



Foundations of food chemistry for plant-based processing



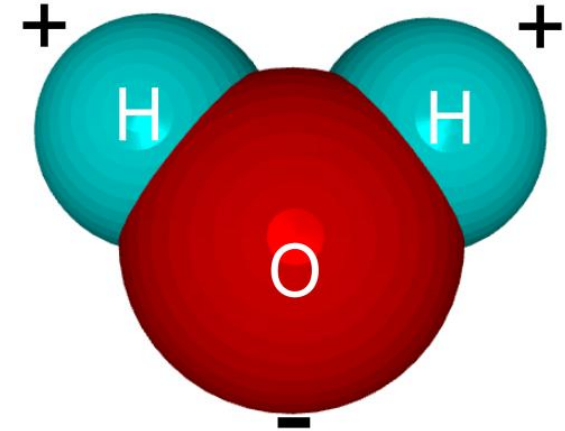
- Foundations of food chemistry for plant-based processing
- Chemical composition of plant-based foods
- Functional behaviour of constituents during processing and storage
- Reaction pathways: enzymatic, oxidative, thermal, and physicochemical
- Stability, safety, nutritional retention, and sensory quality



Water



Water



Water states in food matrices

- Free water: solvent medium, readily available
- Capillary water: weakly held, participates in reactions
- Adsorbed/bound water: hydrogen-bonded to macromolecules
- Monolayer water: tightly bound, minimal reactivity

Physicochemical implications

- Diffusion, plasticisation, and glass transition
- Water as a reactant or catalyst
- Influence on microbial growth and enzyme activity

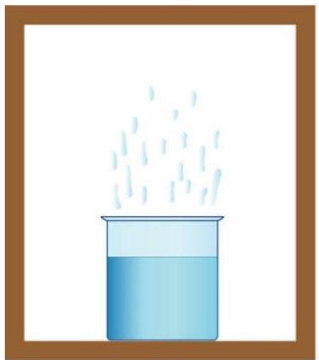




Water Content vs Water Activity

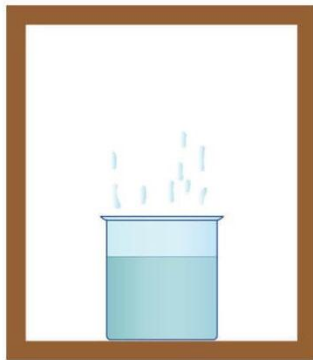
$$\frac{P_1}{P_0} = \text{Water Activity (A}_w\text{)}$$

Vapour Pressure
 P_0



Distilled Water

Vapour Pressure
 P_1



Sample Water

- Moisture content: total water in food (g water per 100 g food; % w/w)
- Water activity (a_w): fraction of “free” or available water
 - Defined as vapour pressure of water in the food divided by vapour pressure of pure water at the same temperature
 - Influences:
 - microbial growth
 - enzymatic and non-enzymatic reaction rates
- Foods with similar moisture can have very different a_w
- Typical a_w values:
 - Fresh fruits & vegetables: 0.98–0.99
 - Cooked rice: 0.95–0.99
 - Jams / jellies: 0.80–0.85
 - Dried fruits: 0.60–0.70
 - Crackers / dried spices: 0.20–0.35
- Lower a_w slows microbial growth and many chemical / enzymatic reactions.



Water content vs Water activity

- High moisture but high a_w
- High moisture but low a_w
- Low moisture but high a_w
- Low moisture and low a_w



Water content vs Water activity

- **High moisture but high a_w**
 - foods here contain a lot of water and *most of it is free*
 - microorganisms grow easily
 - spoils quickly unless cooled or processed
 - Fresh mango: 82–85% moisture, a_w 0.98–0.99
 - Leafy vegetables: 90–95% moisture, $a_w \approx 0.99$
 - Fresh cassava root: 60–65% moisture, $a_w \approx 0.98$
 - Fresh tomato: 94–95% moisture, $a_w \approx 0.99$
 - Cooked rice: 70% moisture, $a_w \approx 0.97$ –0.99
-
- High moisture but LOW a_w
 - Low moisture but high a_w
 - Low moisture and low a_w





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 - foods have a lot of water, but water is *bound* by sugar or salt, so it is not freely available
 - microbial growth is limited even though water content is high
 - Jam / jelly: 30–35% moisture, a_w 0.80–0.85
 - Honey: 18% moisture, a_w 0.55–0.65
 - Sweetened condensed milk: 25–30% moisture, a_w 0.82
 - Salted fish paste: 50–60% moisture, a_w depends on salt but often 0.75–0.85
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- Low moisture but high a_w
 - Low moisture and low a_w





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- **Low moisture but high a_w**
 - Foods look dry, but because of structure, water is still available
 - Foods can mould quickly because fungal growth is possible at these a_w levels
 - Fresh bread: 35–40% moisture, a_w 0.94
 - Soft cakes / pastries: 20–25% moisture, a_w 0.85–0.95
 - Cooked noodles (air-dried): ~25–30% moisture, a_w often ≥ 0.90
- Low moisture and low a_w





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- **Low moisture and low a_w**
 - Water is both low in quantity and low in availability
 - These products can still spoil chemically (e.g., rancidity in cashew), but microbial spoilage is minimal.
 - Dried mango: 12–20% moisture, a_w 0.55–0.70
 - Dried cassava chips: 10–12% moisture, a_w 0.50–0.65
 - Cashew kernels: 4–6% moisture, a_w 0.20–0.40
 - Dried spices (pepper): 10–12% moisture, a_w 0.20–0.40
 - Crackers / biscuits: 2–5% moisture, a_w 0.20–0.35





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Water Activity control in practice

- Reducing water activity in plant-based products
 - Removal of water = drying/dehydration: sun, solar tunnel, hot-air, vakuum
 - Binding water = addition of humectants: sugars, salt, sorbitol, glycerol
 - Packaging to prevent moisture reabsorption: barrier films, desiccants
 - Intermediate Moisture Foods (IMF): fruit leather, candied fruits
- IMF products are shelf-stable at ambient temperatures.





Intermediate Moisture Foods (IMF)

