Effects of heat on food commodities
Topics

• Meat, poultry and fish
• Eggs and dairy products
• Cereals, cereal products and sugar
• Fats and oils
• Fruits and vegetables
Meat, Poultry and Fish
Meat and poultry - structure

- Meat and poultry are made up of muscles, connective tissues, adipose tissues and bones.

- Connective tissue is a glue that holds muscle fibres together.

- Most abundant protein in connective tissue is collagen.
  - Tough and fibrous,
  - Can convert to gelatine when exposed to moist heat.
Meat and poultry

Texture changes during heating

- Meat becomes tender when cooked, however it becomes tough and dry, resulting in some shrinkage and moisture loss if cooked for a prolonged time or at a high temperature

- at 38°C: proteins start to unfold (red in colour)
- at 49°C: proteins start to coagulate (clump together) and lose water → firm (pink in colour)
- at 60°C: connective tissues shrink and more moisture is lost (pinkish brown in colour)
- at 66°C: connective tissues begin dissolving into gelatine-like substance while proteins are densely packed and become tough (brown in colour)
- at 77°C: proteins are entirely coagulated, most of the moisture is lost and become hard
Meat and poultry

Connective tissues vs. protein

- Proteins denature, coagulate and become tough when temperature increases

- When temperature is higher than 60°C, hydrogen bonds in collagen are broken, some collagen are converted to gelatine, then connective tissues begin dissolving into gelatine-like substance
  - Meats become soft and tender

- There is tension between softening connective tissues and toughening of muscle proteins

- Meat with more collagen should use cooking method which can soften the collagen (moist heat, solubilise collagen)
Meat and poultry - fat in meat and poultry during heating

• Fats in meat and poultry melt which enhance the tenderness, juiciness and flavour of meat and poultry

• Fats should be added to lean meats to improve texture and flavour
Meat: flavour changes during heating

- Coagulation of protein, melting and breaking down of fat contribute to flavour

- Trace amount of carbohydrates in meat can contribute to special flavour of browned meat through Maillard Reaction during heating
Meat and poultry - colour pigments

- Colour of meat is derived from pigment-containing protein:
  - **Myoglobin** (mainly)
  - **Haemoglobin** (lesser extend)

- The higher concentration of myoglobin in raw status, the more intense its colour (bright red)

- Number of myoglobin and haemoglobin in beef and pork are more than poultry and fish
Meat and poultry - colour changes during heating

• High temperature causes the denaturation of pigment containing proteins, meat changes its colour to greyish brown
  • Hemichrome pigment (denatured globin and oxidised heme iron) is formed
Beef : colour changes during heating

• Raw : Strong red interior

• Medium : Rosy pink interior

• Well done : Brown interior
Pork : colour changes during heating

- From pinkish to whiter colour as they are heated to well done stage
Chicken: colour changes during heating
Meat - browning on the surface

- Trace amount of carbohydrates (reducing sugars) in meat can react with amino groups of protein to form brown pigments and flavour compounds.

- This reaction is Maillard reaction and it will be speeded up by heating.
Processed meat

- Myoglobin + nitrite will form nitrosyl hemochrome after heating which is pink in colour
Fish - structure

• Unlike meat and poultry (long bundle of fibres), fish has short fibres and are separated by very thin layers of connectives tissues → flaky texture

• Three structural factors contribute to the tenderness of fish: collagen, amino acid content and muscle structure
  • When compared to meat and poultry (15%), lower amount of collagen: 3% only
  • With less hydroxyl proline in its connective tissues so collagen can be converted to gelatine easily at lower temperature
Fish : texture changes during heating

• Prolonged heating will tighten protein bonds, shrink the protein mesh and cause the loss of moisture, resulting in tough and dry flesh

• Fish is done when it flakes easily with gentle pressure of a fork

• Do not cook for too long or with too high temperature → excessive flakiness, dryness and toughness
Fish – colour of flesh

