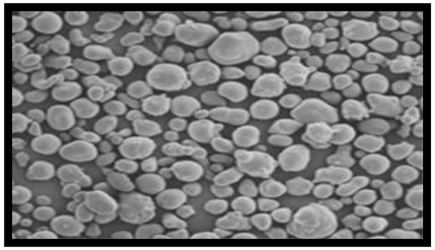
Polysaccharides

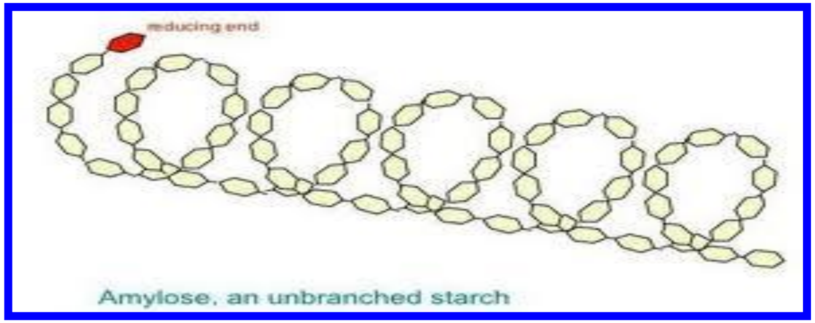
Asst. Prof. Cansu Ekin GUMUS

Starch

It has the most important place among all CHs. It is the main form of storage in plants and 70-80% of the calories consumed by humans originate from starch. Commercial starch can be produced from corn, potatoes, rice and wheat. Starch and modified starch have a wide range of uses in the food industry.

Starch has a granular structure, it is slightly hydrated in water; when dispersed in water, it forms a low viscosity mixture.

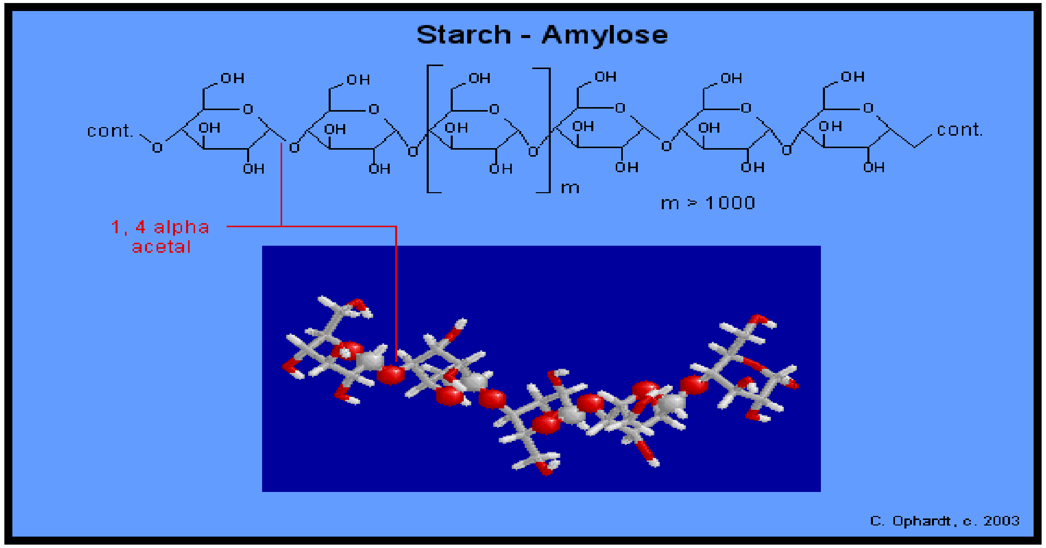




Amylose, an unbranched starch

Starch consists of a mixture of two main polymers.

(1) AMYLOSE: In amylose, glucose molecules are linked together by **α(1→4)** bonds. It has straight chain structure. Average molecular weight is 10^6. The rate of amylose in most starches is around 25%.



C. Ophardt, c. 2003

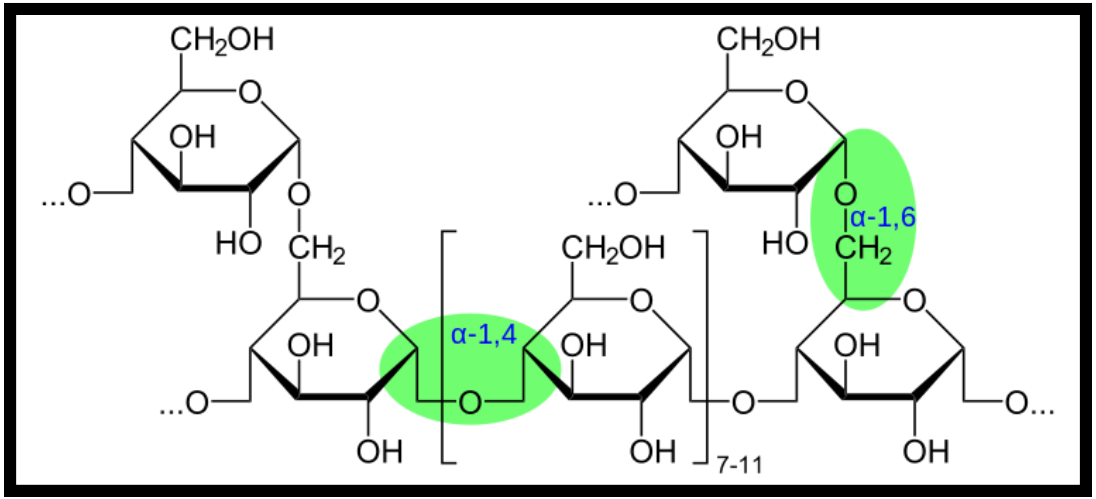
(2) AMYLOPECTIN: It contains a chain mainly connected by α(1→4) bond as well as branched structures in the form of α(1→6).

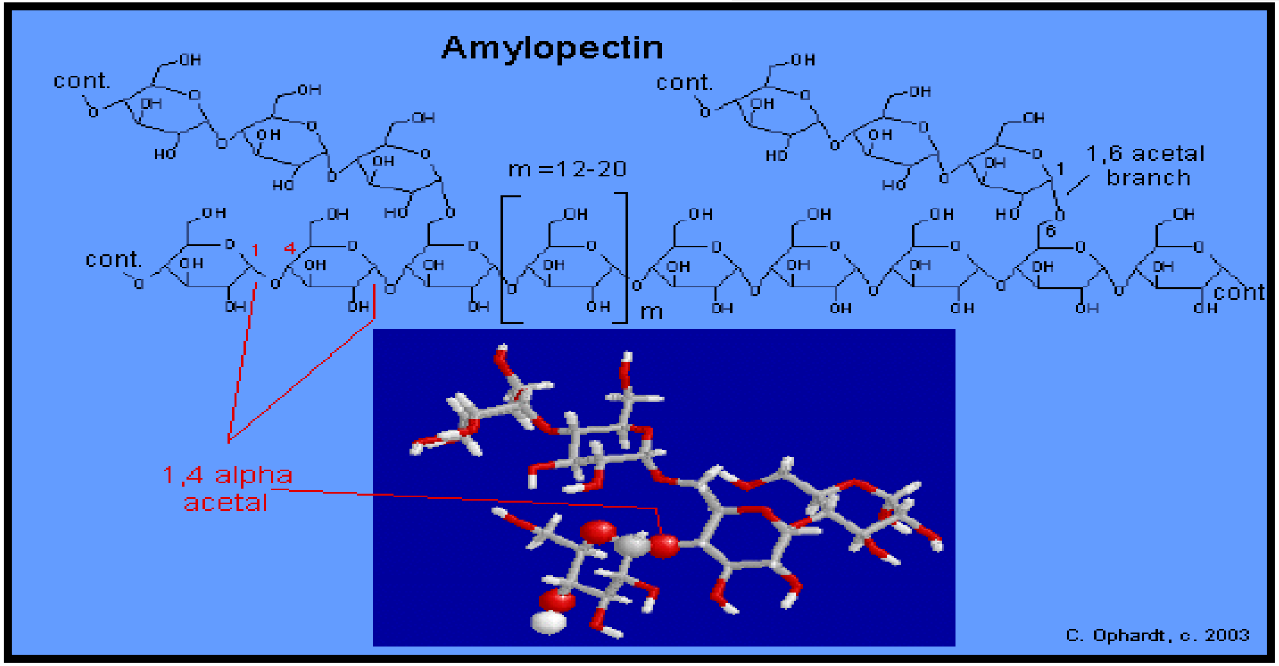
It is a very large and branched molecule. Molecular weight is 10^7-$5x10^8$, with a polymerization degree (DP) between 60,000-3,000,000. It is among the largest molecules in nature. 75% of starch is composed of amylopectin. There are also starches that consist entirely of amylopectin.

These are called waxy starches.

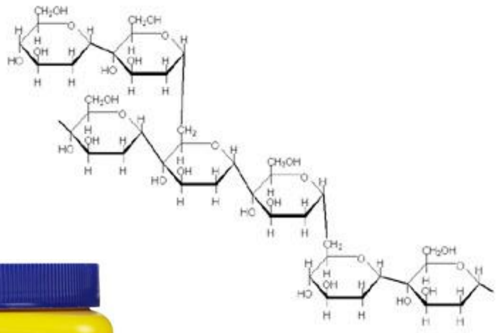
Branches form a compact structure and form multiple chains.

These chains can undergo enzymatic degradation.





Starch



Biological Function: Energy storage

Origin in Foods:

- **Seeds:** corn (maize), wheat, & rice
- **Tubers/roots**: potato

Food Applications:

- Texture modification - gelling, thickening
- Water holding
- Stabilizer
- Coating

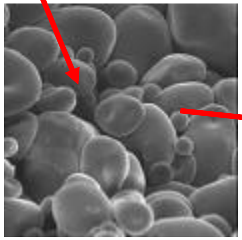
Corn

Wheat

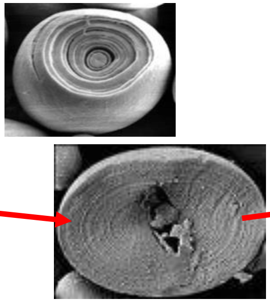
Rice

Potatoes

Starch: Hierarchical Structure



Starch Granules

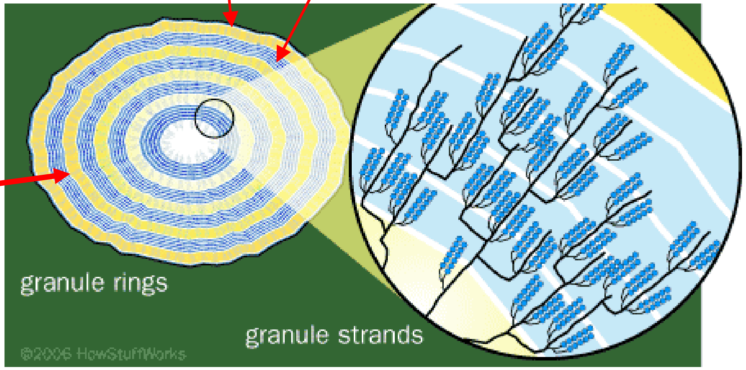


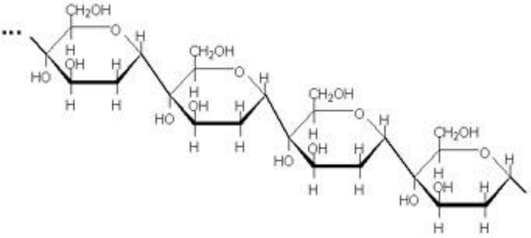
Internal structure

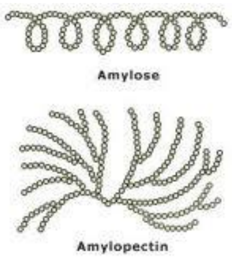
Starch Granule

Amorphous Region

Crystalline Region

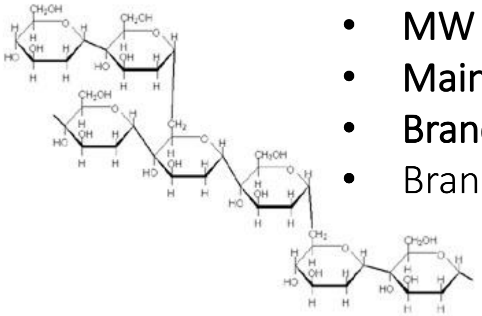






Amylose ≈ 25%

- MW = 2×10^5 - 2×10^6 Da
- **Main Chain:** α-1,4 linked D-glucose
- Linear chair

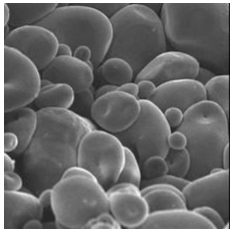


Amylopectin ≈ 75%

- MW = 10^7 -10^8 Da
- **Main Chain**: α-1,4 linked D-glucose;
- **Branch**: α-1,6 linked D-glucose)
- Branched chain

Polymers of Glucose

Starch Properties: Gelatinization

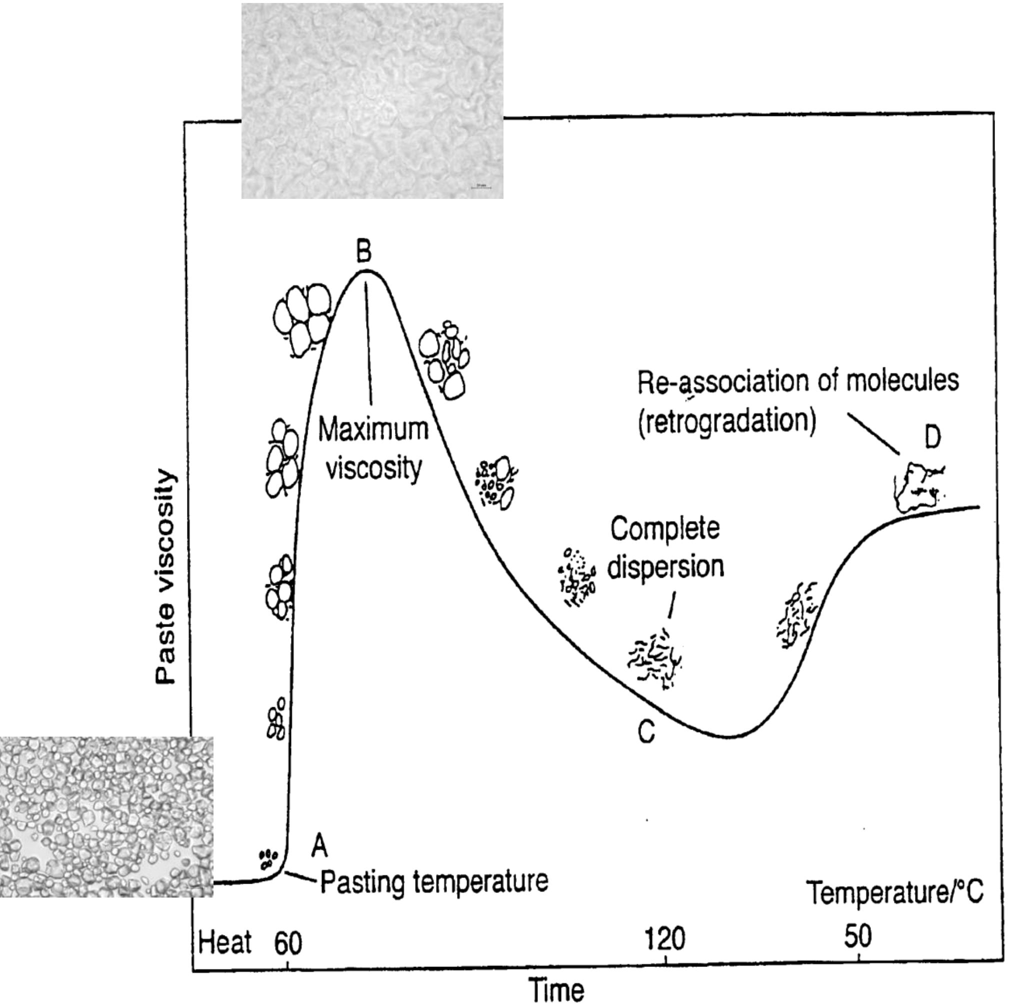


starch molecules tangle and trap water molecules to form a gel

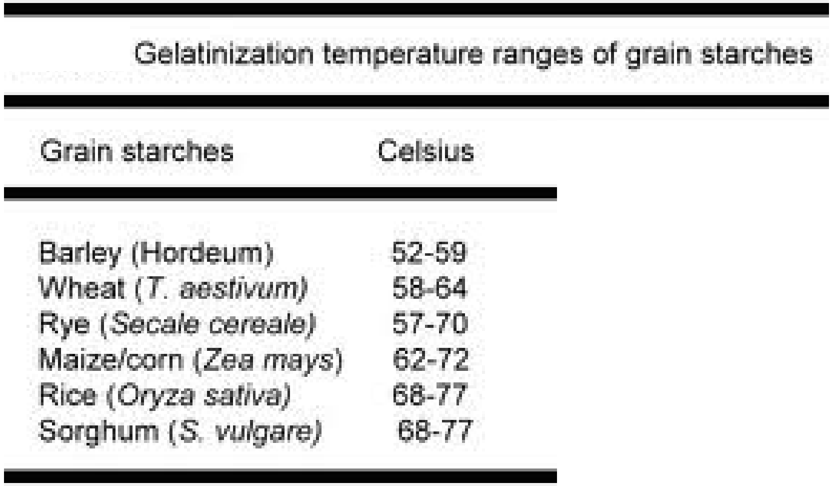
e.g. custard

Thermal processing of starch granules in water causes swelling, bursting and release of starch molecules (amylose and amylopectin)