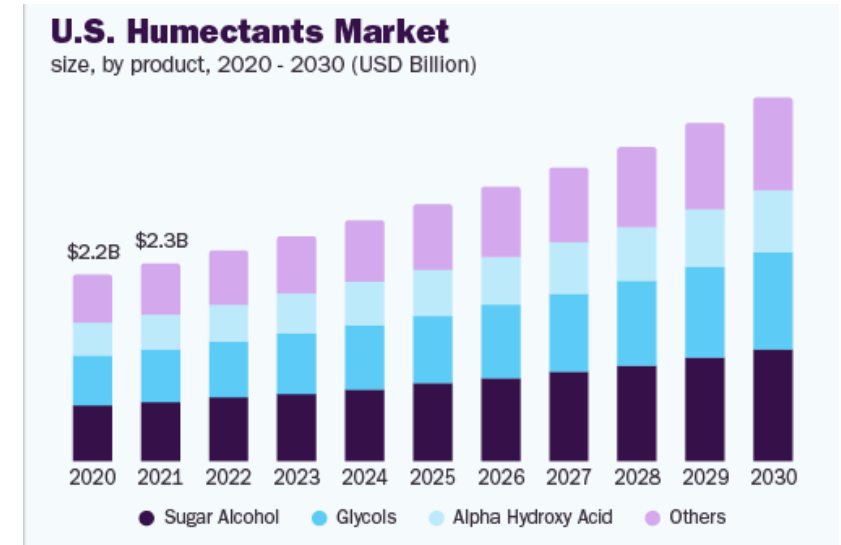
- Moderate moisture content:
 - typically 10–40% w/w
 - a_w usually between 0.60 and 0.85
- Shelf-stable at ambient temperature
- Soft, flexible or chewy texture
- Microbial growth greatly reduced
- How stability is achieved:
 - Partial drying
 - Addition of humectants (sugar, salt, glucose syrup, glycerol, sorbitol)
 - Proper packaging to prevent moisture gain
- Good shelf life, pleasant texture, minimal refrigeration needed
- Examples:
 - fruit leather
 - soft dried mango or banana
 - sweetened dried fruit snacks (turmeric, galangal)
 - confectionery pastes
 - some traditional salted or sweetened pastes
 - sweetened ginger
 - soft rice snacks
 - mung bean or soybean paste candies
 - rice–palm sugar bars
 - honey-coated sesame bars





Humectants

- food ingredients that lower a_w and extend shelf life
- humectants = substances that bind water
- do not necessarily reduce total moisture content
- common humectants in plant-based foods:
 - sugars: sucrose, glucose, fructose
 - salt (sodium chloride)
 - natural syrups (palm sugar, honey)
 - food-grade humectants: glycerol, sorbitol
- effects of humectants:
 - increase shelf life
 - slow microbial growth
 - stabilise texture in dried and semi-dried products
- used in:
 - dried fruits, fruit pastes,
 - jams, intermediate moisture foods (IMF)



sucrose, glucose, fructose, high-fructose corn syrup, invert sugar, maltose, honey, palm sugar, molasses, glycerol, sorbitol, mannitol, xylitol, propylene glycol, sodium chloride, potassium chloride, calcium chloride, sodium lactate, potassium lactate, glycine, polydextrose, corn syrup solids, trehalose, maltodextrin, erythritol, betaine, sea salt, coconut sugar, maple syrup



How much humectant to add?

- a_w target method
 - choose desired a_w for safety and shelf life
- Soluble solids approach (°Brix)
 - adjust sugar until target soluble solids reached
- Validated formulation standards
 - use known safe % sugar or salt for traditional products
- **Hurdle approach**
 - combine humectants with pH, heat, preservatives, drying
- Empirical formulation tables
 - use industry/technical tables relating humectant % to stability
- Texture-based adjustment
 - modify humectant to achieve required texture and flexibility
- Moisture sorption isotherms (advanced)
 - scientific calculation of required binding capacity

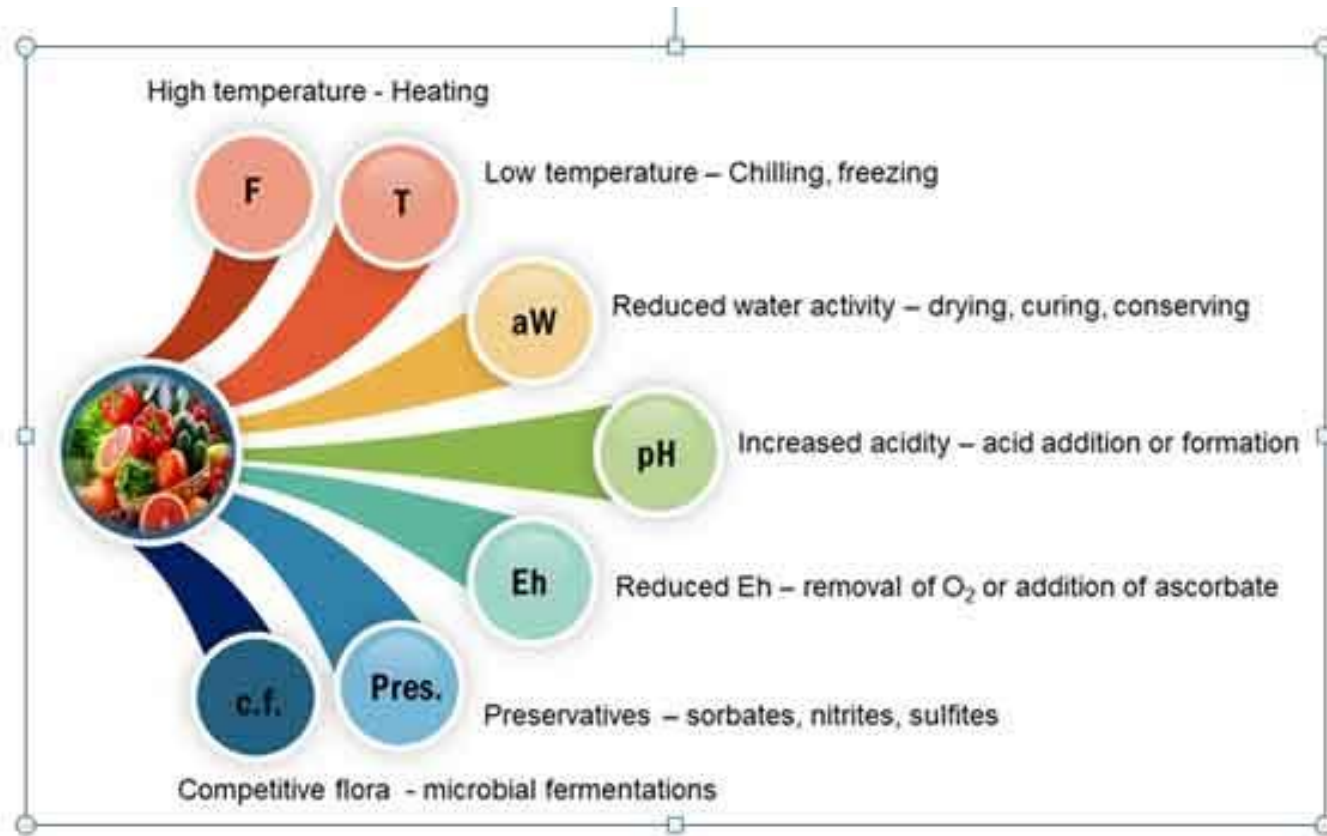
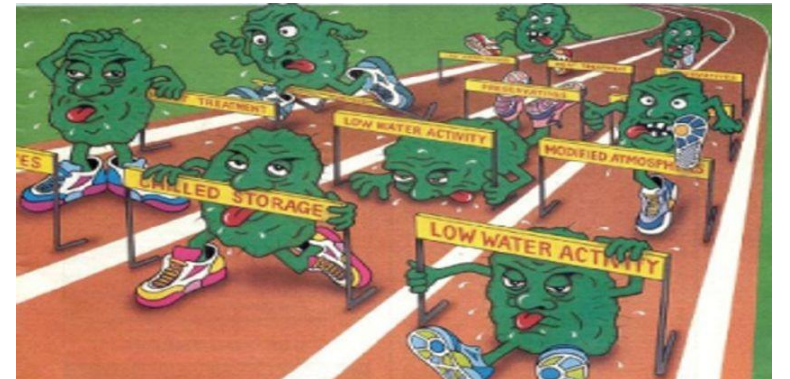