• Colour of flesh depends on whether fish relied on slow or fast movements predominantly
  • Long distance swimming → with slow twitch fibre → red or darker colour in flesh
  • Quick bursts of speed and brief duration → with fast twitch fibre → white flesh
  • With both slow twitch and fast twitch fibre → dark, red and white flesh
Fish with orange flesh

- Carotenoid pigment and astaxanthin → orange pink in colour e.g. salmon
Fish: colour changes during heating

• Flesh of fish turns opaque during heating
• Heat causes the denaturation of proteins
• Proteins unfold and clump together with one another so that water can attach to them resulting in a whitish hue
Eggs and dairy products
Egg : texture changes during heating

- Heat causes → egg white and yolk become hard and firm

- Egg white : starts coagulation at ~ 60°C and is completely coagulated at 65-70°C

- Egg yolk : coagulates within 62°C – 70°C

- Egg can be cooked at 61°C for an hour and still has a soft yolk

- Beaten egg coagulates at slightly higher temperature (69°C)
# Boiling of eggs

<table>
<thead>
<tr>
<th>Temp. of water from 25°C reaching ~80°C</th>
<th>Temp. of water from 25°C reaching ~90°C</th>
<th>~ 100°C water for 2 mins</th>
<th>~ 100°C water for 5 mins</th>
<th>~ 100°C water for 6 mins</th>
<th>~ 100°C water for 7 mins</th>
<th>~ 100°C water for 15 mins</th>
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![Image of boiled eggs at different stages](image-url)
Egg : texture changes during heating

• Heating eggs at high temperature for a long period can diminish their texture, flavour and colour

• Overcooked egg becomes tough, rubbery and shrink because of dehydration

• The key factors in cooking eggs are temperature and cooking time
Egg : colour changes during heating

• Eggs become opaque due to coagulation of protein

• Sometimes, slight browning in eggs because of Maillard reaction

• Undesirable colour changes are found when eggs are overcooked
  • Sulphur in egg white may combine with iron in yolk to form ferrous sulphide, a green coloured compound with strong odour and flavour of a “green yolk”

• Cool hard boiled eggs quickly in cold water or cook in stainless steel equipment with low cooking temperature can prevent changes in colour

Green ring

Normal egg yolk

Green egg yolk
Milk: texture changes during heating

• Heat causes proteins in milk to precipitate
  • When heating milk to almost the boiling point, whey protein become insoluble mesh with calcium phosphate and precipitate
  • A film will be formed on the bottom and sides of pan

• A skin will also be formed on the surface of heated milk
  • The skin is formed by the evaporation of water which is accompanied by an increased concentration of casein, fat and mineral salt
  • Constant stirring can help to prevent the forming of film
Milk: flavour changes during heating

• Slightly sweet flavour of milk comes from lactose, salts, sulphur compound and short chain fatty acid

• “Cooked” flavour develops during heating
  • Heating denatures whey proteins and releases volatile sulphur compounds contributing to the off flavour
Cheese : Meltability

• Cheese is often used as an ingredient to add flavour, colour and texture to a dish

• Heating can melt the cheese

• Meltability depends on the fat and moisture content of cheese
  • The higher fat and moisture content, the greater its meltability is
Cheese: texture changes during heating

• High temperature or prolonged cooking:
  • Toughens cheese protein
  • Causes fat separating out create an oily stringy and inferior product

• Normally cheese is added during the last stages of preparation to prevent separating

• Low fat cheese:
  • Separates more easily when exposed to high heat
  • Higher protein content makes it toughen easily when heating
  • Not good for cooking

• Processed cheeses which contain added water emulsifier can be heated without fat separating and melted more easily than unprocessed cheese
Cheese: browning during heating

- Heating will cause browning of cheese because of the Maillard reaction.
Cereals, cereal products and sugar
Cereals

• Nearly indigestible in natural form
  • Hard hull covering to prevent seeds from immediate consumption

Oatmeal  Rice
Cereal: texture changes during heating

• Heating grains in water can soften the outer covering and make the starchy endosperm digestible.

