Carbohydrates

Role of sugars in foods

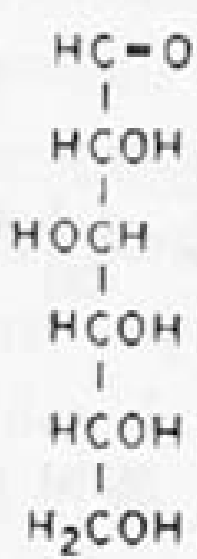
Product	Total Sugar (%)	Mono- and Disaccharides (%)	Polysaccharides (%)
Fruits			
Apple	14.5	glucose 1.17; fructose 6.04; sucrose 3.78; mannose trace	starch 1.5; cellulose 1.0
Grape	17.3	glucose 5.35; fructose 5.33; sucrose 1.32; mannose 2.19	cellulose 0.6
Strawberry	8.4	glucose 2.09; fructose 2.40; sucrose 1.03; mannose 0.07	cellulose 1.3
Vegetables			
Carrot	9.7	glucose 0.85; fructose 0.85; sucrose 4.25	starch 7.8; cellulose 1.0
Onion	8.7	glucose 2.07; fructose 1.09; sucrose 0.89	cellulose 0.71
Peanuts	18.6	sucrose 4–12	cellulose 2.4
Potato	17.1		starch 14; cellulose 0.5
Sweet corn	22.1	sucrose 12–17	cellulose 0.7; cellulose 60
Sweet potato	26.3	glucose 0.87; sucrose 2–3	starch 14.65; cellulose 0.7
Turnip	6.6	glucose 1.5; fructose 1.18; sucrose 0.42	cellulose 0.9
Others			
Honey	82.3	glucose 28–35; fructose 34–41; sucrose 1–5	
Maple syrup	65.5	sucrose 58.2–65.5; hexoses 0.0–7.9	
Meat		glucose 0.01	glycogen 0.10
Milk	4.9	lactose 4.9	
Sugarbeet	18–20	sucrose 18–20	
Sugar cane juice	14–28	glucose + fructose 4–8; sucrose 10–20	

Role of sugars in foods

- Sweetness
- Browning
- Fermentation substrate
- Separating agent – prevent lump formation in starch gels
- Reduce starch gelatinization
- Dehydrate pectin- permit gel formation in jelly
- Aerate batter and dough
- Weaken gluten structure (compete with glutenin and gliadin for water) increase tenderness
- Moisture retention in baked products

- Stabilize egg white foams
- Raise coagulation temperature of protein
- Add bulk and body to foods (yogurt)
- Slow crystallization in candies or syrups that are made with corn sweetner or hydroyzed sucrose (invert syrup)

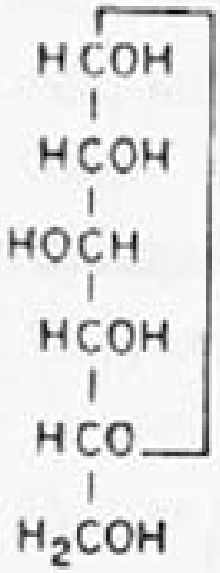
- Monosaccharides – glucose, fructose
  - Free carbonyl group – reducing sugars and participate in browning reactions (Maillard rxn w/protein)
  - Carmelization reactions – decomposition at high temperature
  - Contribute body and mouthfeel to foods (more viscous). Must modify viscosity for foods with non-nutritive sweetner
  - Fermentation
  - Preservative – at high levels (Aw <0.85)