Fig. 1: The major hurdles and its applications in the food preservation





Carbohydrates

- Sugars (mono-, di-, oligosaccharides)
 - Starch (amylose vs amylopectin)
 - Non-starch polysaccharides (cellulose, hemicellulose, pectin)
- Carbohydrates in plant foods:
 - Sugars: sweetness, browning, hygroscopicity
 - Starch: gelatinisation, retrogradation
 - Fibre/pectin: structure, viscosity, gelling
 - Deterioration:
 - Fermentation → acids, alcohols
 - Non-enzymatic browning
 - Starch retrogradation → staling



Simple sugars in plant-based foods

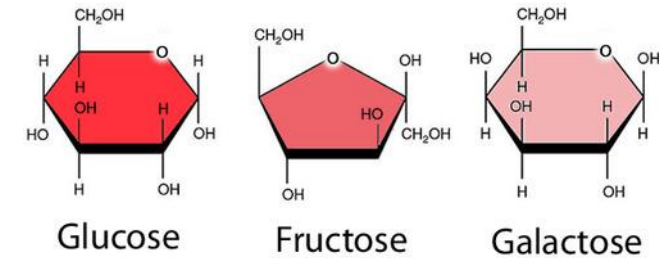
Types:

- Monosaccharides: glucose, fructose, galactose
- Disaccharides: sucrose, maltose, trehalose
- Natural syrups: palm sugar, coconut sugar, honey (complex mixtures)
- Sugar profiles vary strongly with ripening (e.g., mango, banana, jackfruit)

Roles:

- Sweetness and flavour architecture (fructose > sucrose > glucose)
- Humectancy: water-binding, lowering water activity, soft texture retention
- Influencing stickiness, flow, collapse during storage
- Browning substrates: Maillard reaction, caramelisation, ascorbic acid browning
- Fermentation substrates for yeasts, LAB, acetic bacteria
- Cryoprotection and freeze-thaw stability

Monosaccharides





Non-Enzymatic Browning: Maillard & Caramelisation

Examples:

- Palm sugar, coconut sugar, jaggery
- Caramelised syrups for confectionery
- Jams, fruit pastes, candied fruits
- Banana and mango frying/drying
- Beer

Quality considerations

- Colour development
- Flavour complexity
- Risk of burning, bitterness

• Caramelisation

- Sugar-only browning (no amino group required)
- High-temperature thermal decomposition

• Chemical changes

- Dehydration and isomerization
- Formation of caramelans, caramelens, caramelins
- Generation of characteristic volatiles



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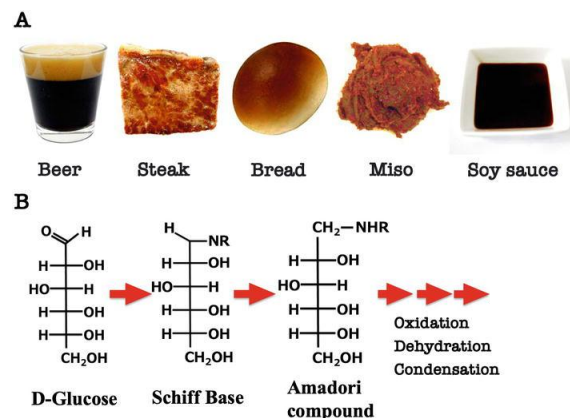
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Non-Enzymatic Browning: Maillard & Caramelisation

Examples:

- Roasted cashew, peanut, sesame
- Palm-sugar confections
- Rice crackers, roasted rice teas
- Dried banana, mango snacks
- Baked bread
- Roasted coffee



- **Maillard reaction**

- Reducing sugars + amino acids
- Heat accelerates the reactions

- Produces Amadori compounds → melanoidins

- brown colour
- aroma compounds

- **Positive effects**

- Flavour development (pyrazines, aldehydes)
- Colour formation (browning)
- Aroma complexity in roasted foods

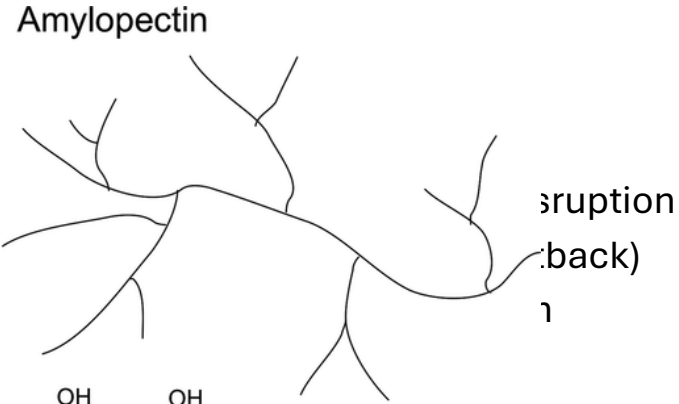
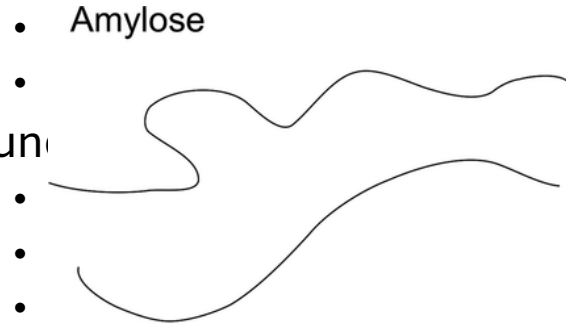
- **Negative effects**

- Lysine loss (nutritional reduction)
- Excessive darkening
- Formation of process contaminants (acrylamide)



Starch

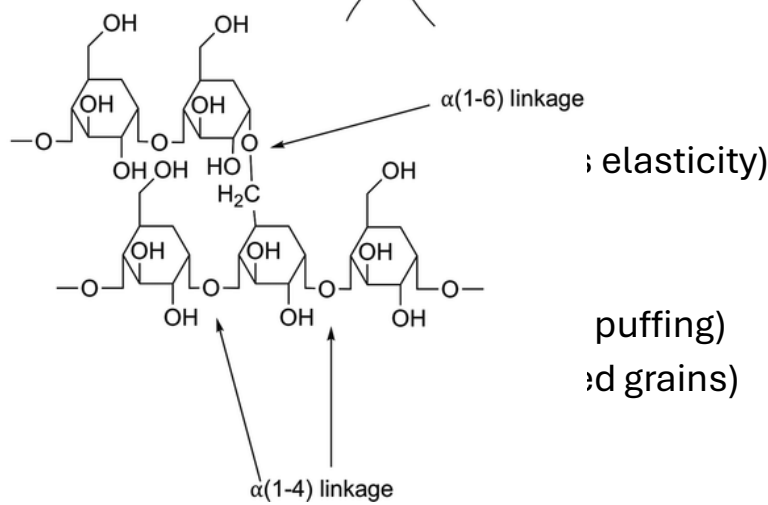
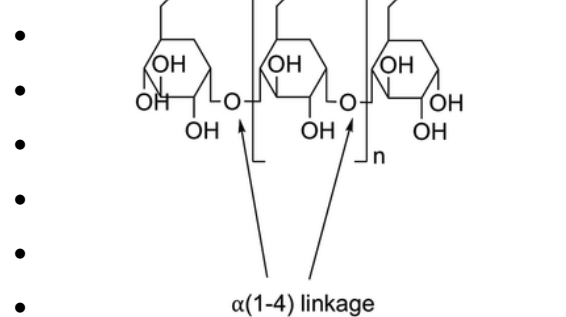
- Starch composition and granule characteristics
 - Amylose–amylopectin architecture (branching degree, molecular weight)