Starch Properties: Gelatinization



Different starches differ in their gelation temperatures, and the rate & extent of gelatinization at a particular temperature

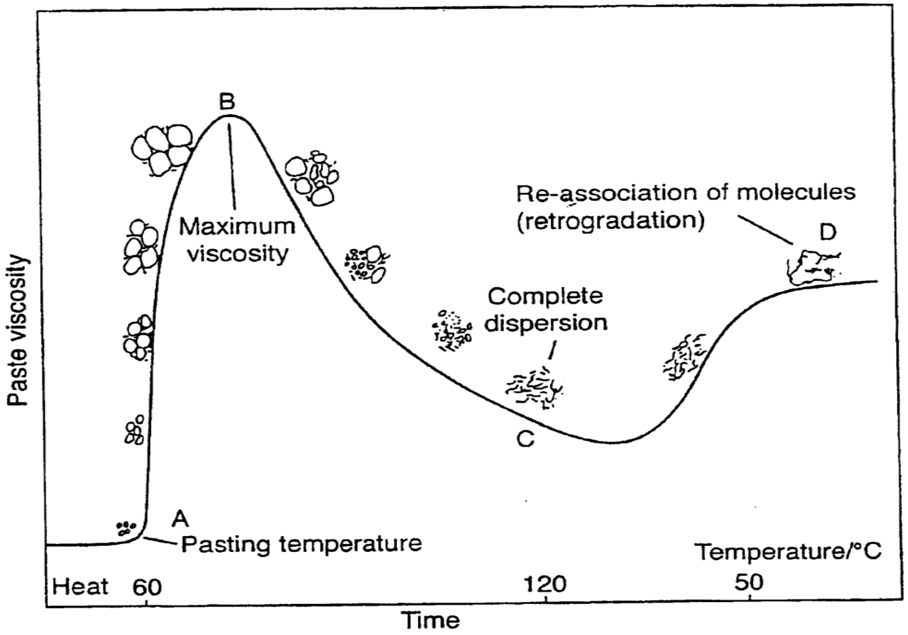


Gelatinization temperature ranges of grain starches

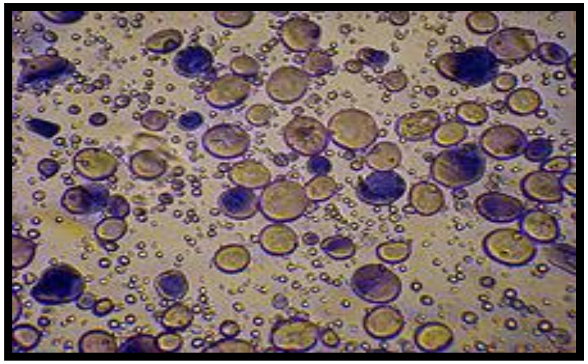
Grain starches	Celsius
Barley (Hordeum)	52-59
Wheat (*T. aestivum)*	58-64
Rye (*Secale cereale)*	57-70
Maize/corn (*Zea mays*)	62-72
Rice (*Oryza sativa)*	68-77
Sorghum (*S. vulgare)*	68-77

potato s. 58-85 °C

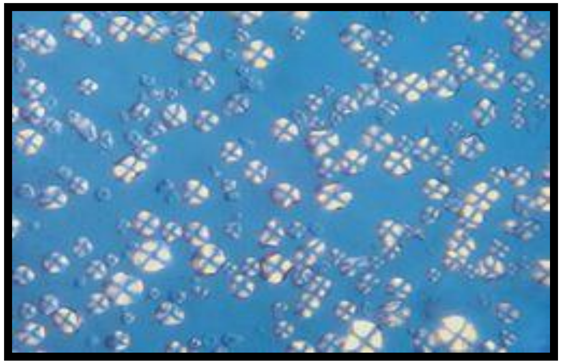
When the maximum viscosity is reached, some granules break down as a result of mixing, and the viscosity drops.



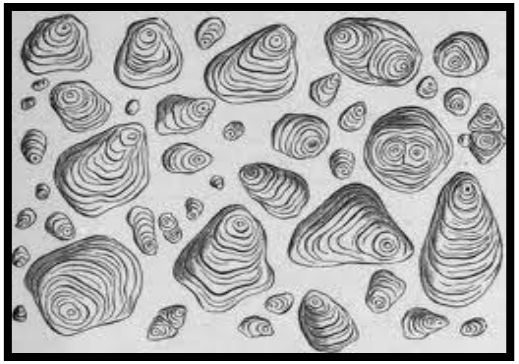
Wheat



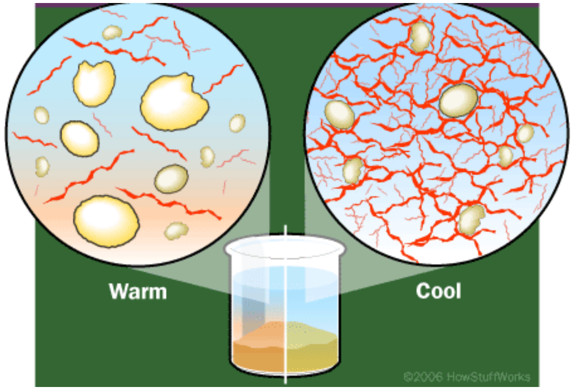
corn

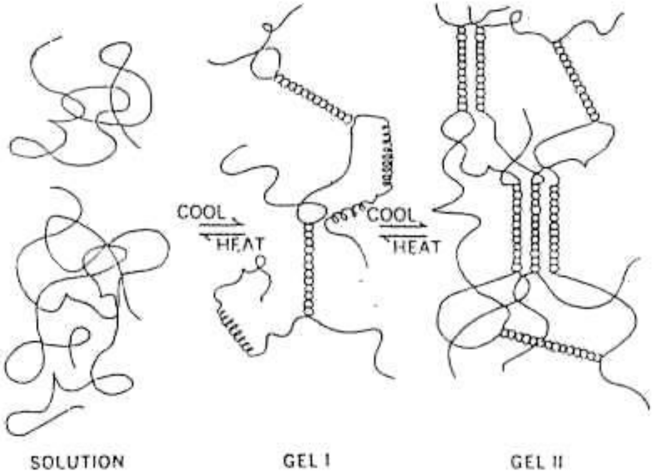


potato starches



Starch Properties: Retrogradation





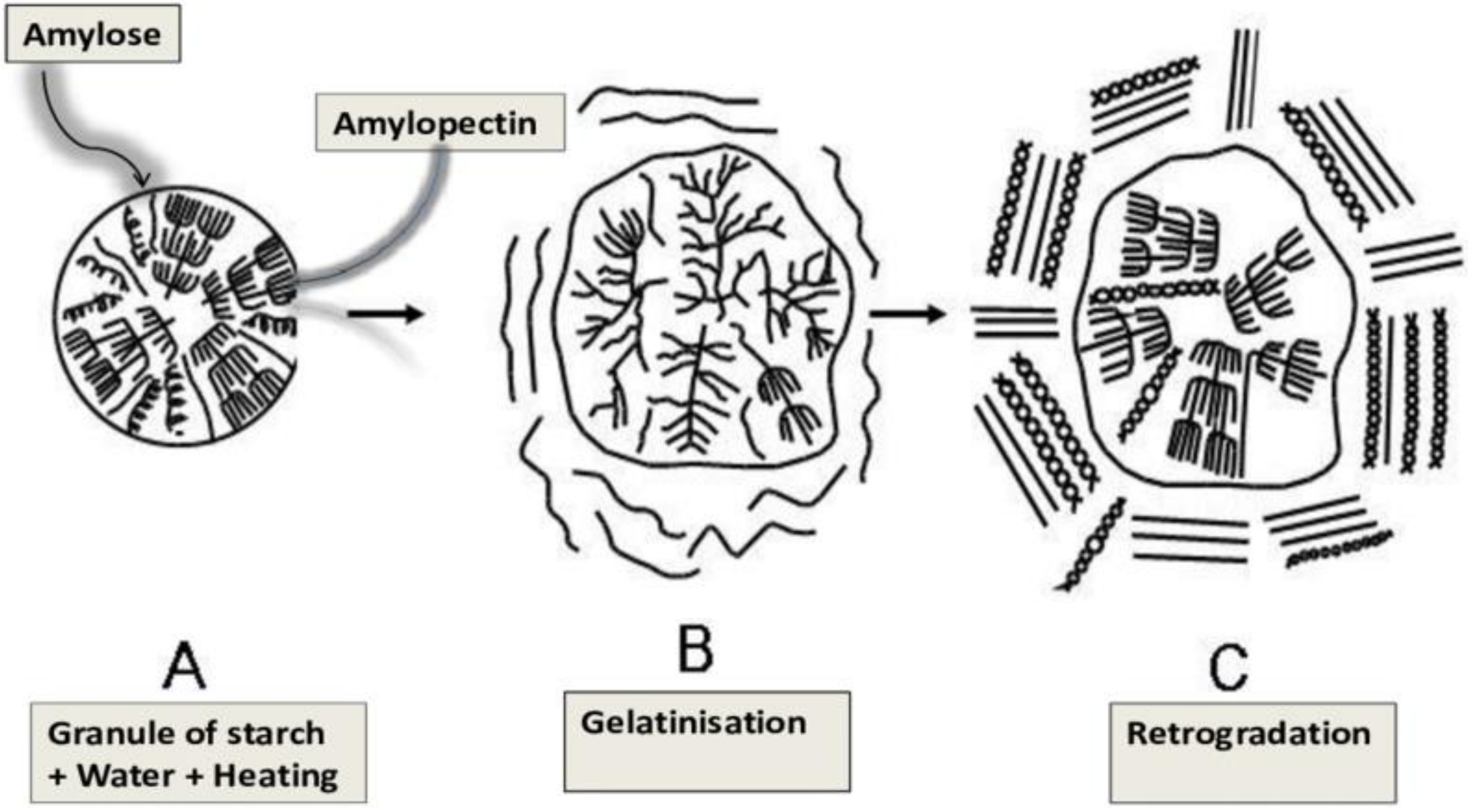
Hot

Cool

Upon cooling starch molecules tend to associate with other through helix formation and cross-linking, which leads to the reformation of crystalline structures over time.

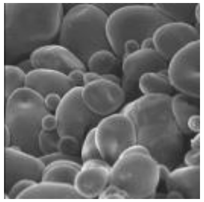
- Linked to staling in bread
- Helps form gels in cooled puddings, sauces, dips etc.
- Amylose retrogrades faster than amylopectin.

Starch Properties: Retrogradation



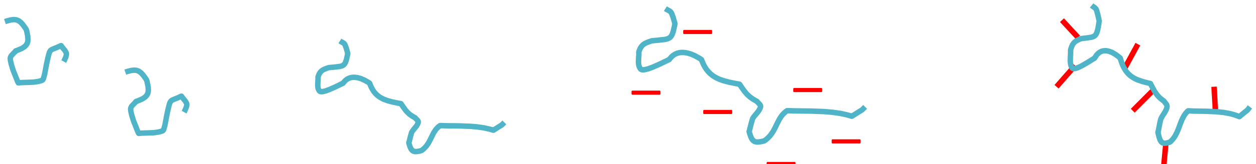
Retrogradation is a reaction that takes place when the amylose and amylopectin chains in cooked, gelatinized starch realign themselves as the cooked starch cools.

Starch: Modified Starches



Starches can be modified by a variety of physical, chemical or enzymatic processes to change their molecular, physicochemical and functional properties (at granular or molecular level)

Name	Process	Applications
Instant starches	Starch granules pre-gelatinized by heating in aqueous solutions	Cold water swelling starches used as thickeners in deserts, sauces, fillings and gravies
Cross-linked starch	Chemically cross link starches in granules	Reduces gelatinization and digestibility
Maltodextrin	Depolymerize by acids, bases or enzymes	Encapsulation, mouthfeel, water activity control
Starch derivatives – phosphates	Chemically attach phosphate groups	Increased viscosity pastes
Starch derivatives – hydroxylpropyl	Chemically attach acetyl or hydroxypropyl groups	Improved freeze-thaw stability, resistance to retrogradation
Starch derivatives – OSA	Chemically attach octenyl succinic anhydride (OSA) groups	Emulsifier in beverages
Oxidized starch	Oxidation using sodium hypochlorite or peroxide	improved adhesion in batters and breading.



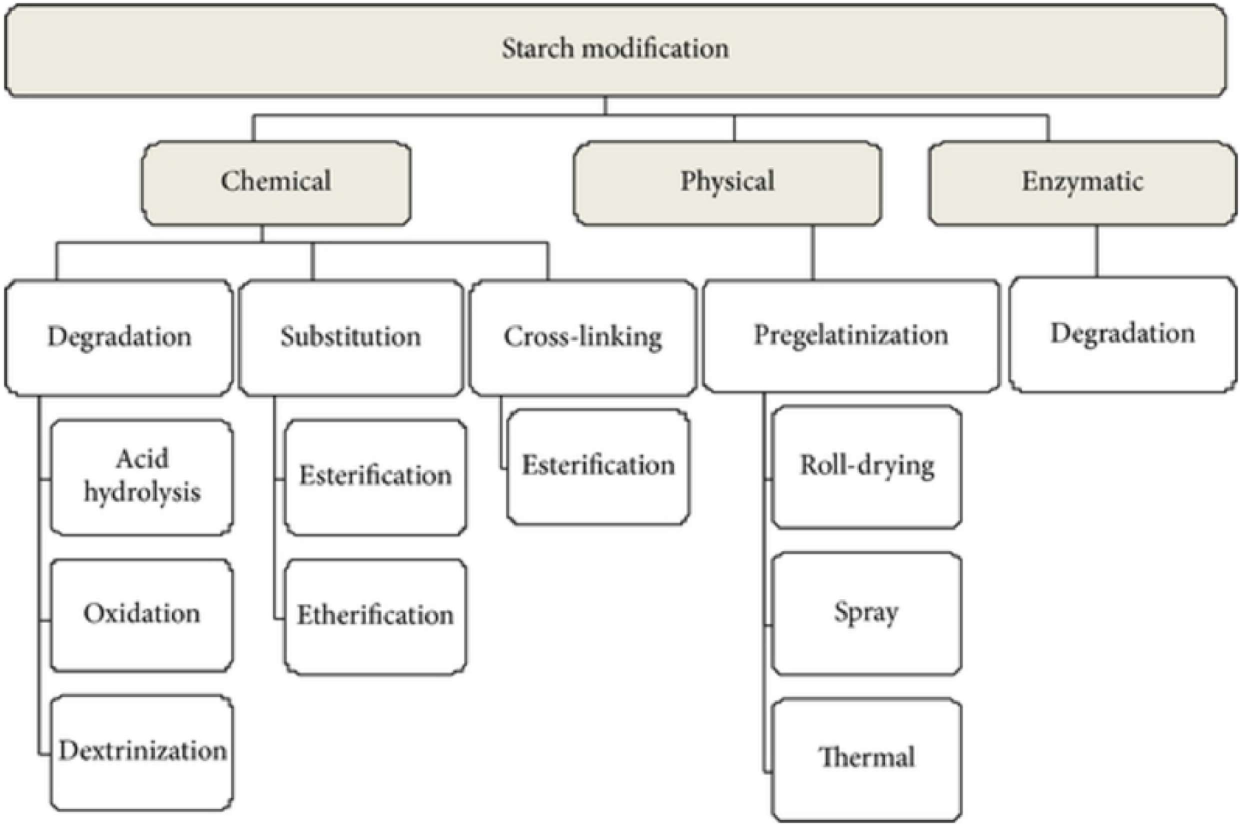
Other modification examples:

Esterification: Acetic anhydride, succinic a., acetic a., Adipic a., Phosphoryl chloride, sodium trimetaphosphate etc ...