Fischer

aldehydo-D

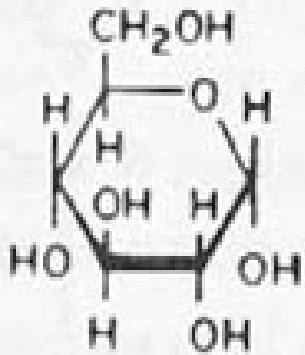
Glucose



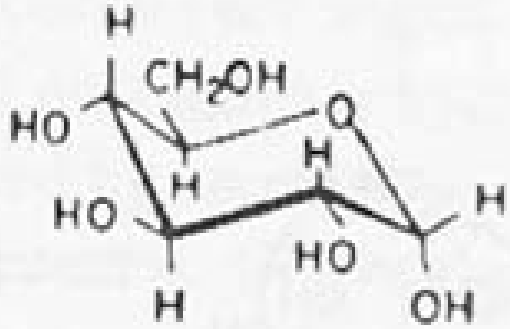
Fischer

α-D-

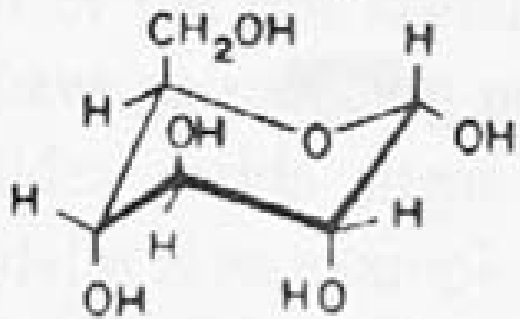
Glucopyranose



Haworth



C1 (D)

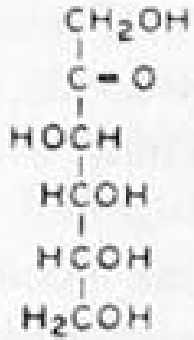


1C (D)

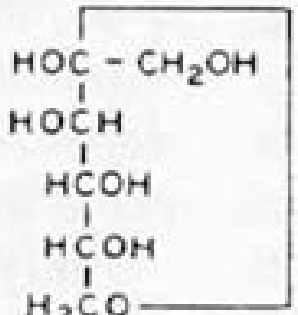
Conformational

GLUCOSE(dextrose)

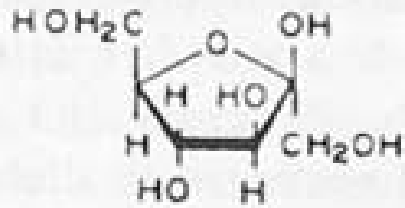
Aldose (aldohexose)



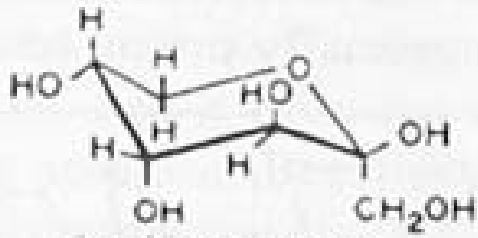
Fischer
keto-D-Fructose



Fischer
β-D-
Fructopyranose
β-D-arabino-
Hexulopyranose



Haworth
β-D-Fructofuranose



Conformational
β-D-Fructopyranose
C1 - D

FRUCTOSE (levulose)
Ketose (2-ketohexose, 2-hexulose)

– Disaccharides – sucrose, maltose, cellobiose

Table 4–3 Common Oligosaccharides Occurring in Foods

Sucrose	(α-D-glucopyranosyl β-D-fructofuranoside)
Lactose	(4-O-β-D-galactopyranosyl-D-glucopyranose)
Maltose	(4-O-α-D-glucopyranosyl-D-glucopyranose)
α,α-Trehalose	(α--D-glucopyranosyl-α-D-glycopyranoside)
Raffinose	[O-α-D-galactopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside]
Stachyose	[O-α-D-galactopyranosyl-(1→6)-O-α-D-galactopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside]
Verbascose	[O-α-D-galactopyranosyl-(1→6)-O-α-D-galactopyranosyl-(1→6)-O-α-D-galactopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside]

Source: From R.S. Shallenberger and G.G. Birch, *Sugar Chemistry,* 1975, AVI Publishing Co.