• Cooking can gelatinise the starch improving the flavour and texture since the grains expand and are softened.

• Grain’s size expands to 2-3 times when cooked.
Rice

• Size expands to 2-3 times when cooked
Hot breakfast cereal: oatmeal

Raw

Cooked
Cooking of Pasta

• Pasta is a mixture of primarily flour starch and water.

• A type of flour derived from durum wheat, protein in durum wheat flour gives pasta its elasticity and helps it maintain its shape during cooking.
Baking of bakery products

- Flour mixture: flour mixed with fats, sugars and leavening agents

- When heat is applied, gases such as steam, CO2 and air immediately expand, creating pressure that stretches the elastic network of gluten
  - Bakery products rise

- Heat melts the fats, gelatinises the starches and coagulates the protein in flour, egg and milk

- Browning the outer surfaces is the result of caramelisation of sugar, Maillard reaction and dextrinisation of starch during baking
Solubility of sugar

• Different types of sugars have different solubility

• Degree of solubility of sugars influence the perceived mouthfeel and texture of food

• Increasing temperature of a sugar solution allows more sugar to dissolve

60°C sugar solution

120°C sugar solution
Learning activity
Crystallisation: Effects of temperature on sugar solubility

- **Turbid solution**
- **Clear solution**

60°C sugar solution 120°C sugar solution

60°C sugar solution 120°C sugar solution

120°C sugar solution

Sugar crystal formed from 120°C sugar solution
Browning of sugar

• Caramelisation: heating of sugars
  • Sugars start to melt when heated
  • If heating continues and the caramelisation temperature is reached, the melted sugars will become smooth and glossy, then start to caramelise

• Fructose starts to caramelise at a slightly lower temperature of 110°C when compared to sucrose at 160°C
Learning activity
Caramelisation of different sugars

Heating of Fructose

~110°C

~130°C

~155°C

Heating of Sucrose

~110°C

~130°C

~160°C

~180°C
Fats and oils
Function of fats and oils in food

• Contribute to the flavour, colour, texture and mouthfeel of food

• Fat is a medium of heat transfer, it can help transfer heat to food without burning them

• Not all fat is suitable for high temperature processing

• Fats and oils for deep frying must be heat stable
  • High smoke point
  • Do not develop rancid off flavour
Smoke point

• Temperature at which fat or oil begins to smoke
  • Release of free glycerol followed by breakdown of glycerol to Acrolein

• Acrolein has offensive odour and harmful to mucous membrane of mouth and nasal passage
Smoke point of different fats and oils

- Butter: 121 - 148°C
- Lard: 183 - 205°C
- Most olive oil: ~ 199°C
- Most vegetable oil: 227 - 232°C
  - Refined peanut oil: ~ 232°C
  - Refined canola oil: ~ 204°C
Flash point and fire point

• When keep on heating fats:
  
  • Reaching flash point (~316°C)
    • Temperature at tiny wisps of fire streak to the surface of heated substance
  
  • Reaching fire point (~370°C)
    • Temperature at which heated substance bursts into flames and burns for at least 5 seconds
Overheating of deep frying fats

• Rapid deterioration of fat through polymerisation

• Increase the viscosity of overheated fat
  • Higher absorption of fat in the fried food making them greasy

• Optimal frying temperatures :
  • 191-199°C for small piece of food
  • 177-185°C for large piece of food
Changes in reused deep frying fats

• More viscous

• Darker colour
  • Pick up protein and carbohydrate from food → browning

• Having smoke easily
  • Smoke point gets lower
  • Each heating hydrolyses some of the triglycerides into smaller molecules

• Higher chance of rancidity
  • Trigger by high temperature process
  • Fat is broken down into smaller units such as acids, alcohols aldehydes and ketones results in rancid of odour and flavour
Learning activity
Deep frying French fries with different fats