- Fun



- Proc





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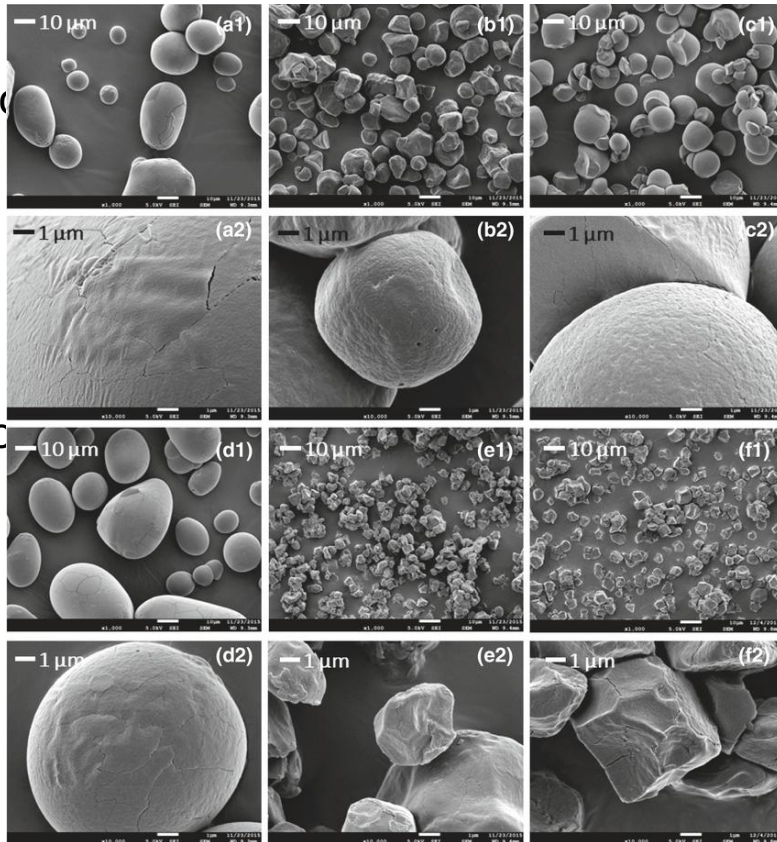
- Granule size differences: rice < maize < cassava

- Function

- Starch granule swelling, crystalline disruption (retrogradation, amylose leaching, amylopectin recrystallisation)

- Processing

- Starch granule expansion (DOI:10.1111/ijfs.14120)
 - Starch granule disruption (extruded snacks, puffed grains)
 - Starch granule modification (starches and texturisers)



a: maize, b: waxy maize, c: cassava,
d: potato, e: rice, f: waxy rice



Starch

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 - Amylose–amylopectin architecture (branching degree, molecular weight)
 - Granule size differences: rice < maize < cassava
 - Variation in gelatinisation temperature across tropical species
- Functional properties
 - Gelatinisation: granule swelling, amylose leaching, crystalline disruption
 - Pasting behaviour under shear (viscosity profiles, breakdown, setback)
 - Retrogradation kinetics: amylose vs amylopectin recrystallisation
 - Syneresis, staling, and textural ageing
 - Interactions with lipids, proteins, polyphenols
- Processing relevance in Southeast Asia
 - Rice noodle and rice paper production (amylose content dictates elasticity)
 - Cassava flour gels: clarity, viscosity, cohesive texture
 - Thickening in coconut-milk-based curries and desserts
 - Starch–heat–moisture treatments in snack expansion (extrusion, puffing)
 - Behaviour in rice-based snacks (crackers, extruded snacks, puffed grains)
 - Use in plant-based meat analogues as binders and texturisers



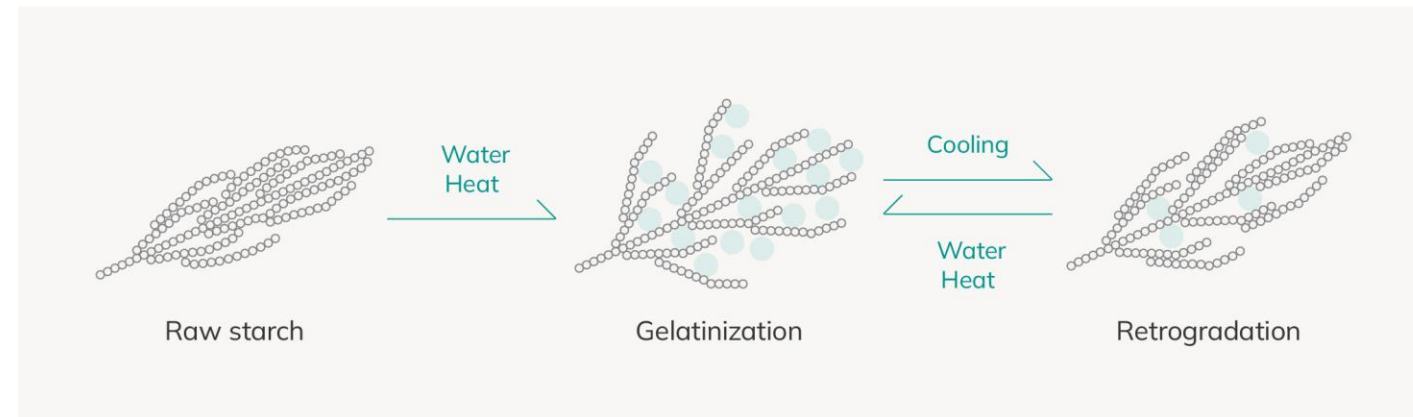
Starch gelatinisation and retrogradation

Gelatinization = irreversible transition of starch granules from an ordered, semi-crystalline structure into an amorphous, swollen, viscous paste when heated in the presence of water

cassava starch – 58–65 °C
rice starch (regular) – 68–78 °C
waxy rice starch – 60–70 °C
sweet potato starch – 60–75 °C
yam starch – 65–75 °C

- water penetrates the granule → disrupting hydrogen bonds and crystalline lamellae → granules swell → amylose begins to leach into the surrounding medium → this produces the viscosity increase characteristic of e.g. rice porridge, cassava gels, starch-thickened coconut desserts
- gelatinisation temperature depends strongly on botanical source
- some types of unmodified native starches start swelling at 55 °C, other types at 85 °C

Retrogradation = gelatinized starch, when cooled for a long enough period (hours or days), will thicken and rearrange itself again to a more crystalline structure