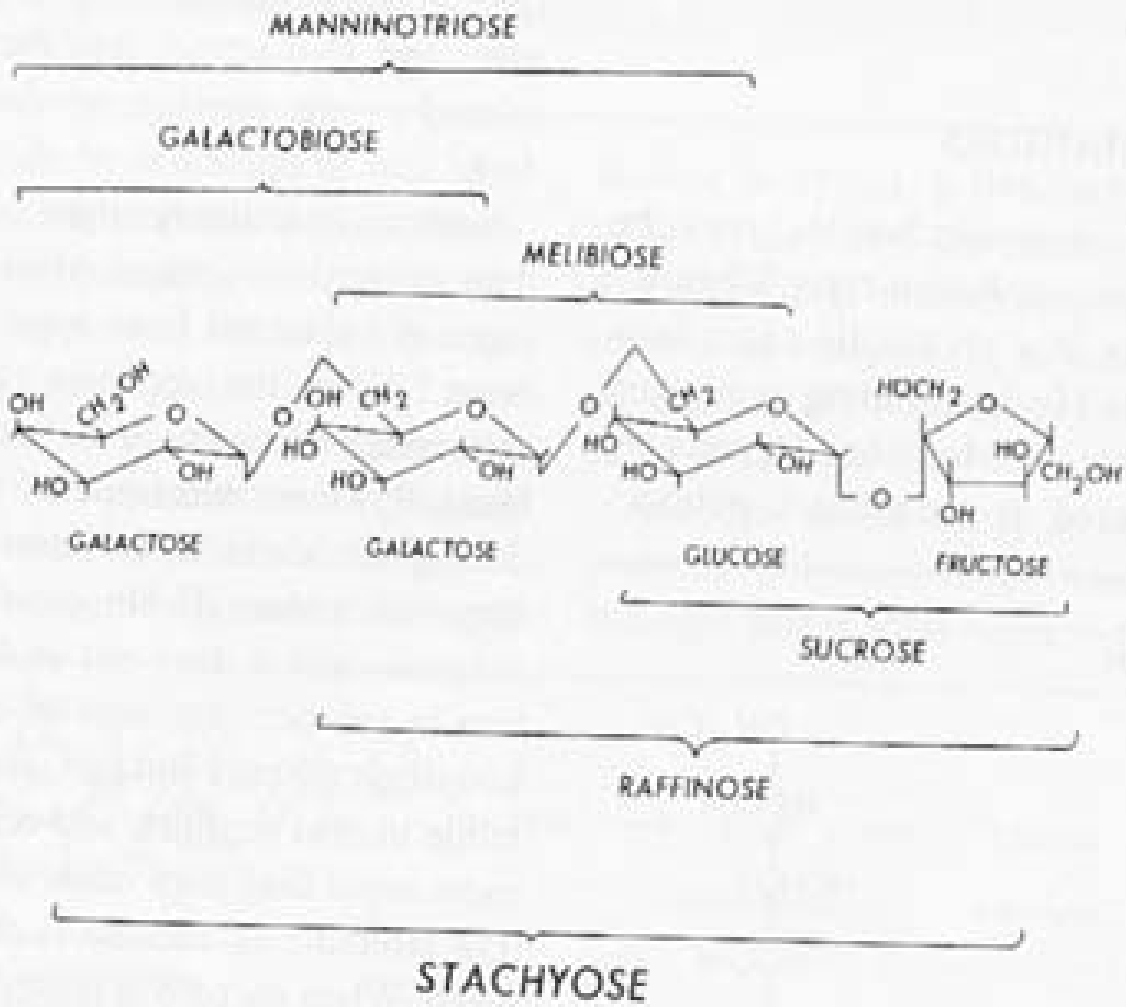
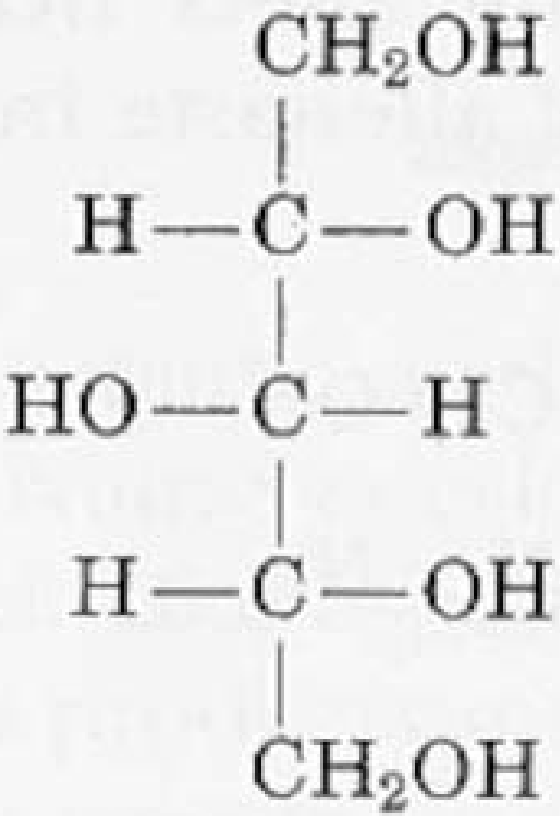


