4.5

• Yoghurt must be chilled to
  – slow down the activity of the starter culture
  – prevent the yoghurt from becoming too acid

• Rennet is not used in the making of yoghurt and the thickening produced is the result of acidification by lactic acid bacteria
Yoghurt

• Most yoghurts contain a significant level of live, active cultures
• Bacterial cultures, such as bifido-bacteria, maybe added to yoghurt as probiotic cultures

Use of live, active bacteria cultures in yoghurts
How is yoghurt made?

General yoghurt processing steps:

- Pasteurisation of milk
- Homogenisation to blend the pasteurised milk and improve yoghurt consistency
- Milk is cooled to the ideal temperature (40-43°C) for growing of the starter culture
How is yoghurt made?

- Addition of starter culture
  - A mixture of equal quantities of *Lactobacillus* and *Streptococcus* bacteria
- The lactic acid bacteria change the lactose in the milk into lactic acid
  - The lactic acid coagulates the milk proteins
- *Acetaldehyde* is a metabolic by product of both bacterial species
  - It gives the plain yoghurt its characteristic flavour
How is yoghurt made?

- The subsequent steps depend on the types of yoghurt products:
How is yoghurt made?

• **Set yoghurt**
  – The fruit is added at the bottom of the cup and the yoghurt is fermented in the cup

• **Stirred yoghurt** (also known as “Swiss” style yoghurt)
  – The yoghurt is fermented in bulk, stirred and then cooled
  – Fruits and/or flavour is then added

• **Drinkable yoghurt**
  – Similar to stirred yoghurt
  – The product is homogenised to produce a smooth beverage product
Fermented vegetables

- General steps for making picked vegetables:
  - Fresh vegetables
  - Deleaf and trim
  - Addition of salt
  - Fill into containers
  - Cover and seal
  - Ferment
  - Package

  - To draw water out of the vegetables being pickled by osmosis to form the brine in which the fermentation will take place
  - Inhibit the growth of unwanted microbes which would cause spoilage
  - Maintains the crisp texture of the vegetables by withdrawing water
  - Contributes to flavour of the product

  - During fermentation, lactic acid bacteria produce acid to decrease pH to below 4 which can further inhibit the growth of unwanted microbes
  - Different kinds of fermented vegetables have different fermentation time
  - Presence of unwanted yeasts and moulds can produce off-odours, loss of acidity and a softened product
## Fermented vegetables

- **Examples of pickled vegetables:**

<table>
<thead>
<tr>
<th>Asian style, e.g.</th>
<th>Western style, e.g.</th>
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</thead>
<tbody>
<tr>
<td>Szechuan pickled vegetables</td>
<td>Sauerkraut (pickled cabbage)</td>
</tr>
<tr>
<td>Pickled Chinese mustard</td>
<td>Pickled cucumbers</td>
</tr>
<tr>
<td>Kimchi (pickled chinese cabbage)</td>
<td>Green olives</td>
</tr>
</tbody>
</table>

- Szechuan pickled vegetables
- Kimchi
- Sauerkraut
- Green olives
Fermented meat

• Meat fermentation is a method for extending the shelf-life of an otherwise highly perishable food products

• Sausage is meat (pork is most commonly used, but beef, mutton and turkey meat are also used) that has been finely chopped or ground and blended with various ingredients, seasonings and spices

• Curing salts contribute to taste, colour, safety, stability and texture of the product

• Lactic acid bacteria are usually the starter cultures
  – Sometimes *Debaryomyces yeasts* and *Penicillium moulds* are also used
Fermented meat

Examples of fermented meat:

- Salami
- Ham
Fermented fish and fermented fish products

• Fermented fish is not common in Guangdong cuisine, but in other cuisines, e.g.
  – Smelly mandarin fish (臭桂魚) is a famous Anhui dish
  – “Hongeo” is fermented skate fish in Korean cuisine

• Fermented fish products are more commonly seen in Hong Kong
  – Lactic acid bacteria is often involved in the fermentation of fish products
Yeast bread

• Fresh or dried yeast is used in making yeast bread
• In the presence of oxygen, yeast produces carbon dioxide gas bubbles and ethanol (alcohol)
  – The gas bubbles expand when heated and push up the dough
  – The alcohol vaporises and escapes from the dough

• Used to make bread and other fermented doughs such as buns and doughnuts
Yeast bread

• Yeast is a living organism that requires certain conditions for growth:
  – **Sugar** in the dough is the food for the yeast to grow
  – **Warmth** helps the yeast to grow
    • if it is too hot, it kills the yeast
    • if it is too cold, it will slow down the rising process
  – **Water** is used to bind the flour together to form the structure of the bread. It needs to be warm to help the yeast grow
Yeast bread

**Before:**
Ingredients:
- Wheat flour
- Sugar
- Butter
- Salt
- Dry yeast
- Water
- Raisins

**After fermentation:**

Use of bread-maker to make yeast bread at home
Beer and Wine

• Beer and wine are alcoholic drinks made by fermentation reactions that use yeasts to convert sugar into **ethanol**
  – Ethanol is the type of alcohol found in wine and beer

Sugar $\xrightarrow{\text{Enzymes in yeast}}$ Carbon dioxide $\text{+} \quad \text{Ethanol}$

Sugars in grain (e.g. barley) for making beer; Sugars in fruits (e.g. grapes) for making wine
Functions of *yeasts* in beer production