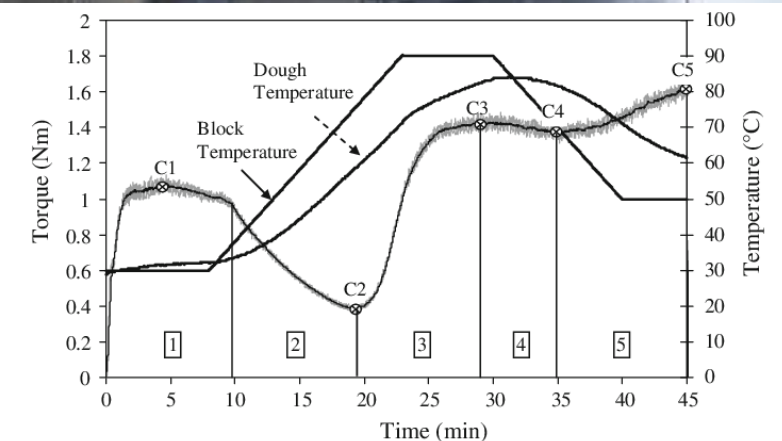
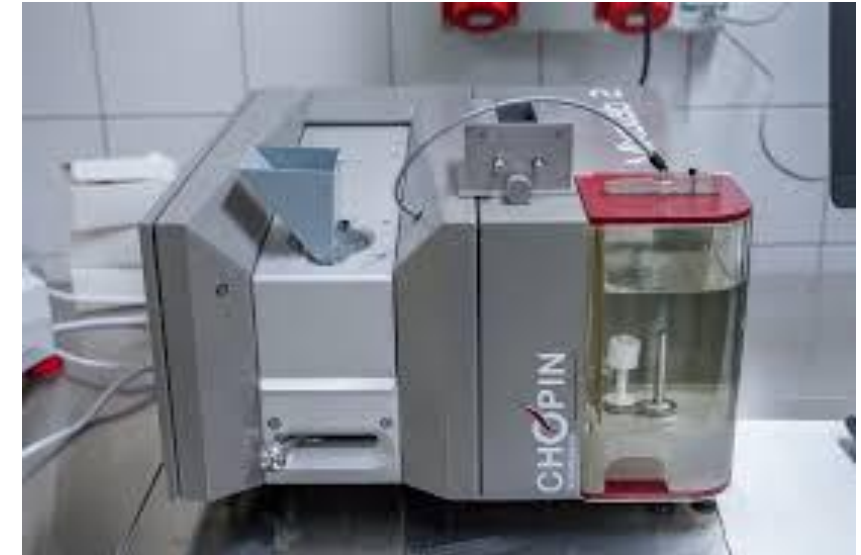




Starch-containing foods - estimation of shelf-life

Mixolab 2: relevance to shelf-life prediction

- Measures protein weakening, starch gelatinisation, enzyme activity, and retrogradation.
- Provides kinetic and rheological indicators linked to ageing.
- Key parameters:
 - C3 – starch pasting/gelatinisation
 - C4 – stability under heat and shear
 - C5 – retrogradation tendency (amylose recrystallisation)
- Useful for: rice noodles, bakery products, extruded snacks, cassava products.
- Supports formulation decisions (enzymes, hydrocolloids, modified starch).
- Enables accelerated shelf-life assessment via rheological profiling.





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Non-starch polysaccharides (fibre)

Major fibre components

- Cellulose: crystalline $\beta(1\rightarrow4)$ -glucan
- Hemicellulose: xylans, mannans, arabinoxylans
- Pectins: homogalacturonan, rhamnogalacturonan I and II
- Soluble gums: guar, xanthan (used regionally), locust bean gum

Functional behaviour

- Structural integrity: cell-wall architecture, firmness
- Water-holding capacity and swelling
- Viscosity modification
- Gelation (pectin–sugar–acid systems; pectin–calcium systems)
- Inhibition or promotion of syneresis
- Fibre–protein and fibre–starch interactions

Processing relevance in tropics

- Fruit-softening behaviour during ripening (mango, papaya, banana)
- Pectin breakdown in heat-processed fruit purées and juices
- Pectin's role in fruit leather texture, mango purée viscosity
- Cellulose and hemicellulose softening in boiled vegetables (morning glory, pumpkin)
- Fibre-rich flours (jackfruit flour, banana flour, coconut flour) as functional ingredients
- Stabilisation of coconut-milk emulsions and plant-based drinks



Proteins

Amino acids

- Essential and non-essential
- Key reactive groups: ϵ -amino (lysine), thiol (cysteine), phenolic (tyrosine), imidazole (histidine)
- Aromatic vs aliphatic residues: hydrophobicity and stability

Peptides

- Bioactive peptides (antioxidant, antimicrobial, antihypertensive)
- Breakdown products from proteolysis
- Contribution to taste (bitterness, umami)

Proteins

- Plant storage proteins: globulins, albumins, prolamins, glutelins
- Structural hierarchy: primary \rightarrow quaternary
- Distribution in tropical plants: rice, mung bean, soy, groundnut, sesame, coconut, moringa, jackfruit seed



Functional properties of plant proteins

- Solubility & hydration → essential for beverage stability (coconut–soy drinks, mung-bean beverages)
- Water-holding capacity → moisture retention in steamed rice cakes, banana flour breads, plant-based patties
- Viscosity & thickening → texture in coconut–legume soups, porridges, curry bases, plant-based “milks”
- Emulsification → stabilisation of coconut milk emulsions; peanut/soy sauces; plant-based mayonnaise
- Foaming → aeration in rice-based batters, mung-bean pancakes, traditional steamed cakes
- Heat-induced gelation → firmness in tofu; mung-bean jelly; gel formation in coconut–mung desserts
- Elasticity & binding → strength in rice noodles; cohesiveness in plant-based meat analogues
- Protein–starch interactions → texture control in rice noodles, rice paper, cassava gels
- Protein–polyphenol interactions → astringency and colour effects in moringa blends, cacao–coconut beverages

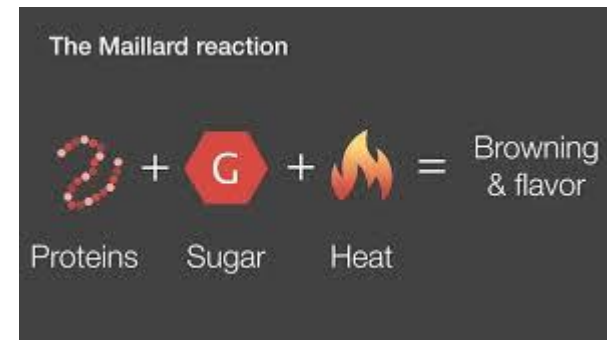




Reactions of proteins: desirable & undesirable

- Beneficial reactions

- Controlled proteolysis → flavour and digestibility
 - Examples: tempeh, fermented soybean/mung bean sauces, rice fermentation
- Desirable Maillard reaction → aroma & colour development
 - Examples: roasted cashew, peanut, sesame, coconut chips, rice crackers
- Protein denaturation → texture formation
 - Examples: tofu, mung-bean jelly, coconut–mung desserts, plant-based patties



fermented foods like yogurt, kefir, and sauerkraut
fruits such as kiwifruit, pineapple (bromelain), papaya (papain)
ginger





Reactions of proteins: desirable & undesirable



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-  Kiwi
-  Sprouts
-  Ginger
-  Asparagus