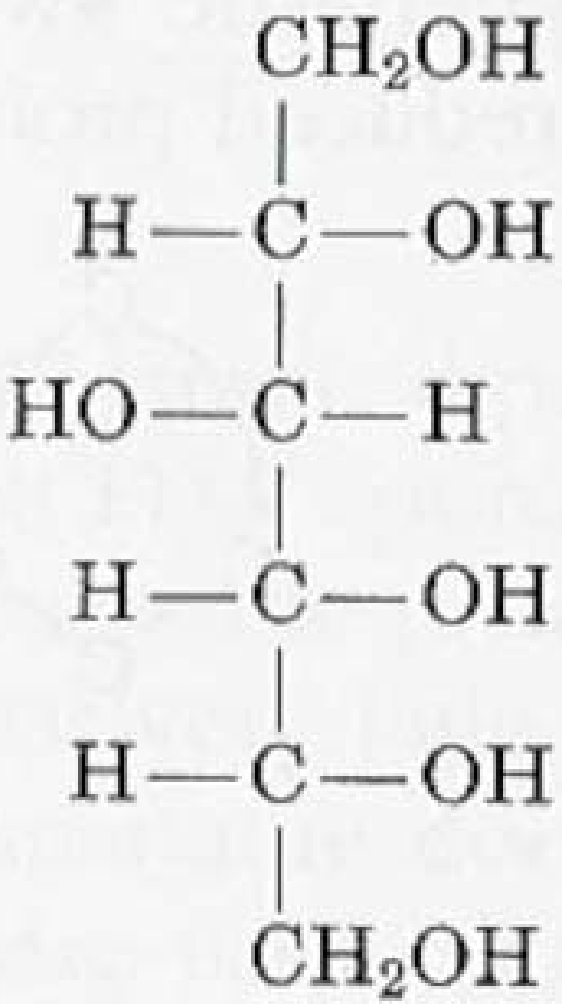
Figure 4–9 Composition of Some Major Oligosaccharides Occurring in Foods. *Source:* From R.S. Shallenberger and G.G. Birch, *Sugar Chemistry*, 1975, AVI Publishing Co.

Sugar Alcohols

- Carbonyl group -> OH.
- Sweet but less than sucrose. Not easily fermented (non cariogenic)
- 1-3Kcal/g
- Low energy bulk ingredient in place of sugar
- Sorbitol – transformed as fructose (diabetic products)



xylitol



sorbitol

Table 8.5 Some Polyhydric Alcohol Sweeteners

Polyol	Sugar Component	Cal/g	Comments/Applications
Maltitol	Maltose	2.1	Chocolates
Mannitol	Mannose	1.6	Bulking agent in powdered products; chewing gum (anti-cariogenic)
Sorbitol	Sorbose	2.6	Metabolized by fructose-1-phosphate pathway (needs no insulin)/baked goods, beverages
Xylitol	Xylose	2.4	Cooling mouthfeel/chewing gum (anti-cariogenic)

Table 4–2 Occurrence of Sugar-Alcohols in Some Foods (Expressed as mg/100g of Dry Food)

Product	*Arabitol*	*Xylitol*	*Mannitol*	*Sorbitol*	*Galactitol*
Bananas	—	21	—	—	—
Pears	—	—	—	4600	—
Raspberries	—	268	—	—	—
Strawberries	—	362	—	—	—
Peaches	—	—	—	960	—
Celery	—	—	4050	—	—
Cauliflower	—	300	—	—	—
White mushrooms	340	128	476	—	48

Source: From J. Washüttl, P. Relderer, and E. Bancher, A Qualitative and Quantitative Study of Sugar-Alcohols in Several Foods: A Research Role, *J. Food Sci.*, Vol. 38, pp. 1262–1263, 1973.

