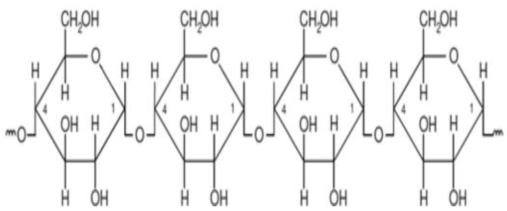
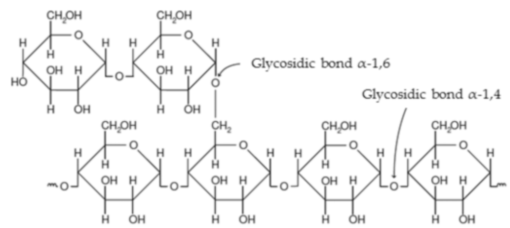


Amylose



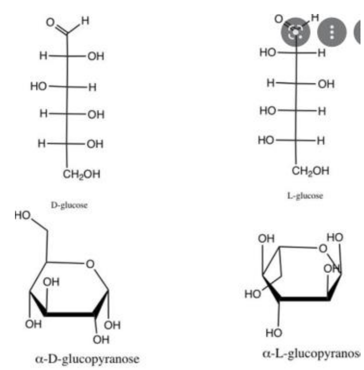
Amylopectin

Thermoplastic Starch TPS

- Starch granules are structurally modified into TPS using plasticizers (water and/or glycerol ($C_3H_8O_3$) /sorbitol) when it is processed with a low water content and the action of shear force and temperature in the presence of the plasticizers which do not evaporate easily during the processing → spontaneous destructurization
  - High temp, high shear condition, low water
- Abundant in plants as amorphous and crystalline granules
- TPS is made by applying mechanical and thermal energy onto the starch granules by adding plasticizer
  - Plasticizers decrease internal h bonding → processability, flexibility, and mobility due to less water affinity
- Use twin-screw extruder followed by takeoff device to make TPS films

<u>Structure</u>

- Polysaccharide consisting of D-glucopyranose (aka Glucose with OH projecting to the right) units joined by α-1,4 linkages and is hydrophilic
- 2 polymers of high molecular weight: Amylose (10-20%) and Amylopectin (80-90%)
  - Amylose: hydrophilic helical structure → H bonding through Hydroxyl groups (can also be oxidized and reduced)
    - 200–20,000 glucose units
  - Amylopectin: high molecular weight, v little branching
    - 10,000 and 20,000,000 glucose units
- Starch naturally occurs as hydrophilic granules w lots of H bonding



<u>Poor Mechanical and Physical Properties</u>

- Sensitive to high humidity & moisture
  - Improved by Lignin (hydrophobic)
- No clear melting point
- Brittle
- Fragile due to low Tg
- High amylose content → less flexible; high amylopectin content → more flexible

- High solubility in water
    - Starch can be modified by esterification, etherification, and oxidation before thermoplastization to become more hydrophobic
- Low permeability to gasses
- Poor water vapor barrier properties
    - Improved by Cellulose microfibrils (CNF)
        - Increase in tensile strength, a decrease in deformation values, an increase in Young's module, and a decrease in WVP of TPS films
- Plasticizers increase flexibility and processability by decreasing absorption of water
    - Starch-starch interactions replaced by stary-plasticizer interactions

Crystallinity

- Semi Crystallinity due to Amylopectin and Amylose/Amylopectin ratio
    - X ray scattering shows native starch is 20-40% crystalline
- Mechanical resistance and flexibility depend on crystalline region
- Remains solid until a given quantity of heat is absorbed and then rapidly changes into a low viscosity liquid
- Useful levels of strength and stiffness

Other Properties

- Inexpensive and abundant
- Native starch granules are completely biodegradable
- Corn and sugar starch show promise
- Renewable and flexible → easily used in thermoplastification processes

Blends	Application	Reference
Starch/plasticizer	• Biodegradable packaging	[1]
	• Starch based film material	[32]
	• Disposable eating utensils	[38]
Starch/PVA	• Water-soluble laundry bags	[61]
	• Biomedical and clinical field	[66]
	• Replacement of polystyrene	[63]
Starch/PLA	• Biodegradable tray	[68]
	• Electronic devices, pharmaceutical	[62]
Starch/PBS	• Packaging materials, fisheryAutomotive	[61,65]
Starch/natural fibre	• Food packaging	[20,25]
	• Biodegradable material	[22,58,68]

- Certain blends improved tensile strength, decreased moisture affinity, decreased density, decreased health hazards, increased insulation, etc.
- TPS with PLA (hydrophobic) offers the MOST advantage based on cost, properties, and biodegradability
    - Drawbacks: low impact strength, flexibility, ductility
- Ex. PLA decreased the water vapor permeability the most → v important for food trays
- PBS increases impact strength and chemical resistance the most → more flexibility/elasticity → good for food packaging

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