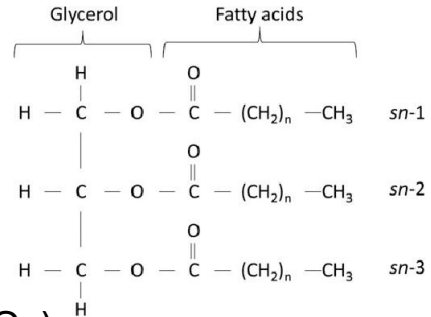


Reactions of proteins: desirable & undesirable

- Undesirable reactions of protein in plant-foods
 - Excessive proteolysis → bitterness, texture loss
 - Examples: over-fermented legume pastes, mushy soaked beans, fruit softening (papaya, banana)
 - Maillard-driven nutrient loss → lysine degradation, darkening
 - Examples: overly browned dried banana/mango, burnt rice snacks
 - Protein oxidation → off-flavours, crosslinking, reduced solubility
 - Examples: rancid rice bran, stale peanuts/groundnuts, oxidised sesame
 - Undesirable denaturation/aggregation → precipitation, graininess
 - Examples: separation in coconut–legume beverages, curdling in soy–coconut blends
 - Protein–phenol browning/complexation → astringency, colour change
 - Examples: moringa beverages, cacao–soy drinks, tea–protein blends



Lipids



Major lipid classes:

- Triacylglycerols (TAGs)
- Phospholipids & glycolipids
- Free fatty acids (FFA)

Minor lipids:

- Sterols
- Tocopherols
- Carotenoids

• Fatty acid profiles (tropical examples)

- Saturated: lauric (coconut), palmitic (palm)
- Monounsaturated: oleic (groundnut, sesame, cashew)
- Polyunsaturated: linoleic & linolenic (rice bran, sesame)
- Unsaturated oils are healthier than saturated oils

• Factors influencing stability

- Degree of unsaturation
- Presence of natural antioxidants
- Enzymatic activity (lipase, lipoxygenase)
- Physical state (liquid vs semi-solid)
- Metal ions, light, oxygen



Lipid oxidation

- **Autoxidation (radical chain reaction)**

- radical formation (heat, light, metals) → lipid peroxy radicals → radical–radical recombination

- **Photo-oxidation**

- Chlorophyll, riboflavin
- Rapid oxidation of unsaturated fatty acids

- **Enzymatic oxidation & hydrolysis**

- Lipoxygenase: hydroperoxide formation
- Lipase: release of free fatty acids (FFA)
- FFA accelerate further oxidation

- **Critical factors**

- Oxygen, temperature, water activity
- Particle size (surface area)
- Mechanical damage
- Packaging atmosphere

- **Consequences**

- Hydroperoxides → aldehydes, ketones, short-chain acids
- Examples: stale peanuts, rancid sesame oil
- Loss of essential fatty acids (PUFA degradation)
- Destruction of vitamins A, E, carotenoids
- Colour fading, loss of crispness (snacks)

- **Stabilisation strategies**

- Process controls: blanching, heat stabilisation (lipase/lipoxygenase inactivation)
- Chemical controls: antioxidants (tocopherols, rosemary extract, ascorbyl palmitate), metal chelators
- Environmental controls: low oxygen, low temperature, low light
- Packaging: oxygen barriers, opaque films, nitrogen flushing, oxygen absorbers



Rancidity

- Development of unpleasant flavours and odours due to lipid degradation
- a *chemical* deterioration
- **Microbial rancidity** refers to a water-dependent process in which microorganisms, such as bacteria or molds, use their enzymes such as lipases to break down fat
- **Types of rancidity**
 - **Oxidative rancidity**
 - Reaction of oxygen with unsaturated fatty acids
 - Produces aldehydes, ketones, short-chain acids
 - **Hydrolytic rancidity**
 - Lipase releases free fatty acids
 - FFA often taste/smell soapy, bitter, sharp
- **Drivers of rancidity**
 - Heat, oxygen, light, metal ions
 - Moisture fluctuations
 - High surface area (broken nuts, milled bran)
 - High enzyme activity in cereals/legumes
- **Control strategies**
 - Rapid stabilisation (heat inactivation of lipase/lipoxygenase)
 - Antioxidants (tocopherols, rosemary extract)
 - Packaging: oxygen barriers, nitrogen flushing, opaque films
 - Low oxygen, low temperature, low humidity
 - Avoid mechanical damage and metal contamination



Rancidity

- Development of unpleasant flavors and odors due to lipid degradation
- a *chemical* deterioration
- **Microbial rancidity** refers to a process in which microorganisms (bacteria, molds), use their enzymes such as lipases to break down fat

- **Types of rancidity**

- **Oxidative rancidity**

- Reaction of oxygen with unsaturated fatty acids
 - Produces aldehydes, ketones, and free radicals

- **Hydrolytic rancidity**

- Lipase releases free fatty acids (FFA)
 - FFA often taste/smell soapy, bitter



Rancidity

oxygen, light, metal ions

temperature fluctuations

large surface area (broken nuts, milled bran)

enzyme activity in cereals/legumes

Prevention strategies

sterilization (heat inactivation of lipase, oxygenase)

antioxidants (tocopherols, rosemary extract)

packaging: oxygen barriers, nitrogen flushing, vacuum packaging, coatings

storage: low temperature, low humidity

minimize mechanical damage and metal contamination



Lipid-containing foods - estimation of shelf-life

- Oxitest is a high-pressure, high-temperature oxidation analyser used to measure the resistance of foods, oils, and complex matrices to oxidative deterioration.
- The device accelerates lipid oxidation by exposing samples to pure oxygen under elevated pressure and controlled heating, allowing rapid determination of induction time and oxidative stability.
- Suitable for both simple and complex foods, including oils, nuts, seeds, flours, snacks, emulsions, cereals, and products containing natural antioxidants or pro-oxidants.
- Induction time from Oxitest correlates with real-time shelf life, helping predict rancidity development, evaluate packaging systems, compare formulations, and assess ingredient quality.





Enzymes in plant products

- Plant tissues contain active hydrolases and oxidoreductases that continue driving biochemical changes after harvest.
- **Colour-related enzymes (PPO, peroxidase)** cause browning and pigment alterations in fruits and vegetables.
- **Texture-modifying enzymes (pectinases, cellulases)** soften tissues during ripening and processing.
- **Carbohydrate-active enzymes (amylases)** change sweetness, viscosity, and digestibility in cereals and fruits.
- **Protein-acting enzymes (proteases)** alter texture, release peptides, and influence flavour during fermentation.
- **Lipolytic enzymes (lipase, lipoxygenase)** initiate rancidity and off-flavour formation in nuts, seeds, and rice bran.