Artificial Sweetners

- Acesulfame K- no bitter aftertaste. 200x sucrose. Sunette®
- Aspartame –asp-pne-me. 180-200x sucrose.Not originally intended for heated products. Encapsulated form for bakery products.Equal®
- Saccharin- Me anthranilate. Naturally found in grapes.300-700x sucrose. Requires labeling. Sweet-n-Low®

Artificial Sweetners

- Sucralose. Trichloro-derivative of sucrose. 400-800x sucrose. Measures cup for cup like sucrose. Stable over wide pH, T range. Splenda® Cyclamate. Banned in 1970. 30x sucrose. Canada
- Stevioside. Glycoside 300x
- Thaumatin – peptide. 2000-3000x. Talin®

Table 8.1 Relative Sweetness of Selected Sugar Solutions (5%) and Other sweeteners[a]

Sweetener	Relative Sweetness
Thaumatin[b] (Talin®)	2000–3000
Monellin[b]	1500–2000
Sucralose[b] (Splenda®)	5–2000
Stevioside[b]	300
Saccharin[b]	200–300
Acesulfame K[b] (Sunette®)	130–200
Aspartame[b] (Nutrasweet®, Equal®)	100–200
Cyclamates[b]	30–80
Fructose	1.3[c]
Xylitol[b]	1.01
Sucrose	1.0[d]
Tagatose (Naturlose™)	0.92
Invert sugar	0.85–1
Xylose	0.59
Glucose	0.56
Galactose	0.4–0.6
Maltose	0.3–0.5
Lactose	0.2–0.3

[a]Figures compiled from multiple sources including Godshall, M. A. 1997. "How carbohydrates influence food flavor". *Food Technol. 51* (1): 63.

[b]Nonsugar sweetener.

[c]Highly variable, depending on temperature. This is a representative value, but measurements may range from 0.8 to 1.7.

[d]Value of sucrose arbitrarily set at 1.0 for reference purposes.

Polysaccharides

- Polysaccharides
- Starch
- Gums (plant, microbial)
- Cellulose (modified)
- Dietary fiber

Polysaccharides – Glucose polymers

- Dextrin-intermediate length linear glucose polymers(α-1,4). Starch hydrolysis.
- Maltodextrin – fat replacers - similar mouthfeel as fat
- Dextran-(α -1,6). Produced by fermentation.

Polysaccharides – Glucose polymers

- Starch-
  - amylose linear glucose polymer (α-1,4) and
  - amylopectin –branched glucose polymer (α-1,4 & α -1,6(branch point each 15-30 glucose). Very large ‘tree shaped’ molecule. Less soluble than amylose
  - Forms gels – corn, wheat
  - Does not form gels – waxy maize, tapioca

Polysaccharides

- Pectins – plant cell wall material. Polymer of α-D-galacturonic acid. Water soluble, gelling agents
- Gums – stabilizers and thickeners
  - terrestrial (arabic, tragacanth, guar, locust bean)
  - marine plant (carrageenan, alginate, agar) Alginate form gels (calcium bridges).
  - Microbial (xanthan, gellan, dextran,curdlan)
  - Synthetic- microcrystalline cellulose, cellulose, methyl cellulose, carboxymethyl cellulose

Starch- Picking one

- Thickening or gel forming ability
- Mouthfeel (gummy, stringy)
- Freeze-thaw stability- (waxy or crosslinked starch)

Starch properties- Controlling gelatinization

- **Acid-** hydrolyzes starch. Less water absorption **-**Less firm cooled product. Add acid (lemon juice for filling – at end of cooking process)
- **Agitation-** aids in independent swelling of starch granules. More uniform paste. Less lumps. Excessive stirring will rupture granules and lead to thin, opaque pasty mixture

Starch properties- Controlling gelatinization

- **Enzymes**
  - ✓ α–amylase (intentionally added – random hydrolysis), limit retrogradation (formation of crystalline form when cooled)
  - ✓ β-amylase (produces maltose (malting barley), germinating wheat
- Fats and protein- coat (fat), adsorbs (protein) to surface of starch granule. Delays hydration and increase in viscosity. Fat used as separating agent for flakey pie crusts