Etherification: With propylene oxide

Acid modification: Hydrochloric a., Sulfuric a.,

Bleaching: Hydrogen peroxide, peracetic a., K-permanganate,



HYDROLYSIS OF STARCH

Starch can be hydrolyzed with acids or enzymes. Generally HCl is used in acid hydrolysis, and bacterial and fungal amylases of *Bacillus* and *Aspergillus* origin are used in enzymatic hydrolysis.

In acid hydrolysis, HCl is sprayed on the starch, which is thoroughly mixed. It is heated until the desired level of depolymerization occurs. Then the acid is neutralized, washed, dried. This substance is still in granular form.

$$\begin{array}{ccccc} \text{Starch} & & \text{Water} & & \text{Glucose} \\ n\,C_6H_{10}O_5 & + & n\,H_2O & \rightarrow & n\,C_6H_{12}O_6 \\ 162\text{g} & & 18\text{g} & & 180\text{g} \end{array}$$

$$\begin{array}{ccccccc} \text{Sucrose} & & \text{Water} & & \text{Glucose} & & \text{Fructose} \\ C_{12}H_{22}O_{11} & + & H_2O & \rightarrow & C_6H_{12}O_6 & + & C_6H_{12}O_6 \\ 342\text{g} & & 18\text{g} & & 180\text{g} & & 180\text{g} \end{array}$$

HYDROLYSIS OF STARCH

Maltodextrins are formed as a result of incomplete depolymerization. Maltodextrin level is defined in DE (dextrose equivalent) unit.

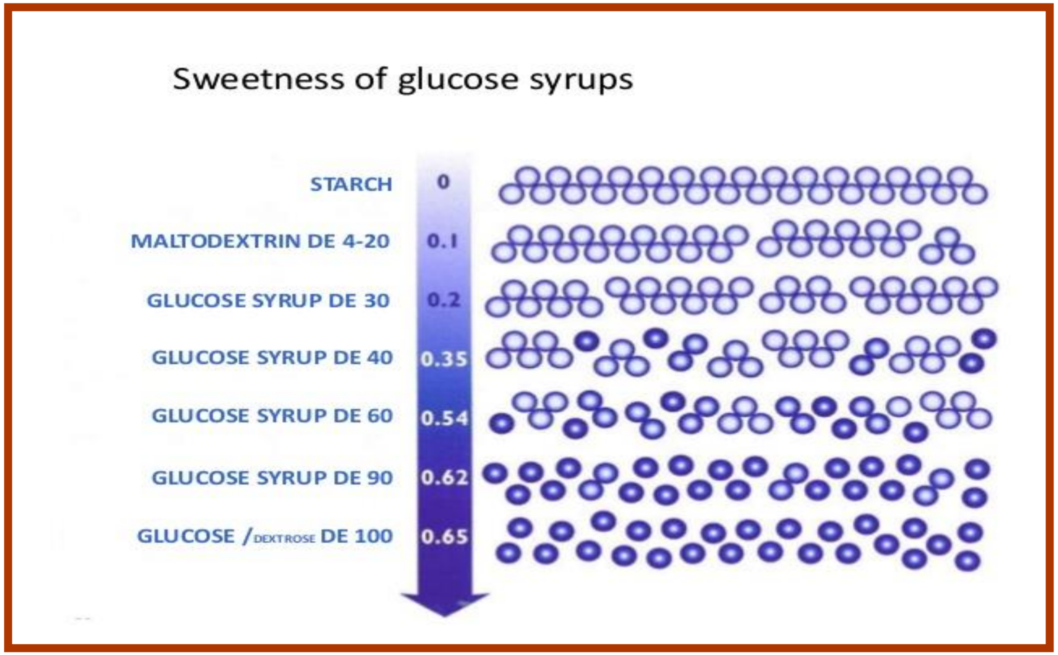
DE = The conversion level of starch to dextrose (D-glucose).

DE value

In starch: 0 For dextrose: 100

Those with DE = 20-60 are called solid corn syrup.

It dissolves quickly and is slightly sweet. (e.g. coffee creamer)



During hydrolysis, maltooligosaccharides such as maltose are formed. The most common syrup is DE = 42. Its dry matter is about 70%.

DP (degree of polymerization) indicates the number of monomeric units in the macromolecule.

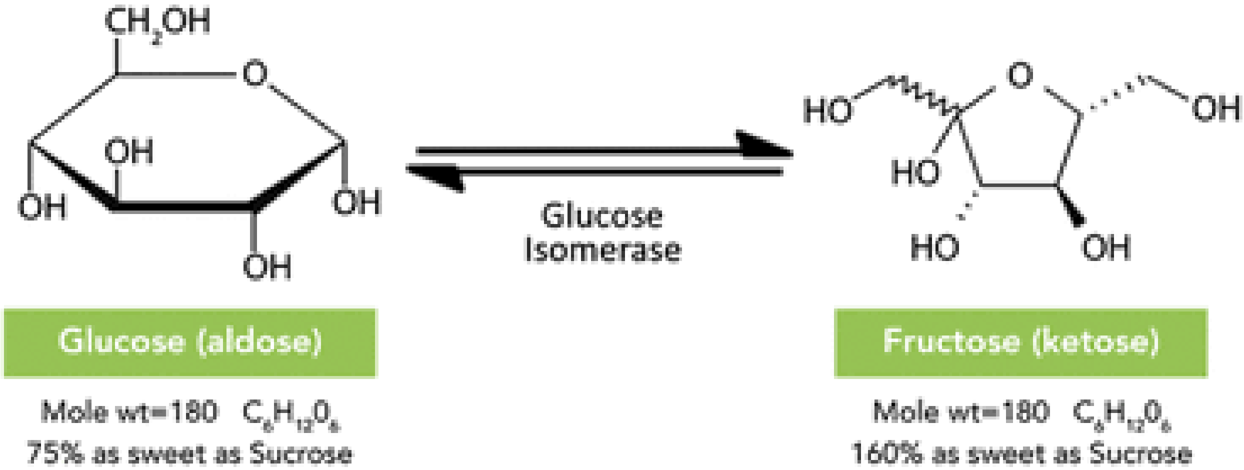
DP = Total molecular weight of macromolecule / molecular weight of monomer

for example

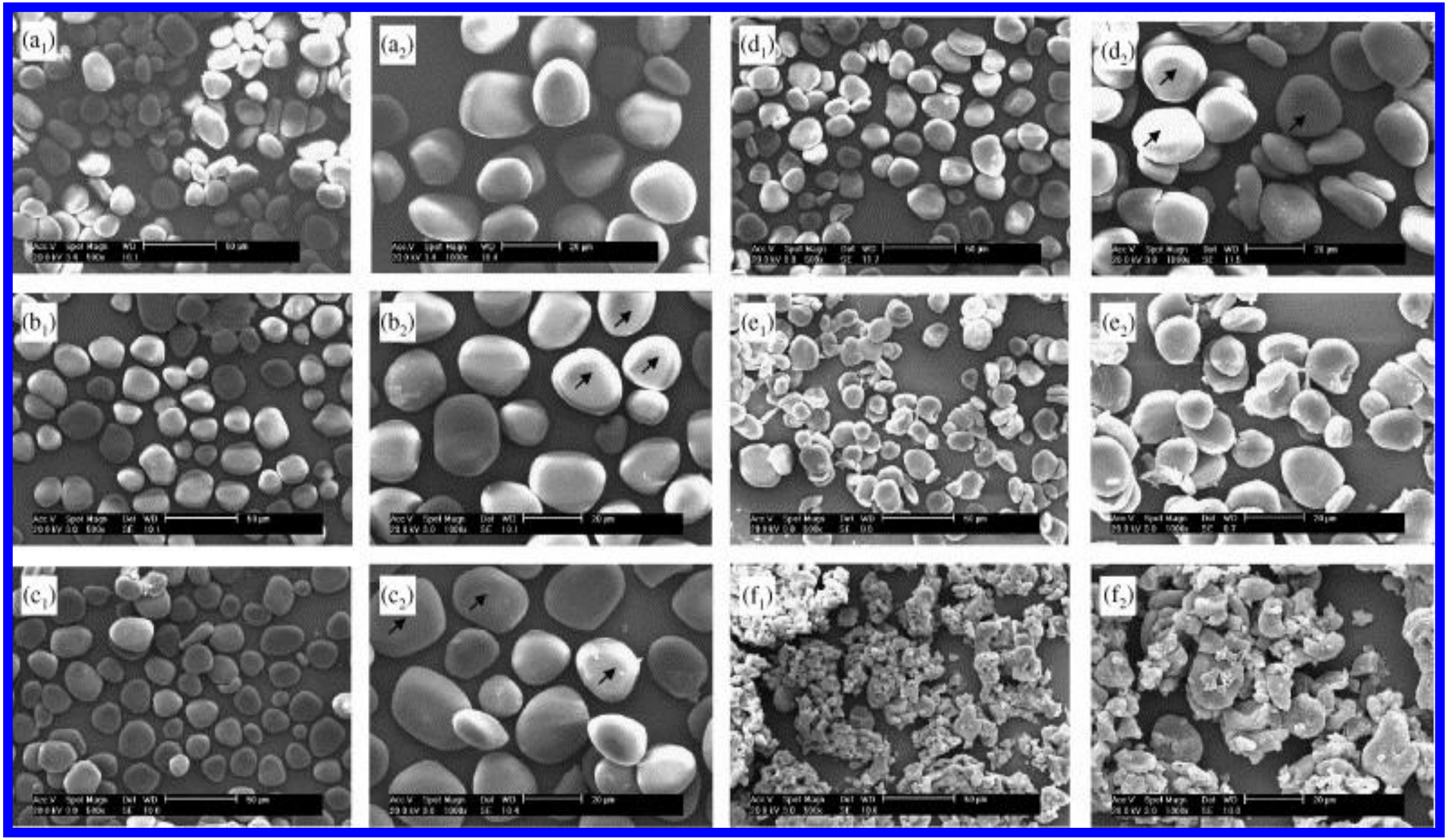
If amylose with a molecular weight of 10^7 *is completely hydrolyzed, DP = 10,000,000 / 180 = 55,555*

(Glucose MW=180)

The syrup obtained by hydrolysis is generally used in the food industry after glucose, which is mostly formed as a result of hydrolysis, is converted into fructose by glucose isomerase enzyme.

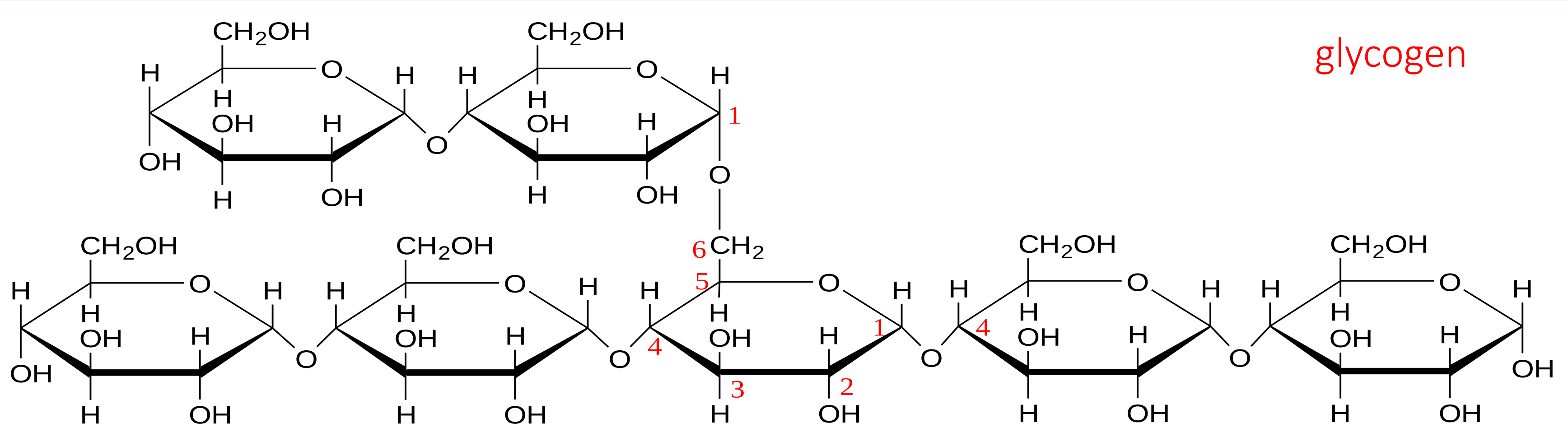


Untreated (a1 and a2) and treated starches (with acid for different durations)



GLYCOJEN

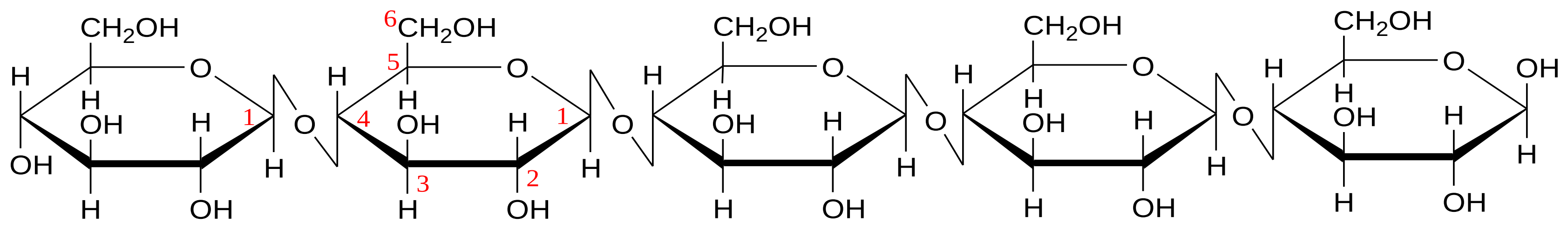
Glycogen is the glucose storage polymer in animal tissues and its structure is similar to amylopectin. The difference is that, the number of α(1→6) links is higher.



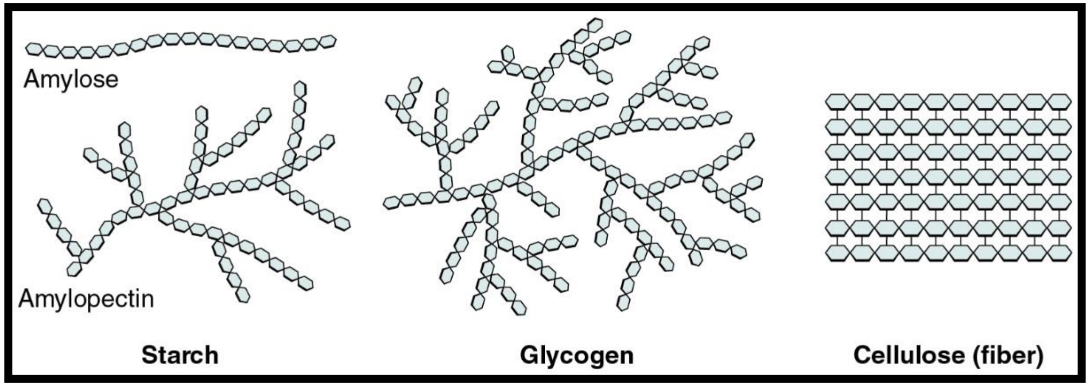
CELLULOSE

Cellulose is the main component of the cell wall and contains straight glucose molecules linked by β(1-4) bonds. With this bond, glucose folds over each other and forms filamentous structures.