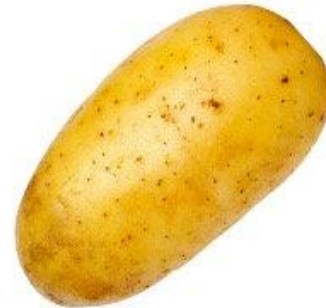
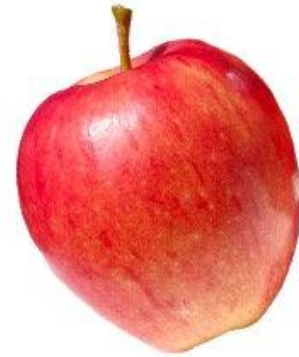
Enzymatic browning (polyphenol oxidase, PPO)

- Enzymatic browning is caused by polyphenol oxidase (PPO), which oxidises naturally occurring phenolic compounds to quinones that polymerise into brown or black pigments whenever plant tissues are damaged and oxygen is present.
- The reaction is common in tropical fruits and vegetables: e.g. banana, mango, guava, papaya, taro, potato, and eggplant
 - When exposed during cutting, peeling, slicing, damage
- Browning is strongly influenced by pH, oxygen availability, metal ions, and processing speed
- Result: undesirable darkening, bitterness, flavour changes, and quality loss in fresh-cut, puréed, dried, or minimally processed products.
- Control strategies:
 - inhibiting the enzyme (blanching, acidification, antioxidants)
 - excluding or limiting oxygen (rapid drying, modified atmospheres)
 - preventing tissue disruption where possible



Enzymatic

- Enzymatic browning naturally occurring in many fruits and vegetables
- The reaction is catalyzed by polyphenol oxidase (PPO)
- When exposed to oxygen, PPO converts phenolic compounds into brown or black pigments
- Browning is strong in apples, guava, papaya, and mango
- Result: undesirable in fresh-cut, pureed, and dried products
- Control strategies:
 - inhibiting the enzyme
 - excluding or limiting oxygen
 - preventing tissue damage



PPO)

is naturally occurring in many fruits and vegetables. It is responsible for the brown or black pigments that develop in fresh-cut produce.

is in fresh-



Enzymatic browning

- Occurs when damaged tissue meets oxygen
- Example:
 - cut mango, banana
- Control:
 - Blanching
 - Acidification
 - Antioxidants
 - Reduced oxygen



Food preservatives – principles and role in plant products

- Substances that inhibit microbes or slow deterioration (spoilage, rancidity, browning).
- Used alongside other hurdles: water activity, pH, temperature and packaging.
- Important in plant products such as juices, nectars, pickles, jams, dried fruit, sauces and snacks.
- Must be authorised, used within legal limits and technologically justified.
- Types:
 - chemical (synthetic) preservatives
 - natural preservative systems (salt, sugar, acids, plant extracts, fermentation)



Traditional and natural preservative ingredients I – salt and sugar

- Salt (sodium chloride): reduces water activity and exerts osmotic stress, key in pickles and fermented plant products.
 - Health: excessive sodium intake is linked to hypertension and cardiovascular risk.
 - Price and sustainability: very cheap; obtained by mining or seawater evaporation and generally sustainable.
- Sugar (sucrose, glucose syrups, palm sugar, honey): lowers water activity and stabilises jams, jellies, candied fruits and fruit leathers.
 - Health: high sugar intake is associated with obesity, type 2 diabetes and dental caries.
 - Price and sustainability: widely available; environmental impact depends on crop and farming system





Traditional and natural preservative ingredients II – acids, smoking and drying

- Organic acids from vinegar and fermentation (acetic and lactic acid) lower pH and inhibit many micro-organisms in pickles and fermented vegetables.
 - Health: generally favourable; fermented foods may offer gut-health benefits and improved digestibility.
 - Price and sustainability: vinegar production and lactic fermentations are low-cost and low-energy processes.
- Smoking and drying: remove water and, in the case of smoking, deposit antimicrobial and antioxidant compounds on the food surface.
 - Health: drying is very safe; poorly controlled heavy smoking can generate polycyclic aromatic hydrocarbons (PAHs), so good smoking practice is essential.
 - Price and sustainability: highly sustainable when using solar or efficient heat sources; minimal external inputs are required.



Natural preservatives – plant extracts, spices and essential oils

- Many herbs and spices contain phenolics, terpenes and aldehydes with antimicrobial and antioxidant activity.
 - Examples: garlic, onion and shallot (allicin compounds); ginger, galangal and turmeric (gingerols, shogaols, curcuminoids); lemongrass, basil and kaffir lime (citral, linalool, eugenol); clove and cinnamon (eugenol, cinnamaldehyde).
 - Health: generally safe at culinary levels and often associated with antioxidant and anti-inflammatory benefits; concentrated extracts require regulatory control.
 - Price and sustainability: most herbs and spices are moderately priced and can be grown locally; essential oil extraction is more energy-intensive but uses renewable plant materials.
 - Limitations: strong flavours and aromas limit the maximum usable dose; natural variability and stability must be managed in product development.



Natural preservatives – biopreservation with lactic acid bacteria

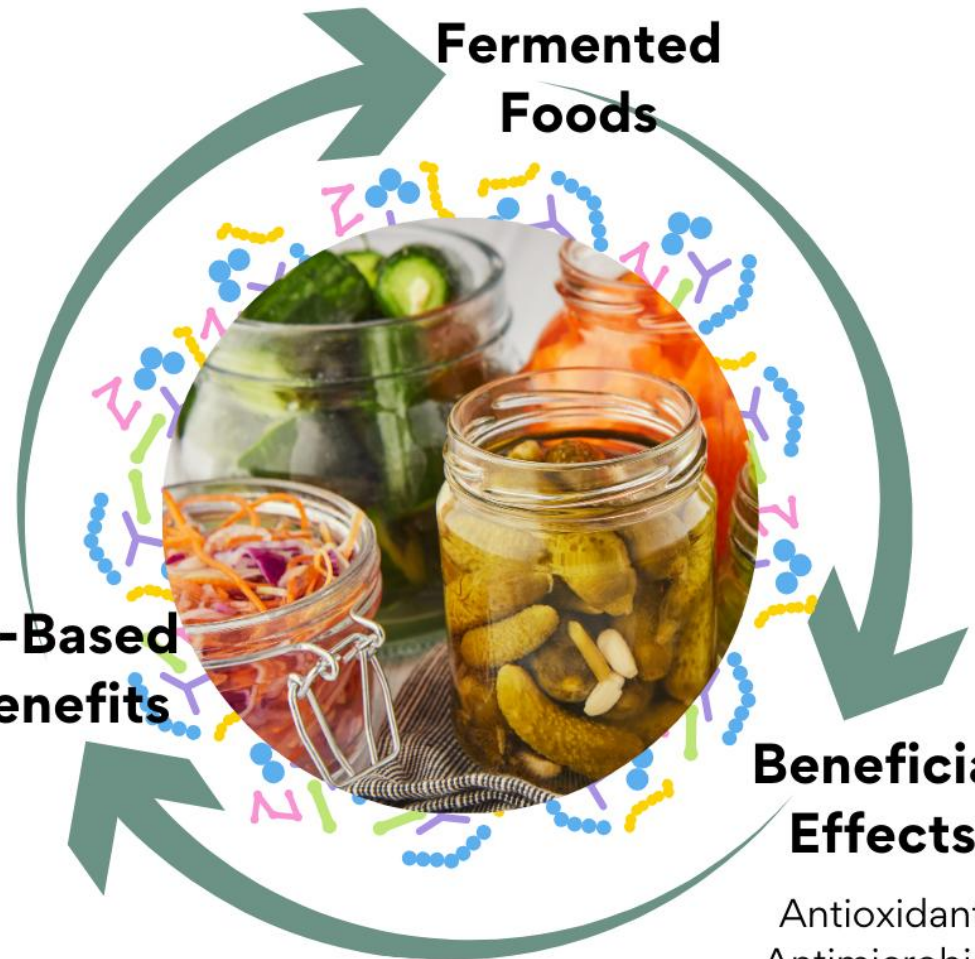
- Biopreservation uses beneficial microbes, especially lactic acid bacteria (LAB), and their metabolites to inhibit spoilage organisms and pathogens.
- LAB produce lactic and acetic acids, hydrogen peroxide and bacteriocins, lowering pH and suppressing competing microflora.
 - Health: fermented plant products are associated with improved gut health, better digestibility and increased dietary diversity.
 - Price and sustainability: LAB cultures are inexpensive; fermentation requires relatively little energy and is highly sustainable.
- Bacteriocins such as nisin (E234) and pediocin are safe antimicrobial peptides produced by LAB and used at very low levels in foods.
- Nisin and related bacteriocins are produced by fermentation, are degraded in the digestive tract and fit well with clean-label preservation strategies.