- Barley is the principal grain used in the production of beer
- Main steps in producing beer
  - **Malting and Brewing**
    - Barley contains enzymes to convert starch to simple sugars (malt) which is needed for fermentation
  - Soaking barley in water for germination
    - germination of barley activates the starch-breaking enzymes
  - Variety of barley determines the colour, texture and flavour of beer
  - Hops are added to give flavours, aromas, and bitterness in the beer
  - Hops also act as preservative

![Diagram of the process of converting starch into sugar](image)
Functions of yeasts in beer production

• Main steps in producing beer
  – Fermentation by yeasts

• Types of beer
  – Lagers
    » lighter in colour
    » produced with yeasts that form clumps at the bottom of fermentation tank and prefer cooler conditions
  – Ales
    » stronger, darker in colour
    » produced with yeasts that form clumps at the top of the fermentation tank at warmer temperature
Key points in wine production

• Wines are made from fermented juice of fruits (usually grapes), grains and vegetables
• The sugar in fruit juices and starch in grains/vegetables contribute to yeast fermentation
• The yeast strain used in wine production determines the flavours found in wine
Key points in wine production

• The word “wine” usually refers to wine made from grapes
  – White wines can be made from white, green, red/black grapes
  – Red wines are made from red/black grapes
    • red wines are produced from dark-coloured grapes that are fermented together with their skins (which contain most of the colour pigments)
    • sulfites are usually added to red wines to maintain their red colour
• Chinese wine, whiskey and sake are made from grains
• Vegetables can also be used such as potatoes (for vodka), sweet potatoes (for Korean Shochu), cassava (for tequila) and sugar cane (for rum)
Key points in wine production

Sulphite are usually added to red wines to maintain their colour red.
Health claims of alcoholic drinks

• Moderate consumption of wine can be beneficial to our health
  – Moderate consumption means no more than one to two drinks per day for men and no more than one drink per day for women
  – Red wine is rich in plant chemicals called polyphenols which may protect us against diseases
  – Resveratrol is a kind of polyphenol found in red wine that may offer heart-protective benefits, e.g.
    • reduce damage to blood vessels
    • lower ‘bad” cholesterol
    • prevent unwanted blood clotting

• Excessive consumption of alcohol may cause liver diseases, cardiovascular diseases and are linked with several cancers
MICRO-ORGANISMS ADDED TO FOODS TO ENHANCE NUTRITIONAL VALUE
What is probiotics?

- Probiotics are live microbial food ingredients (i.e. bacteria) that have a beneficial effect on human health

- Functions of probiotics
  - maintain a healthy digestive system by improving the intestine’s microbial balance
  - strengthen the immune system

- Yoghurt is one of the most familiar sources of probiotics
  - the most common probiotic bacteria added to yoghurt are *Lactobacillus* and *bifidobacterium*
Example of foods with probiotics

Ingredients:
Skim milk, milk solids, live yoghurt cultures (incl. *L. Acidophilus*)

Use of *L. Acidophilus* (a type of *Lactobacillus* bacteria) in yoghurt
Example of foods with probiotics

Use of probiotics (e.g. Lactobacillus and bifidobacterium) in dietary supplements

Ingredients: Water, sugar, skimmed milk powder, glucose, Lactobacillus paracasei, flavouring

Use of Lactobacillus bacteria in drinks
DIRECT USE OF MICRO-ORGANISMS AS FOOD SOURCES
Use of *cyanobacteria* as food

- Cyanobacteria is a type of bacteria that can undergo photosynthesis
- Also known as blue-green algae
- Examples:

  **Spirulina**
  - Have a spiral coil shape
  - Rich in proteins, essential fatty acids, vitamins and minerals
  - Also used as dietary supplement

  **Black moss**
  - Structure similar to Spirulina
  - A Chinese food rich in proteins
  - Black when dried
Use of **algae** as food

**Sea grapes**
- A kind of green algae live in the sea

**Chlorella**
- It is a fresh water, single-celled green algae that grows in fresh water
- Rich in proteins, vitamins and minerals
- Also used as dietary supplement

**Nori (Porphyra)/ seaweed**
- It is dried edible sheets of a species of red algae called porphyra
- Commonly eaten in China and Japan
Uses of **fungi** in the production of Quorn

**Quorn**
- A man-made vegetarian food product which is made from **mycoprotein**
- Quorn is derived from the mould *Fusarium venenatum*

**Mycoprotein**
- Mycoprotein (protein from fungi) is the ingredient common to all Quorn products
- It is made up of tiny, fine fibres called **hyphae**
- The hyphae are responsible for giving Quorn products their meat-like texture
Uses of *fungi* in the production of Quorn

- Quorn is a healthy, meat-free source of protein
- It is a good source of dietary fibre (because of the cell walls of the fungal structure)
- It is also low in fat, contains no cholesterol and no trans fats
- Quorn is turned into a variety of products such as burgers, minced quorn, sausages, and ready meals
Uses of fungi in the production of Quorn

• Quorn is not suitable for a vegan diet because during manufacture egg white protein is used and some quorn products contain milk protein

What is a vegan diet?

– Vegan diet contains only plant foods such as cereals, nuts and seeds, pulses (peas, beans and lentils), as well as fruits and vegetables
– No animal food products are allowed, even if the animal has not been killed to provide the food product
– Vegans are sometimes called strict vegetarians