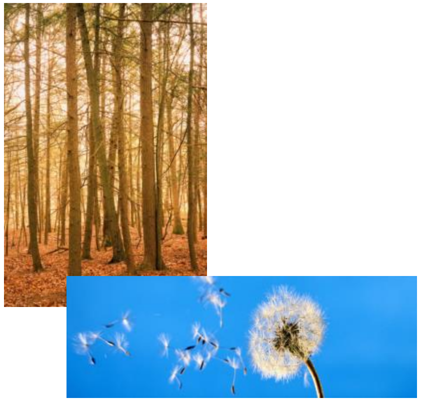
It is insoluble in water, but can be converted into gum substance by derivatization (such as CMC, MC). Cellulose and its modified forms are effective as dietary fibers because they are indigestible, calorie-free.



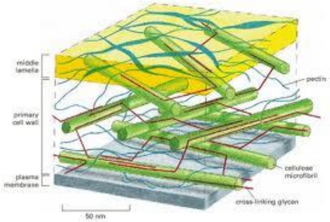
cellulose



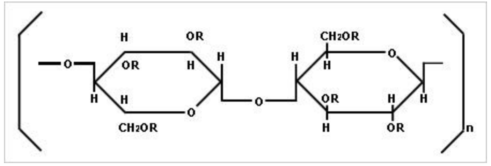
Cellulose & Derivatives



Origin: Cellulose normally comes from wood or cotton. Derivatives prepared by physical and/or chemical modification of cellulose



Chemistry: Native: β-1,4 linked glucose backbone. Derivatives: Charged, non-ionic or non-polar moieties

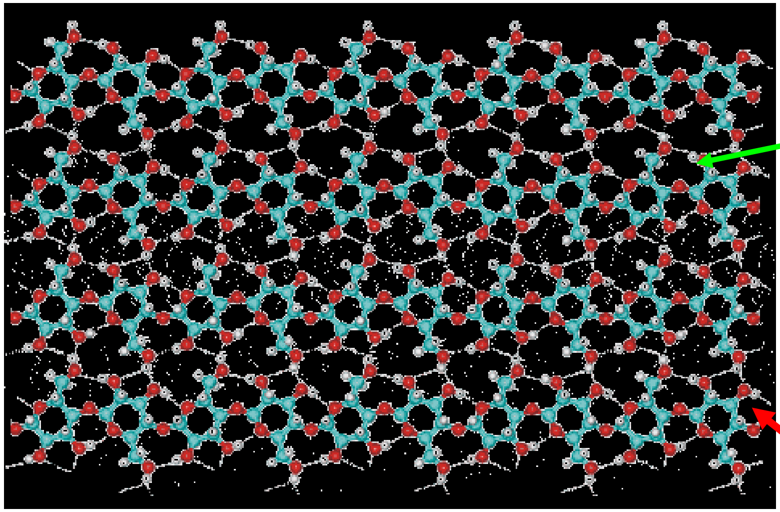


Molecular Structure: Neutral linear backbone with possible branches or side groups: MW ~ 350 to 2,500 kDa

Functions: Thickening Agents, Gelling Agents, Stabilizers, Bulking Agents, Emulsifiers

Cellulose Structure

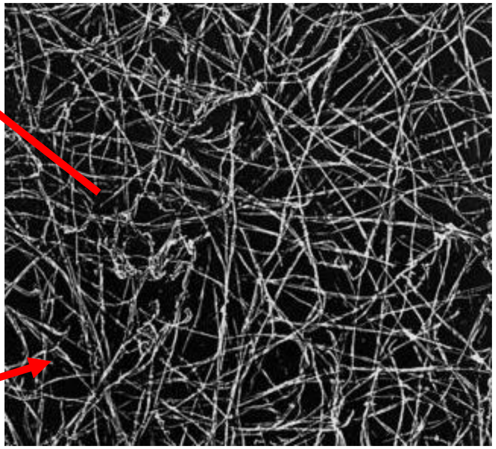
Native Cellulose



Strong H-bonding

Stronger than H-bonds in water so it is insoluble in water and hence, indigestible

Micro-fibrils

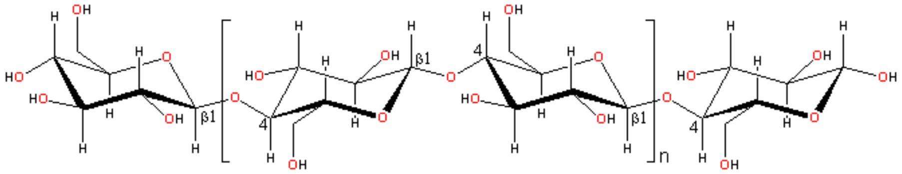


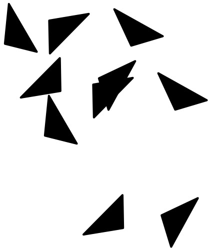
Properties:

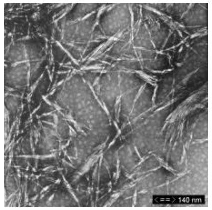
- Strong hydrogen bonding
- Insoluble in water

Cellulose Structure: Native & Modified Celluloses

Native Cellulose & Microcrystalline Cellulose (MCC)





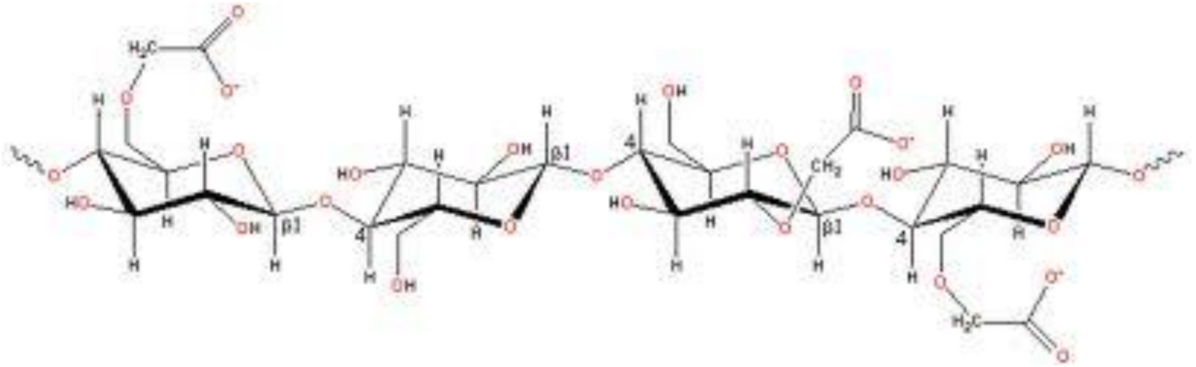


- Non-ionic
- Water insoluble

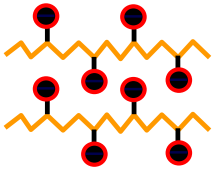
Microcrystalline cellulose (MCC) is formed by acid treatment (HCl) and mechanical disintegration of cellulose fibers to form small fragments. It is used as a filler, thickener agent, stabilizer, for mouthfeel, and fat replacer (opacity and texture) in processed foods. Comes in powdered or colloidal forms.

Cellulose Structure: Native & Modified Celluloses

Carboxymethyl Cellulose (CMC)



- Anionic
- Water soluble

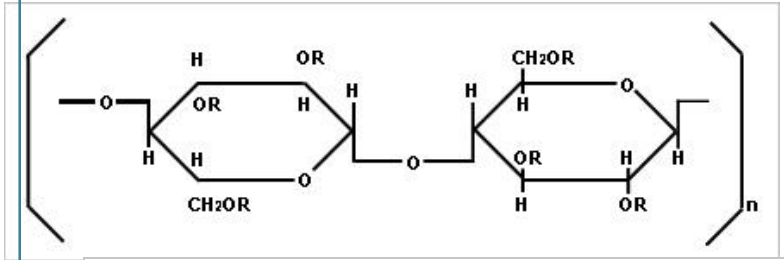


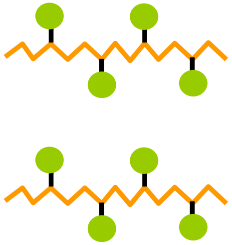
- Carboxymethyl cellulose (CMC or “Cellulose Gum”) usually comes as the sodium salt of cellulose that has been chemically modified to have anionic carboxylmethyl side groups attached. Usually comes as a white powder in a range of different molecular weights, particle sizes, and viscosities.

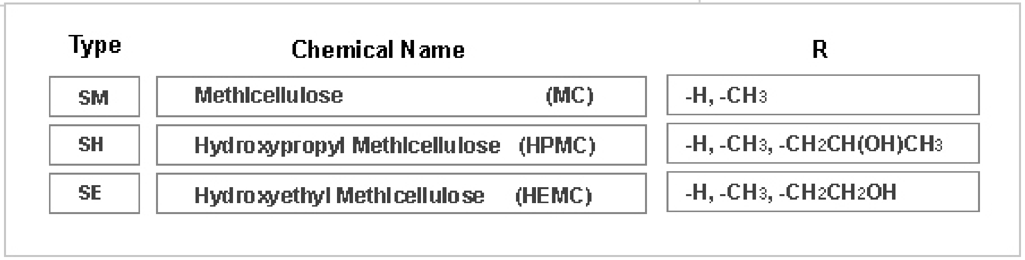
Cellulose Structure

Native & Modified Celluloses

Methyl Cellulose (MC)







Type	Chemical Name	R
SM	Methlcellulose (MC)	$-H, -CH_3$
SH	Hydroxypropyl Methlcellulose (HPMC)	$-H, -CH_3, -CH_2CH(OH)CH_3$
SE	Hydroxyethyl Methlcellulose (HEMC)	$-H, -CH_3, -CH_2CH_2OH$

- Non-ionic
- Water soluble
- Surface-active
- Thermo-gelling

- Methyl cellulose (MC) is formed by chemical derivatization of cellulose to have methyl side groups (which are non-polar). It is typically used as a thickener and emulsifier in many food products.

Applications

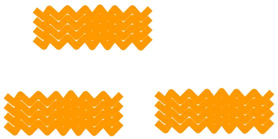
Modified Celluloses

Native Cellulose

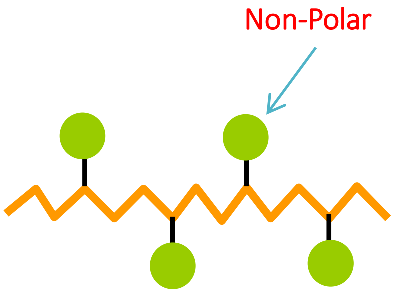
- Bulking Agent
- Water holding
- Anticaking (prevents the formation of lumps)

MCC

- Bulking Agent
- Texture Modifier
- Anticaking Agent
- Freeze-thaw Stabilizer

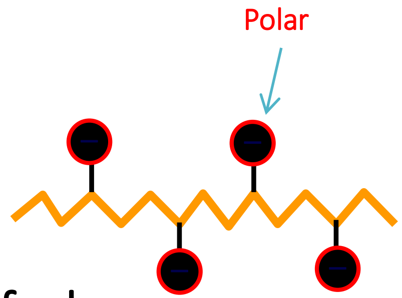


MC



- Thickening Agent
- Gelling Agent (heat setting)
- Emulsifier

CMC



- Thickening
- Gelling, Mouthfeel
- Freeze-thaw Stabilizer

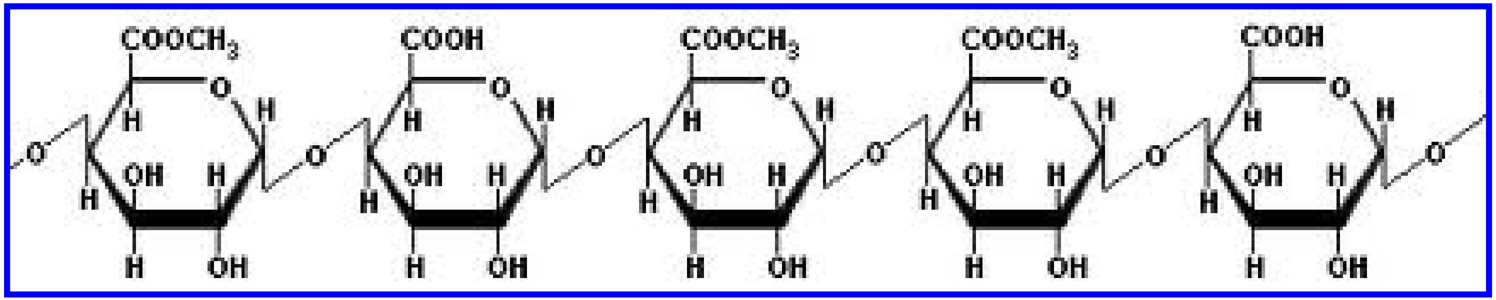
Products:

- Dressings, Sauces, Dips,
- Syrups & Deserts
- Meat Products
- Fillings, Toppings, Spreads
- Beverages

PECTIN

- It is the most widely used gum substance. It is the building material of the vegetative cell wall. In food industry it is produced from apple and citrus peels. It forms a <u>spreadable</u> gel in the presence of sugar and acid. Its composition varies according to the raw material used, production technique and subsequent processes. So, the word pectin refers to a group, not a compound.

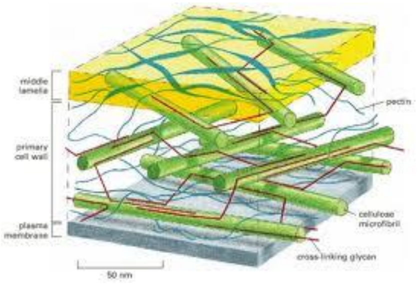
- Its main component is galacturonic acid, a sugar acid derived from galactose. Some galacturonic acids in its structure are esterified.



- If more than half of the carboxyl groups are esterified with methyl group(CH_3), they are called high methoxylated (HM) pectin (high methoxyl). The remaining carboxyl groups are in the form of free acid (COOH) and salt (eg COONa). If less than half of the carboxyls are methylated, it is called low methoxylated (LM) pectin.

- The level of methylation is indicated by the degree of esterification (DE) or the degree of methylation (DM).