Starch properties- Controlling gelatinization

- Sugar
  - decrease firmness of cooked and cooled starch product.
  - Absorbs water that granule would have absorbed
  - Delays absorption - preventing complete swelling of starch granule
  - Separating agent – allows individual swelling of granules
  - Increases gelatinization temperature.
  - Reduces hydrolytic affect of acid on starch hydrolysis

Modified Starch

- Thin boiling- hydrolyzed, very thin as hot liquid easy to pump. Form strong gels when formed (fewer branches, easier to form H bonds)
- Oxidized-sodium hypochlorite – softer gels than acid hydrolyzed
- Crosslinked-alter OH groups to reduce retrogradation (OH ethyl on C2). More stable to heat and agitation than native starch.
- “Resistant” starch – not digestable (chemically modified or repolymerized). Dietary fiber source that has functional properties of starch

Pectins

- Pectin– galacturonic acid polymer. Dispersible in water. Variable degree of methyl esters
- Low methoxy pectin – mostly free carboxyl groups. 20-40% methylated. Forms gels by crosslinking with Ca.
- High methoxy pectin – 50-58% esterified. Form gels with addition of acid and sugar. pH <3.5 for gel formation. Align at junction zones and form crosslinks.

Gums and hydrocolloids

- Complex -branched –hydrophilic- heteroglycans. 1000DP
- Galactose (little or no glucose)
- Viscous solutions rather than gels

Functions of gums in food

- Thickeners- salad dressing, sauces, soups, beverages
- Stabilizer-ice cream, icing, emulsions
- Control crystal size- candy
- Suspending agent-salad dressing
- Gelling agents-fruit pieces, cheese analogs
- Coating agents- batters (fried foods)
- Fat replacers- low-fat salad dressings, ice cream, desserts
- Bulking agent-low fat foods
- Source of dietary fiber-beverages, soups, baked goods

Seed Gums

- Guar gum-contains only mannose/galactose 2:1. Soluble in cold water. Won’t gel alone. Forms gels with carrageenan and locust. Dressings, soups, sauces ice cream crystal inhibitor. Inhibits digestion and absorption of glucose.
- Locust bean - mannose/galactose 4:1.soluble only in hot water. Stabilizer in meat and dairy products. Gels with xanthan.

Plant Exudate Gums

- Arabic – highly water soluble. Newtonian flow.
  - Stabilize emulsions and control crystal size
- Tragacanth- very viscous sols. Impart creamy texture, suspend particles

Microbial Gums

- Xanthan- viscous sols stable over wide range of pH and T
- Thickener, stabilizer and suspending agent
- Forms gel with locust bean gum.
- Shear thins

Marine polysaccharides- Carrageenan

- Stabilize milk products (ice cream, process cheese, chocolate milk)
- (-)Galactose polymer with varying amount of (-) sulfate esters: Kappa (lowest sulfate), iota, lambda (highest sulfate) fractions. These generally used in combination
- Kappa -forms strong gels with K+
- Iota-forms strong gels with Ca++
- Lambda- too highly charged to gel
- Crosslinks with other gums

Marine polysaccharides- Agar

- Red algae. Galactose (a,b) polymer
- 2 fractions- agarose and agaropectin (sulfate esters)
- Strong, transparent, heat-reversible gels
- Meat products and gels

Marine polysaccharides- Alginates

- Brown algae
- Mannuronic and guluronic acids
- Gel with Ca++
- Fruit purees, “sythetic fruit” and vegetable pieces, kosher caviar, candies

Synthetic Gums- Cellulose Derivatives

Glucose polymer, 3000+DP

Microcrystalline - Acid hydrolysis of cellulose. Bulking agent.

Methyl (MC) and carboxymethyl (CMC) cellulose – alkaline hydrolysis.

CMC- binder, thickener (fillings, puddings). Retard ice crystal and sugar crystal growth

MC- will gel when cooled

Hydroxypropyl , hydroxypropylmethyl cellulose – coatings for fried food (moisture migration)

Dietary Fiber

- Structural polysaccharides
  - Cellulose- B-D-glucose polymer
  - Hemicellulose- heteropolysaccharides of xylose, mannose, galactose
  - Pectins
- Structural non-polysaccharides – Lignin
- Nonstructural polysaccharides
  - Pentosans- polymers of arabinose and xylose (other sugars)
  - Gums