Changes in fats

Butter :
Before | After
--- | ---

Canola oil :
Before | After
--- | ---

Peanut oil :
Before | After
--- | ---

French Fries
Fruits and vegetables
Vegetables: texture changes during heating

• High temperature:
  • Gelatinises starch
  • Decreases bulk by softening the cellulose
  • Causes a reduction in turgor due to water loss

• Long cooking time is suitable for potatoes or legumes but not for most vegetables
Vegetables: texture changes during heating

- Adding alkaline ingredients can speed up the breakdown of cellulose and produce a mushy texture

Baking soda in water  Water only  Vinegar in water
Vegetables: flavour changes during heating

- Vegetables obtain their flavour from volatile oils, organic acids, sulphur compounds, mineral salts, carbohydrates and polyphenolic compounds.

- Cooking with water will lose the flavour of vegetables.
Odour released during heating

- When onion and cabbage are cooked, pungent odour is released especially when overheating.

- In cabbage, heat triggers the enzyme to release excess hydrogen sulphide.
Fruits : texture changes during heating

- Fruits will become soft when cooked and mushy if cooked for a long time
  - Conversion of fruit protopectin to pectin

- Degradation of cellulose and hemicellulose

- Denaturation of cell membrane protein $\rightarrow$ cell membrane loses its function to maintain turgor

![Raw Bananas](image1.png) ![Cooked Bananas](image2.png)

![Raw Blueberries](image3.png) ![Cooked Blueberries](image4.png)
Fruits: flavour changes during heating

- Sugars and acids contribute to the sweet and sour taste in fruits

- Phenolic, aromatic compounds and essential oils contribute to the flavour

- Some flavour substances and volatile compound can be lost during heating so aroma will be lost
Fruits and vegetables: colour pigments

- Chlorophyll, carotenoids and anthocyanins are three common pigments in fruits and vegetables.

- There will be loss of pigmentation during heating.
Chlorophyll changes during heating

• Chlorophyll is rich in broccoli, choi sum and kiwi
• Chlorophyll (blue green) → bright green when start heating (deficient of air)
• Application of heat continues → acid in cells released form pheophytin (dull olive brown)
Chlorophyll changes during heating

• Fat soluble
  • Chlorophyll leaching out to the medium when boiling with fat
Keeping vegetables green

• If alkaline such as baking soda is added in the water, acid from vegetables will be neutralised and the chlorophyll in vegetables can keep its colour

• Drawback : loss of vitamins is much faster
Learning activity
Heating green vegetables under different pH conditions

- Baking soda in water
- Water only
- Vinegar in water
Carotenoid changes during heating

• Carotenoid is rich in carrots, sweet potatoes, lemon, and oranges

• Carotenoid is fat soluble → leaching out when cooking with fat

• Lead to degradation of the pigment when undergo oxidation → lighter orange colour
  • Boiling for a long time (contact with oxygen) → pale food colour
Carrots boiled in water for long

- Carotenoid leach out to boiling water
- Cooked carrots became pale in colour when compared to the raw ones
Anthocyanin changes during heating

- Anthocyanin is rich in red cabbage, blueberry and red cherry

- Anthocyanin will be red in colour in an acidic environment, while blue in colour in alkaline situation

- Anthocyanin is water-soluble → leaching out during boiling → becomes dull reddish brown

With baking soda | Control | With vinegar
Anthocyanin, pH and heating

- Baked goods with baking soda or powder in the flour mixture will discolour anthocyanin to blue

- Use sour cream instead of milk can maintain its colour

- Red cabbage can be prevented from turning blue when vinegar is added during cooking
Blanching of vegetables

• Polyphenol oxidase can be destroyed during heating
• Enzymatic browning is prevented

Raw potatoes exposed to air
Blanched potatoes exposed to air
Nutrient lost during cooking

• Leaching is the greatest reason of vitamins and minerals loss in fruits and vegetables

• Minimise the loss through
  • Avoid peeling of skin when possible
  • Cutting vegetables into fewer and larger chunks
  • Cooking to the point of just doneness
THE END