Pectin: Origin & Applications

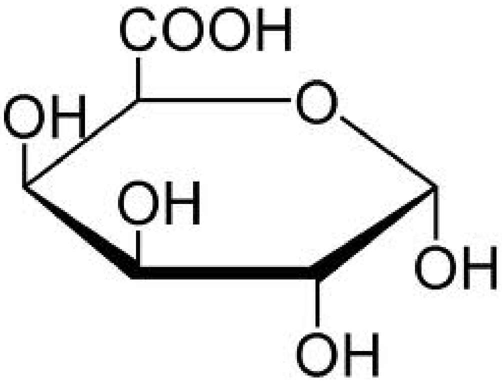


Origin: Obtained by aqueous extraction from certain edible plant materials, such as citrus fruits, apples and sugar beet

Molecular Structure: Anionic linear backbone with various neutral side chains, containing from a few hundred to a thousand saccharide units (MW ~ 50 - 150 kDa)

Functions: Gelling Agent, Thickening Agent, Stabilizer, WHC, (Emulsifier)

Chemical structure:
Polysaccharide backbone consists of galacturonic acid and galacturonic acid methyl ester linked by α-1,4 glycosidic linkages, with various neutral sugar side chains



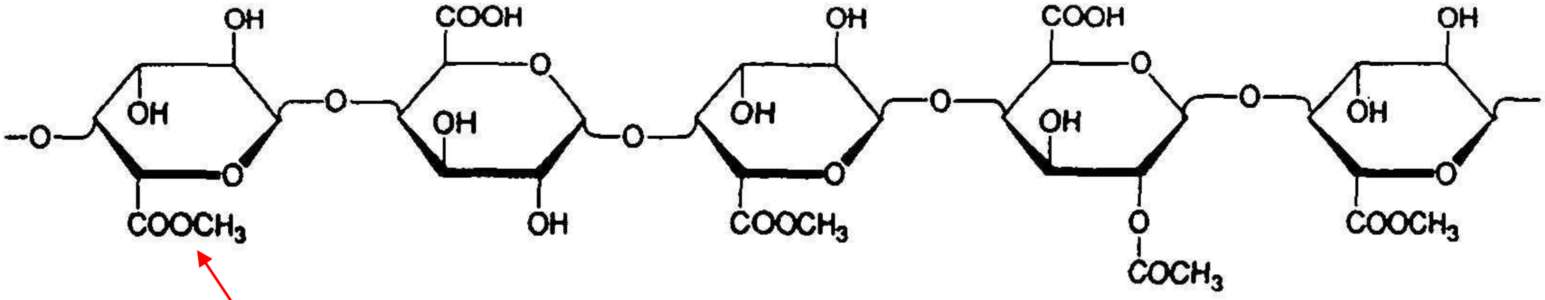
Galacturonic acid

Pectin:
Degree of Methyl Esterification

Backbone:

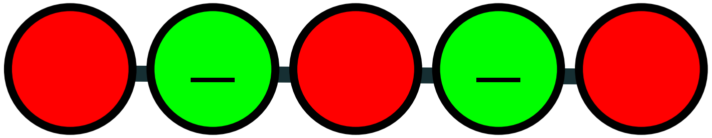
Carboxyl (negative group)

$-COO^{-} \leftrightarrow -COOH$



Methyl Esterified – Carboxyl

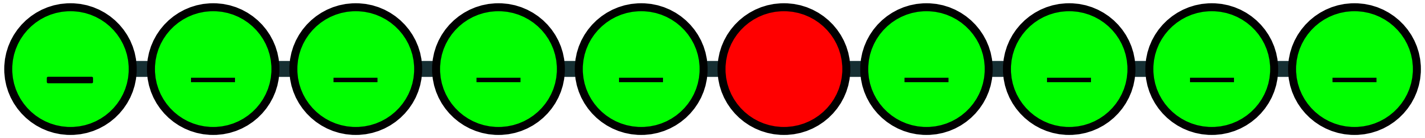
(neutral group)



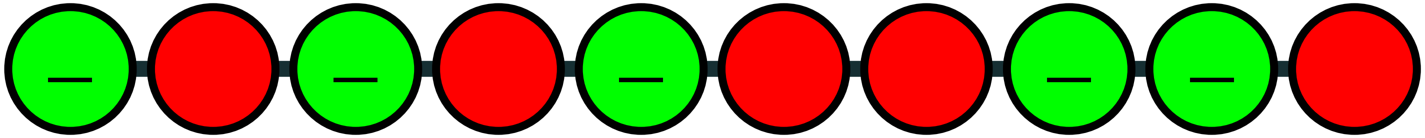
Pectin Structure:
Degree of Esterification (DE)

LM-Pectin

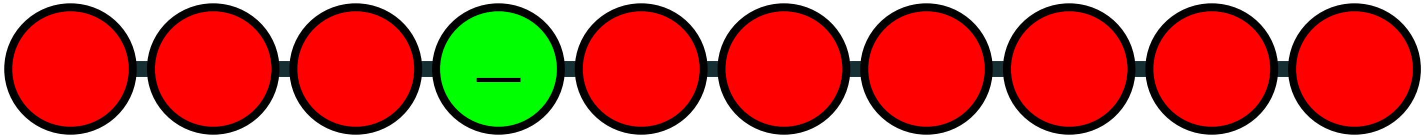
Low Esterification (e.g. DE = 10%)



Intermediate Esterification (e.g, DE = 50%)



High Esterification (e.g. DE = 90%)

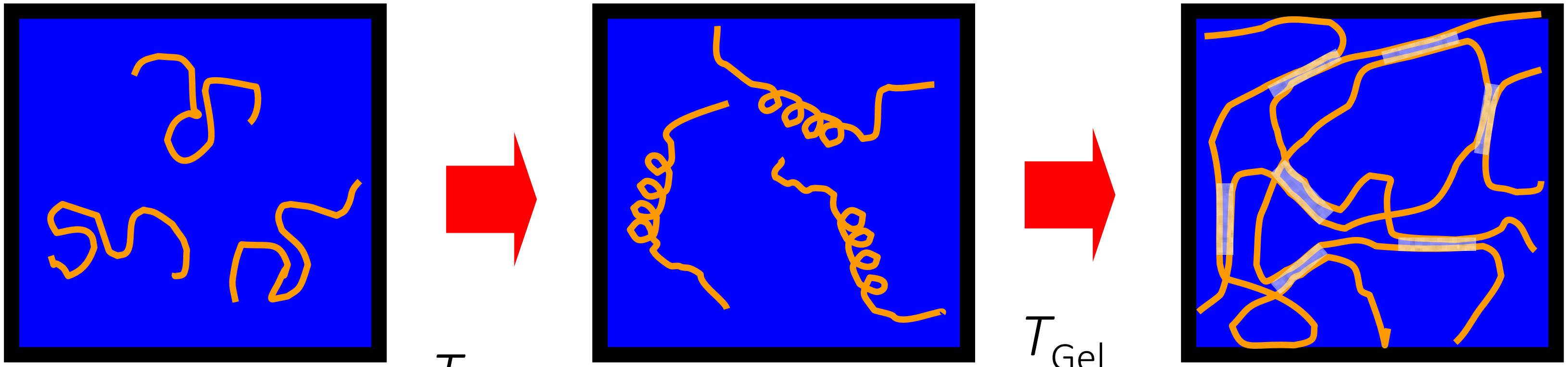


HM-Pectin

Pectin: Gelation Mechanism

High T

Low T



$T_{\text{C-H}}$

T_{Gel}

Random Coil
(Solution)

Helical
(Solution)

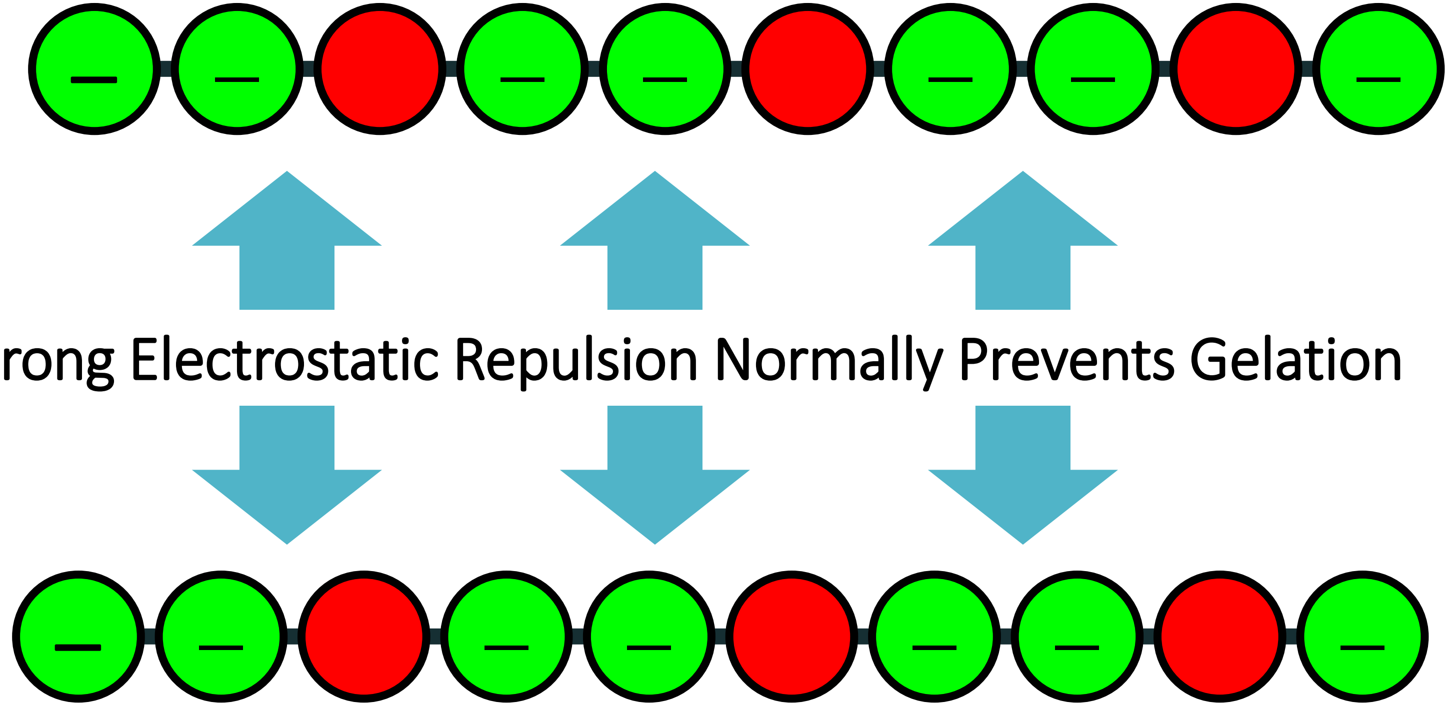
Cross-links
(Gel)

Very thin, transparent (jelly or jam)

Gel Properties:

- **Gelation Mechanism**: Acid/sugar (HMP) or Ca^{2+} (LMP)
- **Structure:** Filamentous - pectin molecules
- **Appearance:** Transparent - Thin structural units
- **Water Holding Capacity (WHC)**: Good - small uniform pores

Gelation Mechanism: Ionic - bridge

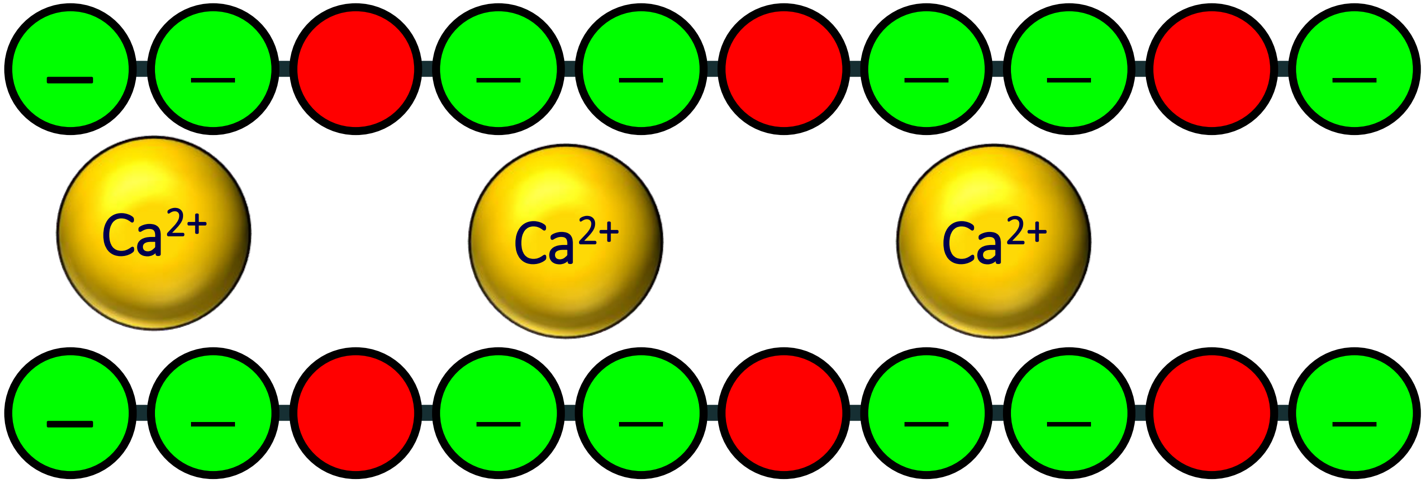


Strong Electrostatic Repulsion Normally Prevents Gelation

No gelation at low $[Ca^{2+}]$

LM-Pectin can only form gels by this mechanism

Gelation Mechanism: Ion Bridge



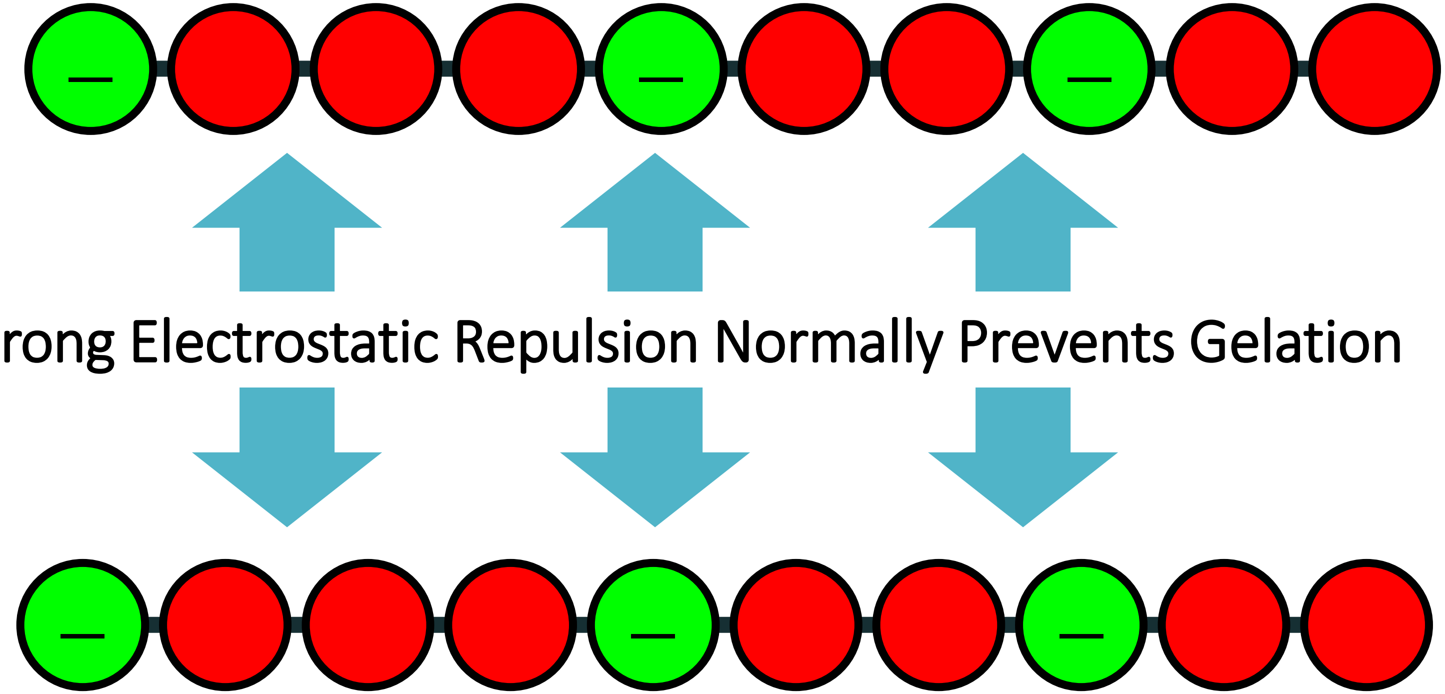
LM-Pectin Gels @ High [Ca^{2+}]

- Salt Bridge Formation

LM-Pectin Gels Characterized by:

- **Setting time** = Rapid or Slow set gels (rate increases as charge increases (DE decreases))
- **Gel strength**= Weak to strong gels (strength increases as charge increases (DE decreases))