MICROBIAL COMMUNITIES

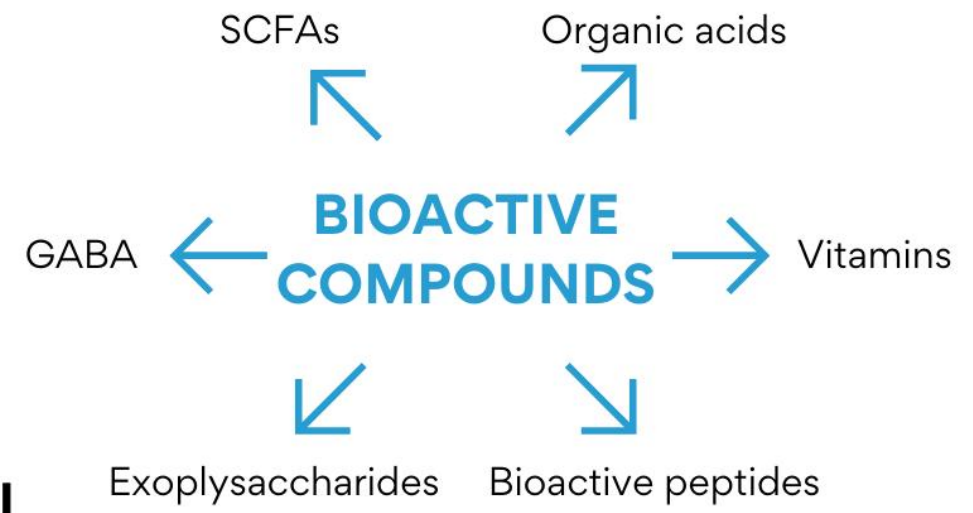
Fermented Foods



Evidence-Based Health Benefits

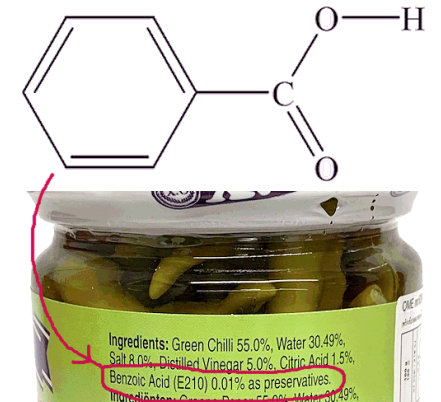
Beneficial Effects

- Antioxidant
- Antimicrobial
- Probiotic
- Antidiabetic
- Hypocholesterolemic
- Anti-inflammatory





Chemical preservatives I – organic acids and their salts



- Benzoic acid and sodium benzoate: control yeasts, moulds and some bacteria in acidic juices, drinks and pickles.
 - Health: considered safe at permitted levels; very high intake may cause mild reactions in sensitive individuals.
 - Price and sustainability: very inexpensive; produced synthetically (petrochemical origin), not perceived as ‘natural’.
- Sorbic acid and potassium sorbate: inhibit yeasts and moulds in juices, jams and fruit snacks.
 - Health: widely regarded as safe with low allergenic potential.
 - Price and sustainability: affordable, effective at low doses; manufactured synthetically.
- Propionic acid and its salts (e.g. calcium propionate): anti-mould agents in bakery items and some dried plant snacks.
 - Health: safe at permitted levels; sometimes associated with a ‘chemical’ taste in sensitive applications.
 - Price and sustainability: very cheap and widely available.



Chemical preservatives II – common preservatives



Foods That Often Contain Parabens



Jams & jellies



Soft drinks



Pickles



Trail Mix



Frozen dairy treats



Flavored Syrups

- Sulphur dioxide and sulphites (e.g. sodium metabisulphite): strong anti-yeast and anti-mould agents and antioxidants in dried fruits, light-coloured juices and some pickles.
 - Health: generally safe but can trigger allergic reactions and asthma-like symptoms in sensitive individuals; mandatory allergen labelling is required.
 - Price and sustainability: economical and highly efficient; overuse in industrial settings can raise environmental and worker-exposure concerns.
- Parabens (methyl and propyl p-hydroxybenzoate): used at low levels in some beverages and syrups, often in combination with other hurdles.
 - Health: evaluated as safe at permitted levels, but public perception is increasingly cautious.
 - Price and sustainability: low cost and synthetic in origin; less compatible with ‘clean label’ product positioning.

High Sulfite Foods





Lyophilisation (freeze-drying)

- Principle: water is removed by sublimation under low pressure.
- Steps:
 - Freezing → water forms ice crystals.
 - Primary drying → ice sublimates under vacuum.
 - Secondary drying → bound water removed at low temperature.
- Outcomes:
 - Excellent retention of colour, flavour, nutrients, volatile compounds.
 - Creates porous structure → rapid rehydration.
 - Minimal thermal damage (non-thermal dehydration).
- Applications (plant-based): fruits (mango, banana, dragon fruit), herbs, spices, instant soups, coffee, microbial cultures, high-value powders.
- Limitations: high energy use, high cost, limited throughput.





Product	Moisture (%)	Carbohydrates (%)	Protein (%)	Lipid (%)	Notes
Polished rice	12–14	78–80 (mostly starch)	6–7	0.5–1	low a_w , shelf-stable
Fresh cassava root	60–65	30–35 (starch)	1–1.5	0.3–0.5	cyanogenic glycosides
Fresh mango	80–85	14–20 (sugars)	0.5–1	0.3–0.6	high a_w , active enzymes
Leafy vegetable (e.g. Chinese kale)	90–95	3–5 (fibre, sugars)	2–3	0.5	very high a_w , high respiration
Cashew kernel (dried)	4–6	20–25	15–20	40–45	lipid oxidation risk
Kampot pepper (dried)	10–12	50–55 (starch, fibre)	10–12	2–3	volatile aroma compounds



Learning objectives

By the end of this session, you will be able to:

- Describe the major constituents of plant-based foods: water, carbohydrates, proteins, lipids, minor components.
- Explain how these constituents deteriorate (enzymatic & non-enzymatic browning, oxidation, hydrolysis, respiration, microbial activity).
- Relate deterioration mechanisms to postharvest conditions: temperature, water activity, gas composition, mechanical damage.
- Interpret sensory indicators of freshness vs spoilage in rice, cassava, mango, vegetables, and nuts.