Gelation Mechanism: Acid/Sugar

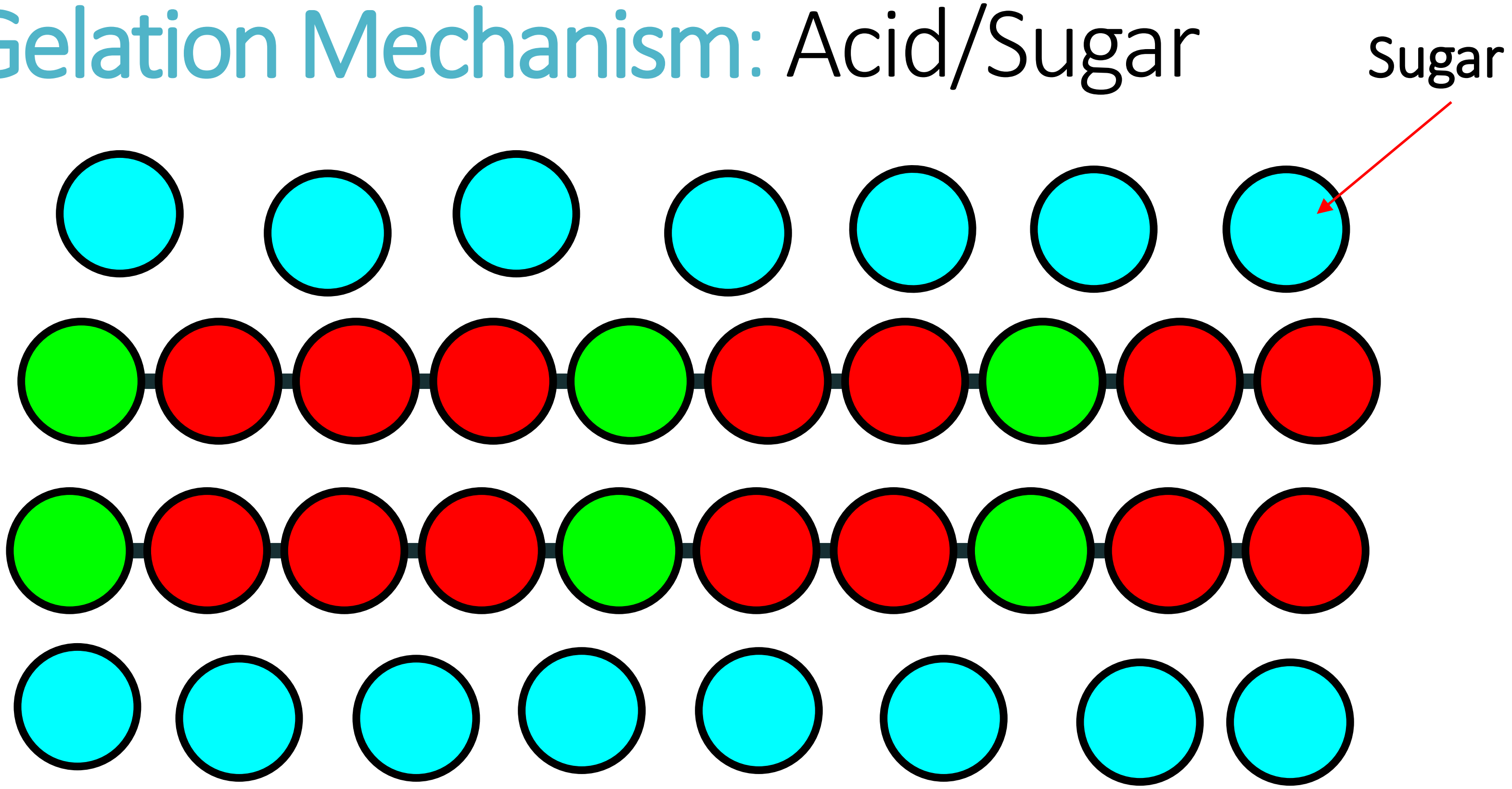


Strong Electrostatic Repulsion Normally Prevents Gelation

No gelation at high pH or low [sugar]

HM pectins do not form gels if there is not enough acid and sugar in the environment (ideal pH 2.8-3.5). LM pectins, on the other hand, do not require sugar for gelation and are therefore used in the production of low sugar jam-marmalade.

Gelation Mechanism: Acid/Sugar



HM-Pectin Gels @ High Sugar and Acid Conditions

- **Low pH** = Weak Electrostatic Repulsion
- **High Soluble Solids** = Strong Osmotic Attraction

HM-Pectin Gels Characterized by:

- **Setting time** = Rapid or Slow set gels (rate decreases as charge increases (DE decreases))
- **Gel strength**= Weak to strong gels (strength gets weaker as charge increases (DE decreases))

LM-Pectin does not gel by this mechanism

Pectins: Gelation Rate

Pectin Type	Methylation level	Amidation level	Common Description
High Methoxy	74-77	0	Ultra Rapid set
High Methoxy	71-74	0	Rapid set
High Methoxy	66-69	0	Medium Rapid set
High Methoxy	58-65	0	Slow set
Low Methoxy	40	0	Slow set
Low Methoxy	30	0	Rapid set
Amidated	35	15	Slow set
Amidated	30	20	Rapid set

If the pectin is treated with ammonia, some methyl ester groups (15-25%) turn into a carboxamide group. This is a type of LM pectin and is called **amidated** LM pectin.

The gelation rate (setting time) is important in many food applications, e.g., to prevent sedimentation.

Pectin Applications

Applications

- Thickening
- Gelling
    - High Soluble Solids (HM-Pectin)
    - Low Soluble Solids (LM-Pectin)
- Stabilization

Products

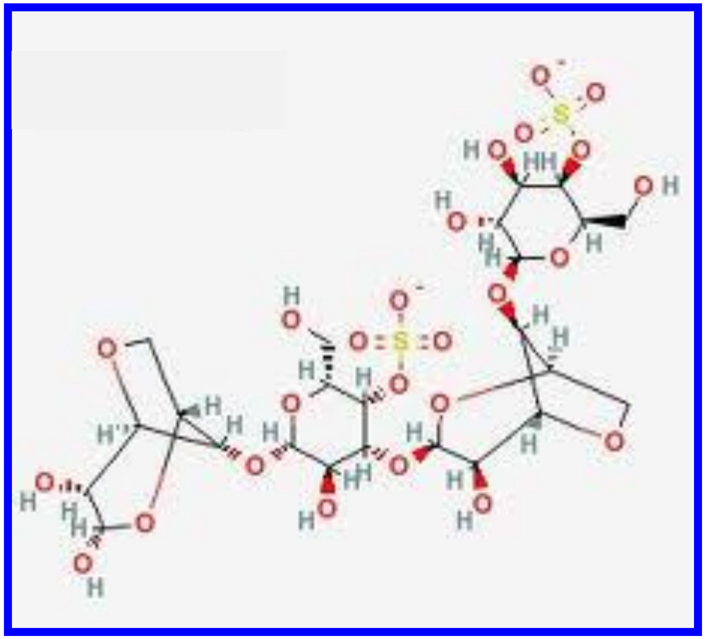
- Jams, Jellies, Sauces
- Fruit Juices & Drinks
- Fruit Yogurts & Deserts
- Confectionary

CARRAGENANS

The term carrageenans is used for sulfated galactans obtained from red seaweed.

Dilute alkalis are used in its extraction and the sodium salt of carrageenan is formed. Carrageenans are a mixture of different sulfated galactans (iota, kappa, and lambda forms).

They form high viscosity. It is effective over a wide pH range. **AGAR and FURCELLARAN (Danish Agar)** gums are also derived from red seaweed. These three gums are mainly used in bakery products to keep moisture in the structure (texture).



Carrageenan

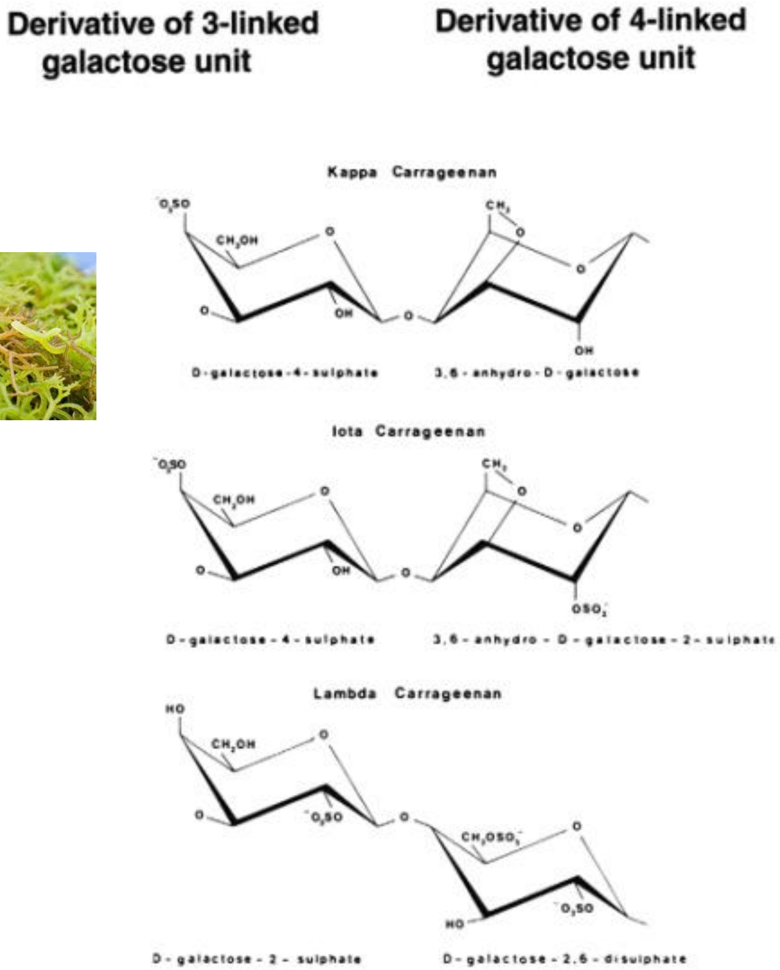
Origin: Obtained by aqueous extraction (neutral or alkaline conditions) from red seaweed (cell walls).

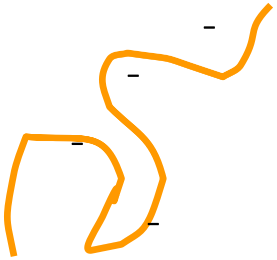
Chemistry: Polysaccharide backbone consists of various salts of sulfated esters of galactose and 3,6-anhydro-galactose linked by alternating α-1,3 and β-1,4 glycosidic linkages.

Molecular Structure: Anionic linear molecules, containing from a few hundred to a thousand saccharide units (MW ~ 50 - 150 kDa). Vary in conformation and charge density (sulfate groups).

Functions: Gelling Agents, Thickening Agents, Stabilizers, WHC

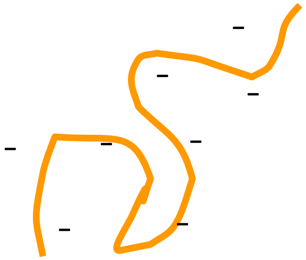
Carrageenan Types





κ-Carrageenan

- 1 sulfate/dissacharide
- Helical
- Gels with K^+



ι-Carrageenan

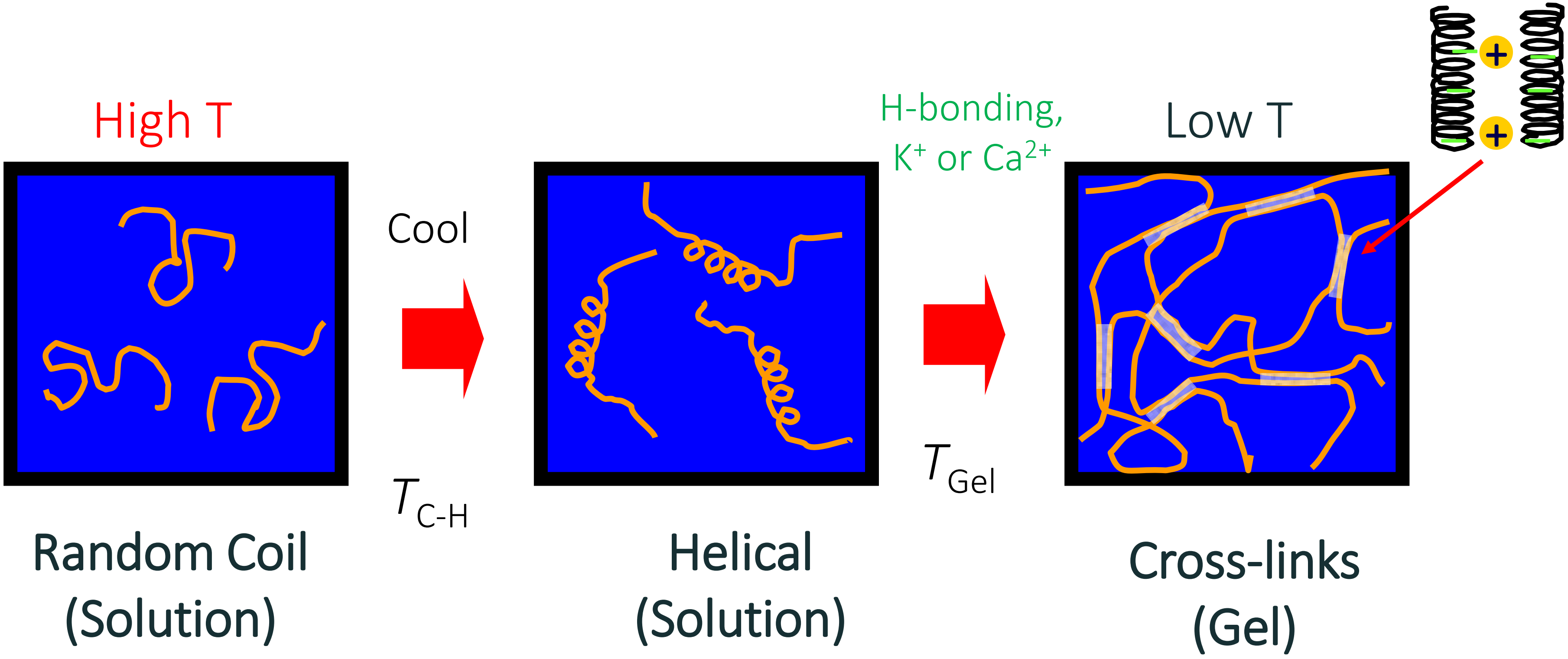
- 2 sulfates/dissacharide
- Helical
- Gels with Ca^{2+}

λ-Carrageenan

- 3 sulfates/dissacharide
- Ribbon like – no Helix formation
- Forms viscous, non-gelling solutions

Carrageenan molecules vary in their MW, linear charge density & conformation depending on biological origin and processing, which alters their functionality

Carrageenan: Gelation Mechanism



High T

Random Coil (Solution)

Cool

$T_{C\text{-}H}$

Helical (Solution)

H-bonding, K^+ or Ca^{2+}

T_{Gel}

Low T

Cross-links (Gel)

Gel Properties:

- **Gelation Mechanism:** Cooling, Coil-helix transition, Junction formation
  - *Hydrogen bonding (low charge, reversible), K^+ or Ca^{2+} (high charge)*
- **Structure:** Filamentous -Carrageenan molecules
- **Appearance:** Transparent - Thin structural units
- **Water Holding Capacity:** Good - small uniform pores

Carrageenan Applications

Applications

- **Thickening**
    - λ
- **Gelling**
    - Thermo-reversible
    - Cold-setting
    - K^+ or Ca^{2+}
- **Stabilization**
    - Sedimentation
    - Freeze-thaw
    - Protein particles

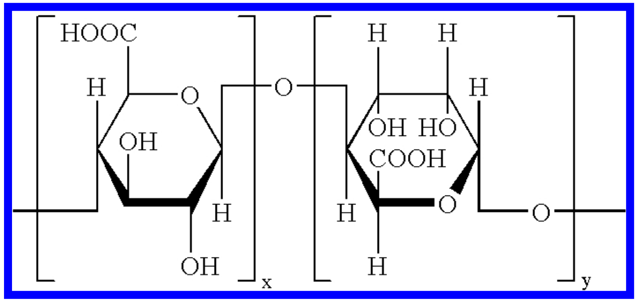
Products

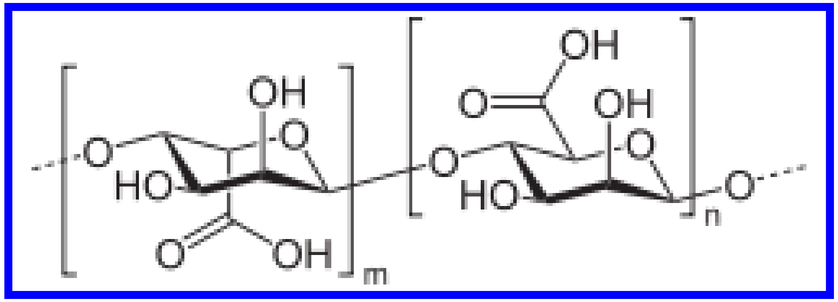
- Sauces, Dips, Dressings
- Processed Meats
- Dairy Beverages
- Yogurts & Deserts
- Baked Products

ALGINATE

Commercial alginate is the sodium salt of alginic acid. It is obtained from brown seaweed.

It consists of two monomeric units. ß-D-**m**annuronic acid and α-L-**g**uluronic acid). The ratio of the two monomers is not always equal. It may contain only one of these monomers (M blocks or G blocks). They form high viscosity at low concentration





Calcium salts of alginates are insoluble.

Alginate

Origin: Obtained by aqueous extraction from Brown Seaweeds

Chemistry: Polysaccharide backbone consists of G-blocks (α-1,4 linked poly-guluronic acid) and M-blocks (β-1,4 linked poly-mannuronic acid).

Molecular Structure: Anionic linear co-polymer containing from 50 to 100,000 saccharide units (MW ~ 10 – 18,000 kDa)

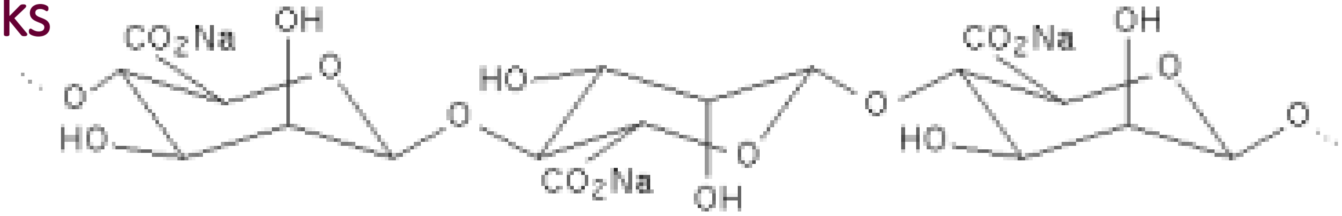
Functions: Gelling Agent, Thickening Agent, Stabilizer, Water Holding

Alginate Structure:

M-Blocks and G-Blocks

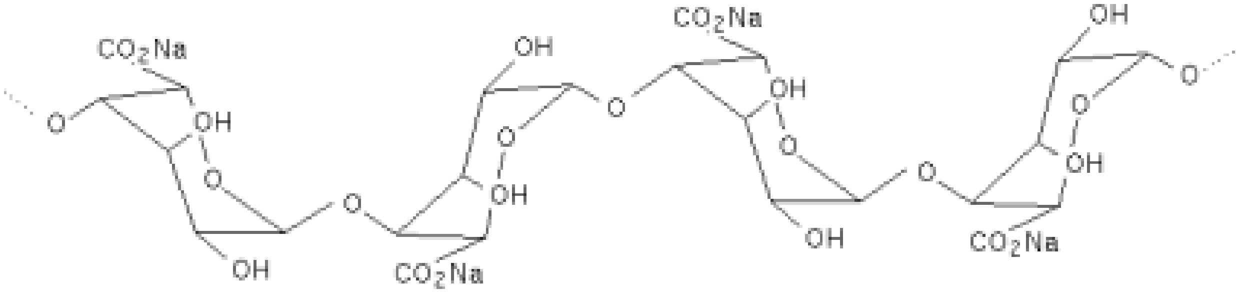
M-Blocks

- Poly-mannuronic acid
- β-1,4 links



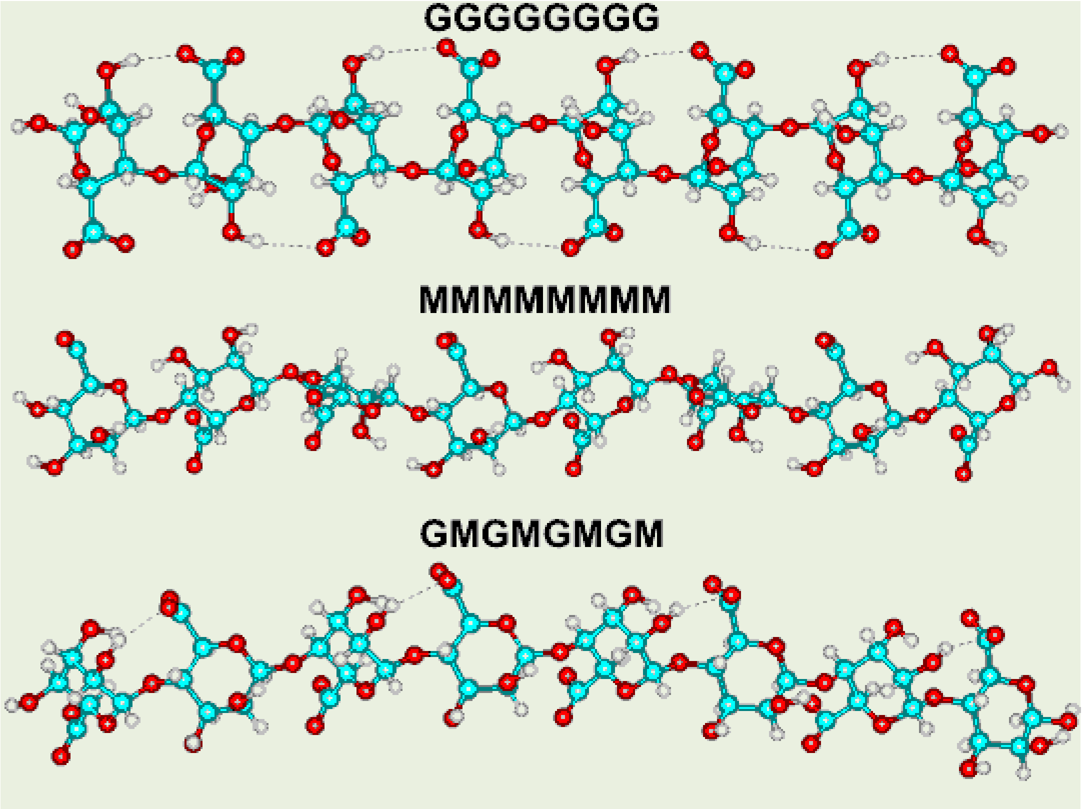
G-Blocks

- Poly-guluronic acid
- α-1,4 links
- Ca^{2+} binding



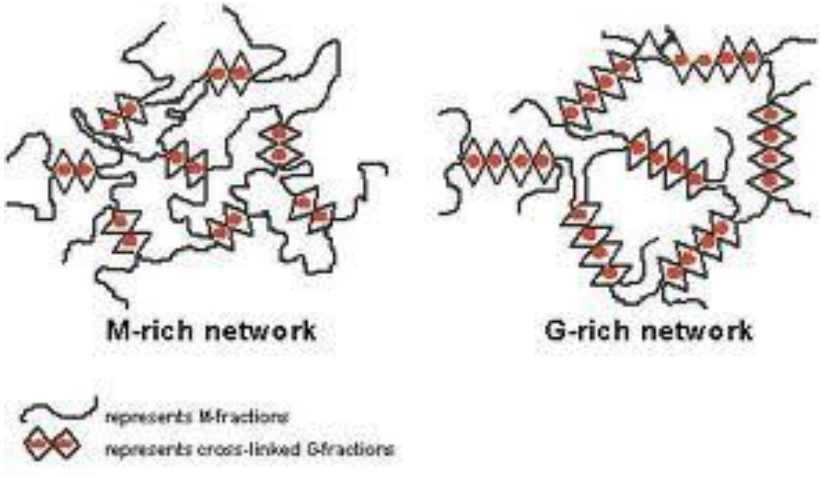
Alginate Structure:

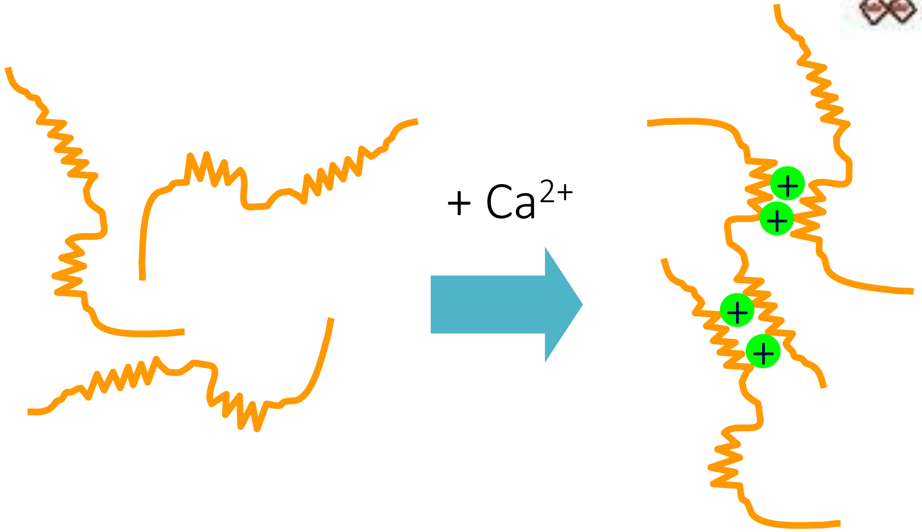
Blocks determine functionality



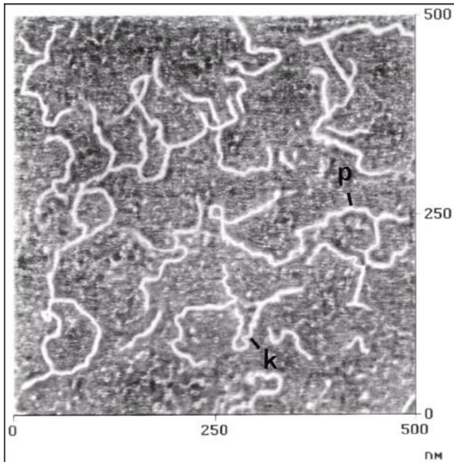
Calcium ions bind strongly to G-blocks, but only weakly to M-blocks, causing them to be zipped together – important for gelation

Alginate:
Gelation Mechanism





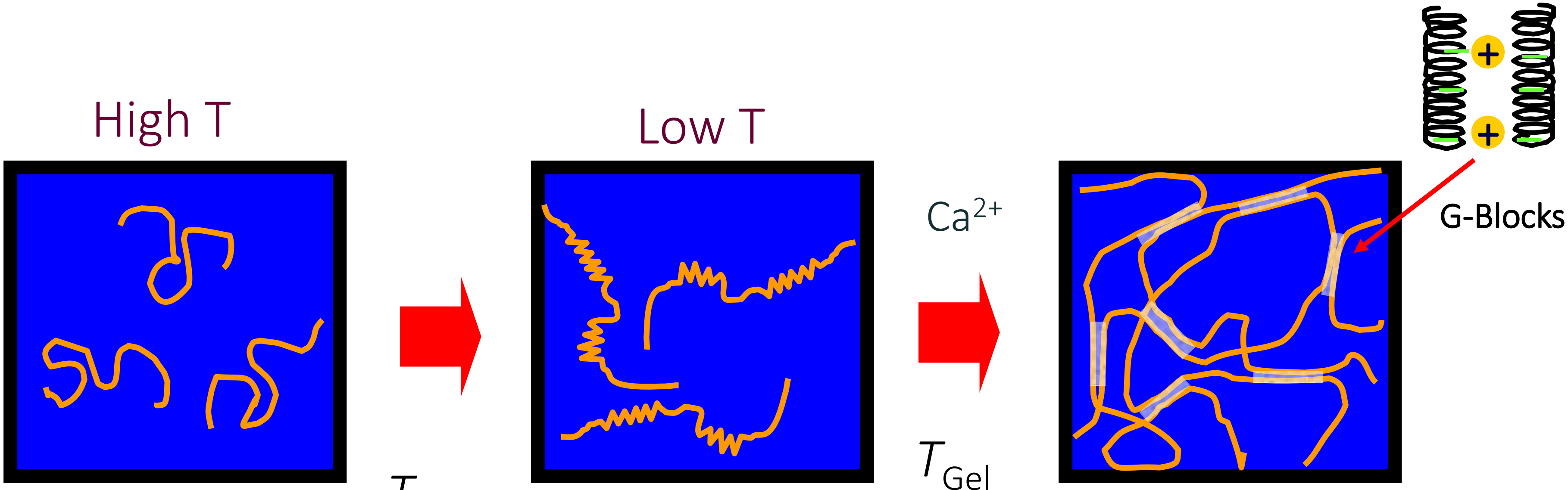
+ Ca^{2+}



Alginate Gels form due to Ca^{2+} cross-links of G-Blocks

- Gel strength increases with Poly-G content

Alginate: Gelation Mechanism



High T

Low T

Ca^{2+}

G-Blocks

$T_{C\text{-}H}$

T_{Gel}

Random Coil
(Solution)

Helical
(Solution)

Cross-links
(Gel)

Gel Properties:

- Mechanism: Cooling, Ca^{2+}, Irreversible
- Filamentous (alginate molecules)
- Transparent (Thin structural units)
- Good/Poor WHC

Depends on
M:G ratio

Calcium alginate gels do not melt below the boiling point of water, so will stay stable in hot foods.

Alginate Applications

Applications

- Thickening
- Gelling
  - Thermo-irreversible
  - Cold-setting
  - Ca^{2+} (G-block)
  - Hydrogen bonding
- Stabilization
  - Sedimentation
  - Freeze-thaw
  - protein particles

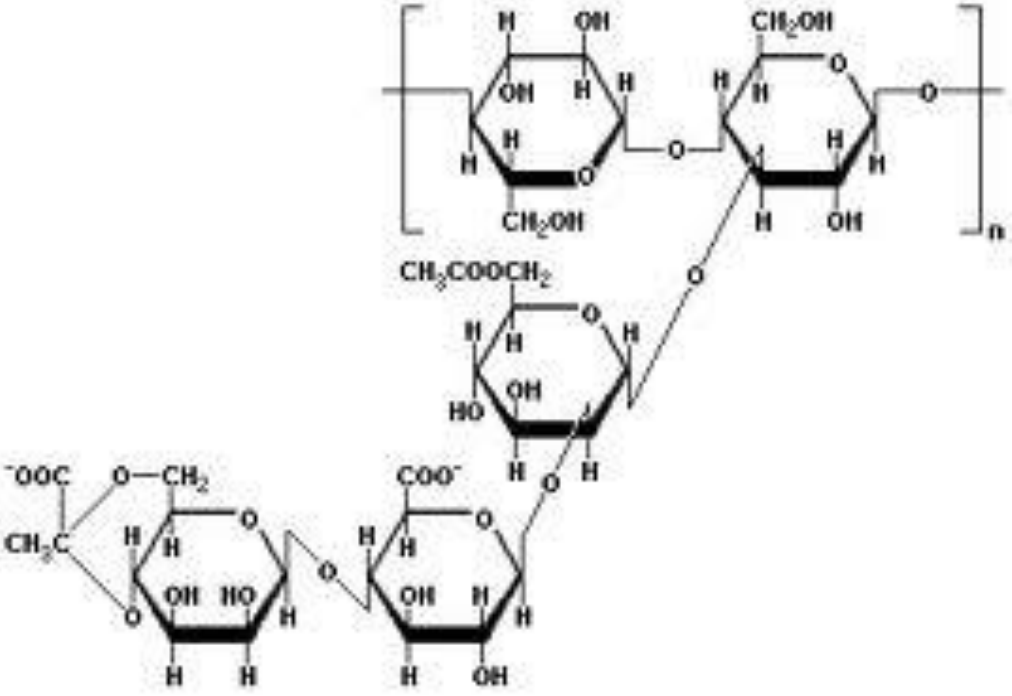
Products

- Jams & Jellies
- Sauces, Dips, Dressings
- Processed Meats
- Dairy Beverages
- Yogurts & Deserts
- Baked Products

XANTHAN GUM

It is produced by bacteria called *Xanthomonas campestris*. Production is carried out in fermentation tanks.

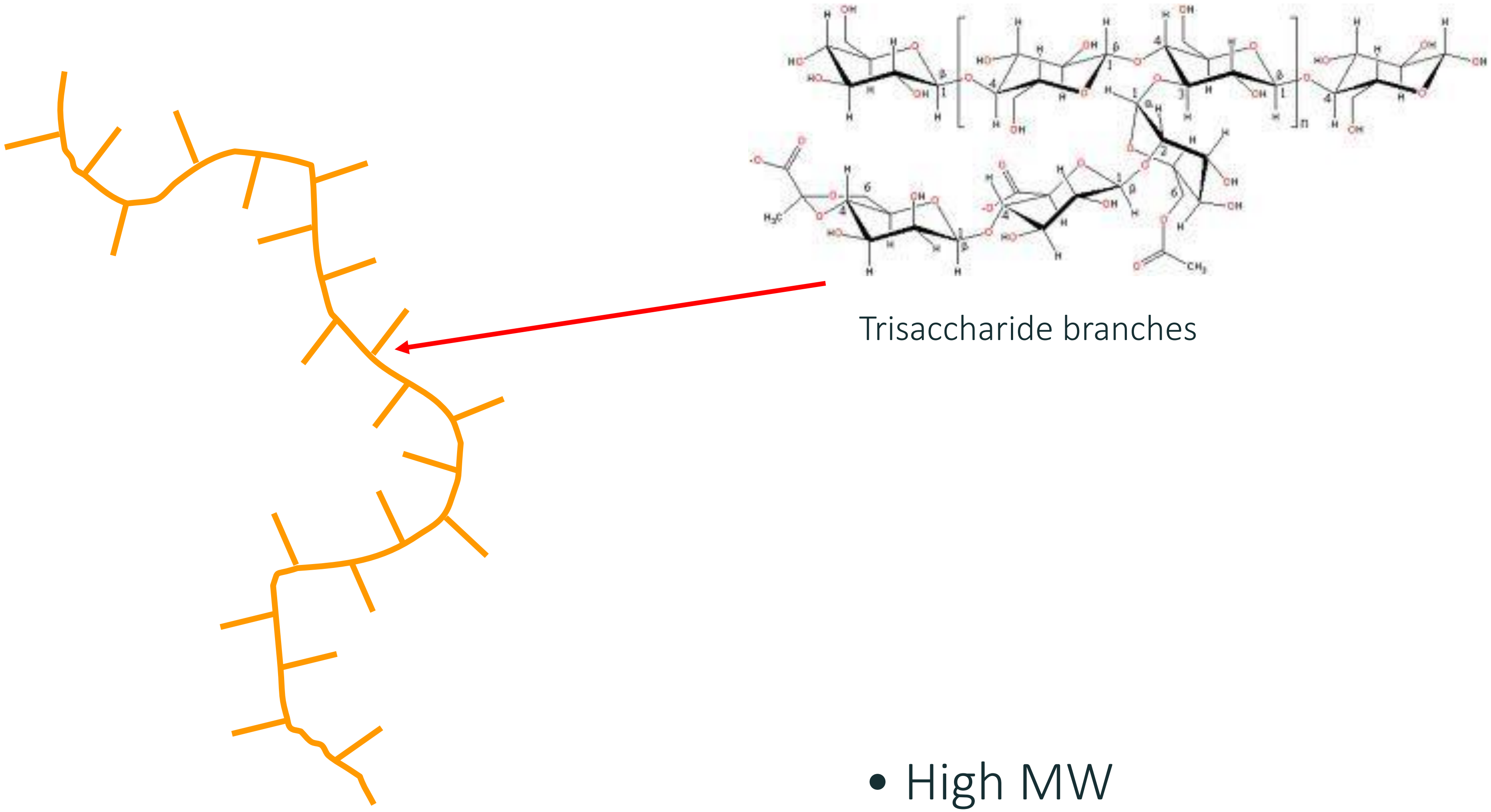
The main structure of the molecule is the same as cellulose. An acetylated trisaccharide unit is attached to this main skeleton in the O-3 position.



- It shows synergetic effect with **Guar gum**, viscosity increases.
- It is widely used in the food industry because it forms a gel in both hot and cold water.
- It gives high viscosity even at low concentration. Viscosity in the 0-100 ˚C temperature range does not change significantly. It is stable in acid systems, freezing and thawing do not affect the gel.

Xanthan Gum

Molecular Properties



Trisaccharide branches

- High MW
- Anionic

Xanthan Gum

Origin: Obtained by aerobic fermentation by specific bacteria (*Xanthomonas campestris*)

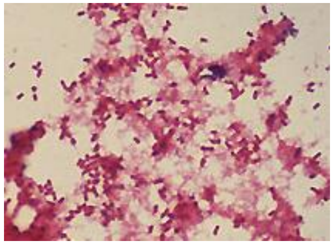
Chemistry:

Backbone: ß-1,4-linked D-glucose residues (similar to cellulose)

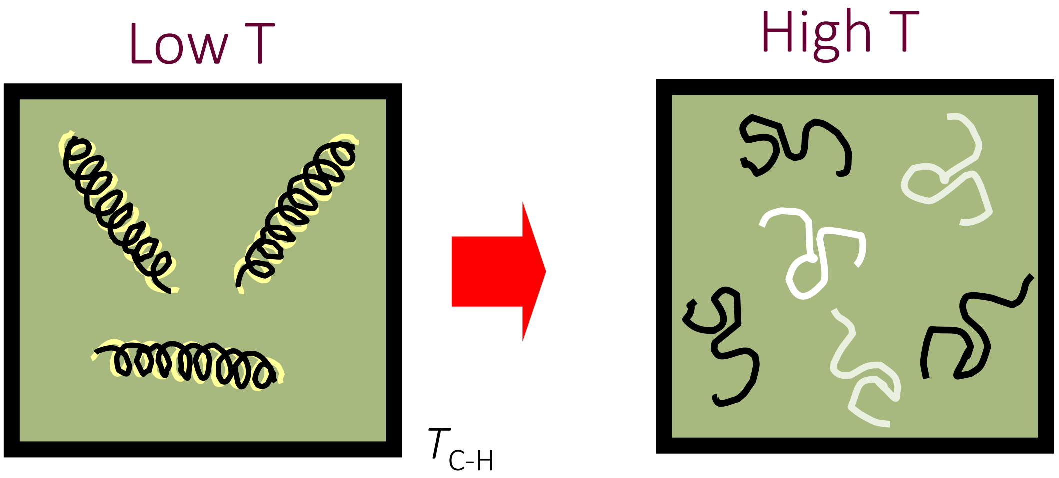
Side chains: Trisaccharide (mannose-glucuronic acid-mannose) linked to every other glucose unit at the number 3 position

Molecular Structure: High MW anionic polyelectrolyte with linear backbone and trisaccharide side chains (MW ~ 1000 kDa)

Functions: Thickening Agent & Stabilizer



Xanthan: Thickening Mechanism

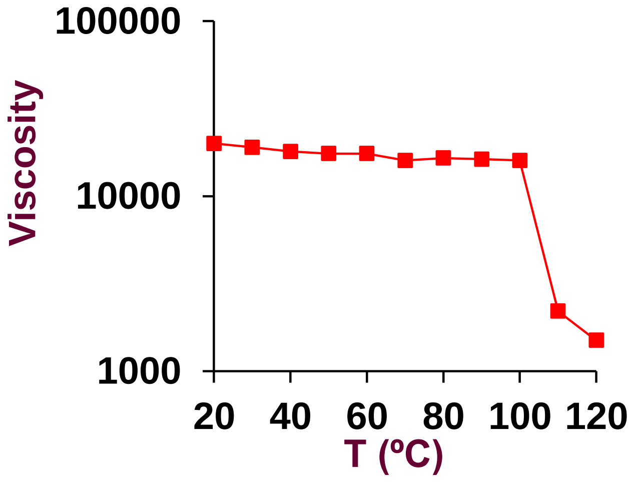


Double Helical
(Viscous solution)

Random Coil
(Solution)

Solution Properties:

- Highly Viscous
- Good Stability (T, I, pH)



Xanthan Applications

Applications

- Thickening
    - Stable to pH, I, T
- Stabilization
    - Sedimentation
    - Synersis
    - Freeze-thaw

Products

- Sauces, Dips, Dressings
- Beverages
- Processed Meats
- Powdered Products
- Deserts
- Baked Products




Seed Gums: Galactomannans

Locust Bean, Guar and Tara Gums

Origin: Extracted from cell walls of plant seeds

Chemistry:

- *Backbone:* ß-1,4-linked D-mannose residues
- *Side chains:* D-Galacatose (varying degrees of substitution)

Molecular Structure: Non-ionic linear backbone with monosaccharide side chains (MW ~ 80 – 250 kDa)

Functions: Thickening Agent & Stabilizer

GUAR, TARA and LOCUST BEAN (LBG) GUM

Guar gum: obtained from guar beans

LBG: It is obtained from carob seed.

Tara Gum: Peruvian carob

Guar is the gum that can give the highest viscosity. The main ingredient in all is galactomannan.

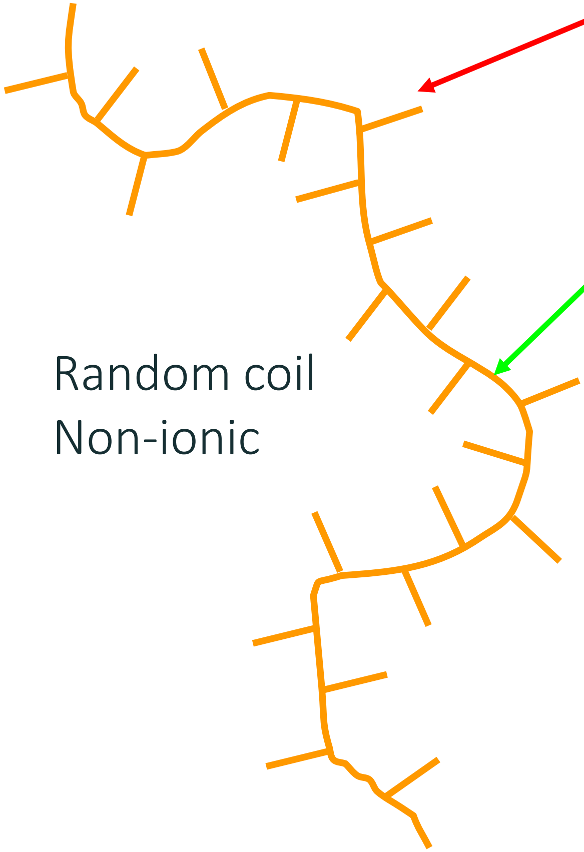
There is less branching in the structure of the LBG. The physical properties of all are different.

Guar gum is mostly used in combination with other gums (LBG, carrageenan, CMC). 85% of LBG produced in the world is used in the ice cream and frozen dessert industry.

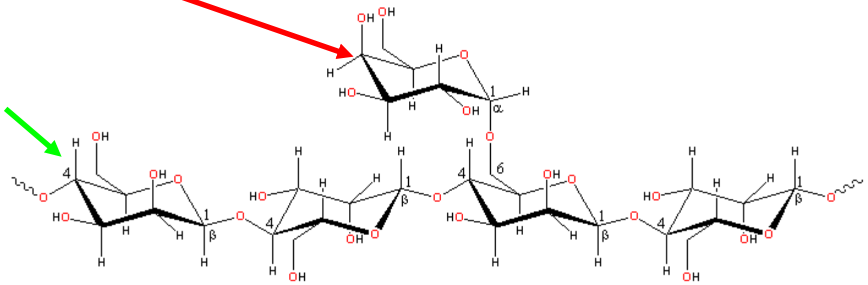
Galactomannans
Molecular Properties

Galactose
Side group

Mannose
Backbone



Random coil
Non-ionic



Gum	Man:Gal Ratio
LBG	3.5:1
Guar	1.6:1
Tara	1.3:1

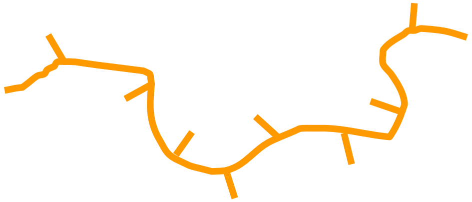
Water
Solubility
Increases

Galactomannans

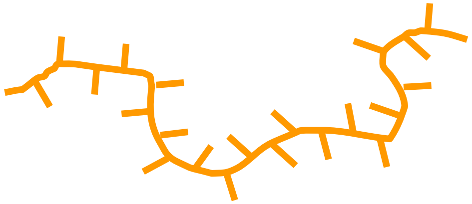
Functional Properties Depend on G:M Ratio

Crystalline

Mannan – Water Insoluble



LBG – Hot water



Random coil

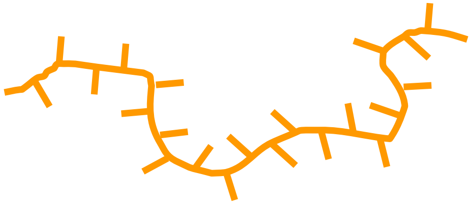
Tara – Cold water

Water
Solubility
Increases

Applications
Galactomannans

Functions

- Thickening Agents
- Water holding
- Stabilizers
- Synergism



Need to select ingredient with
appropriate G to M Ratio

Products:

- Dressings, Sauces, Dips, Soups
- Deserts
- Meat Products
- Frozen Foods
- Beverages

GUM ARABIC (ACACIA GUM)

ACACİA SENEGAL

It forms with the injury of the plant stem. **Karaya gam** and **ghatti gam** are similar to this. Gum arabic is a heterogeneous substance. It consists of two fractions:

1- Polysaccharide chain, 70% of the total

2- Protein fraction, it has a higher molecular weight.

<u>The approximate composition of the whole structure is as follows:</u>

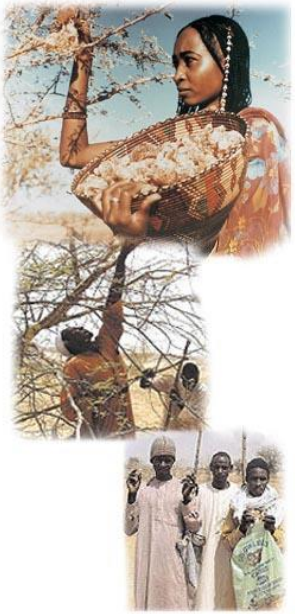
D-galactose 44%; L-arabinose 24%; D-glucuronic acid 14.5%;

L-rhamnose 13%; 4-o-methyl D-glucuronic acid 1.5%

It is easily soluble in water and therefore has a special place among the gums. It dissolves up to 50%. It is a very good emulsion stabilizer (especially in flavor oil in water emulsions). The mixture of essential oil + gum arabic can be spray-dried, thereby ensuring storage stability.

It is widely used in confectionery to prevent the crystallization of sugar, emulsify and disperse fatty compounds.

Gum Arabic



Origin: Prepared from exudate of sub-Saharan trees, *acacia Senegal* or *acacia Seyal*

Chemistry: Complex & variable mixture of arabino-galactan oligosaccharides, polysaccharides and glyco-proteins

Molecular Structure: Anionic polypetide backbone with linear polysaccharide branches: MW ~ 250 kDa (major) & 2,500 kDa (minor)

Functions: Emulsifier

Original use by tree: gum on tree holds in water if the tree is cut and protects the tree.

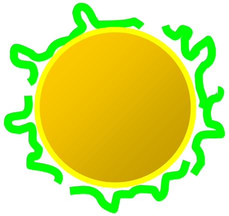
Gum Arabic Applications

Applications

- Emulsifier
    - Surface active
    - Film formation
    - Low viscosity
    - High solubility
- Coating Agent

Products

- Beverage & Flavor Emulsions
- Cereals, Confections, Snacks
- Baked Products
- Icings & Frostings



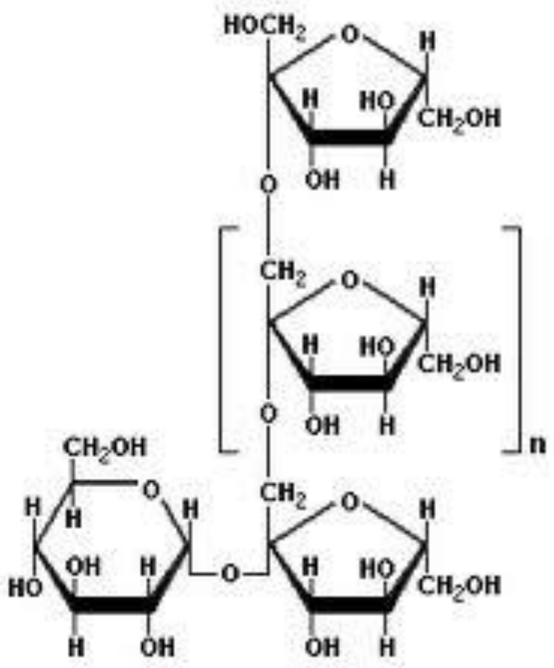
INULIN

It is found as storage carbohydrates in many plants (onion, garlic, asparagus, banana, leek). The main source is chicory roots and yams.

A solution of up to 50% can be prepared. Creates a creamy-oily texture. It cannot be digested by enzymes in the stomach and small intestine, so it is a part of dietary fiber. Its glycemic index is zero and it does not raise blood sugar.

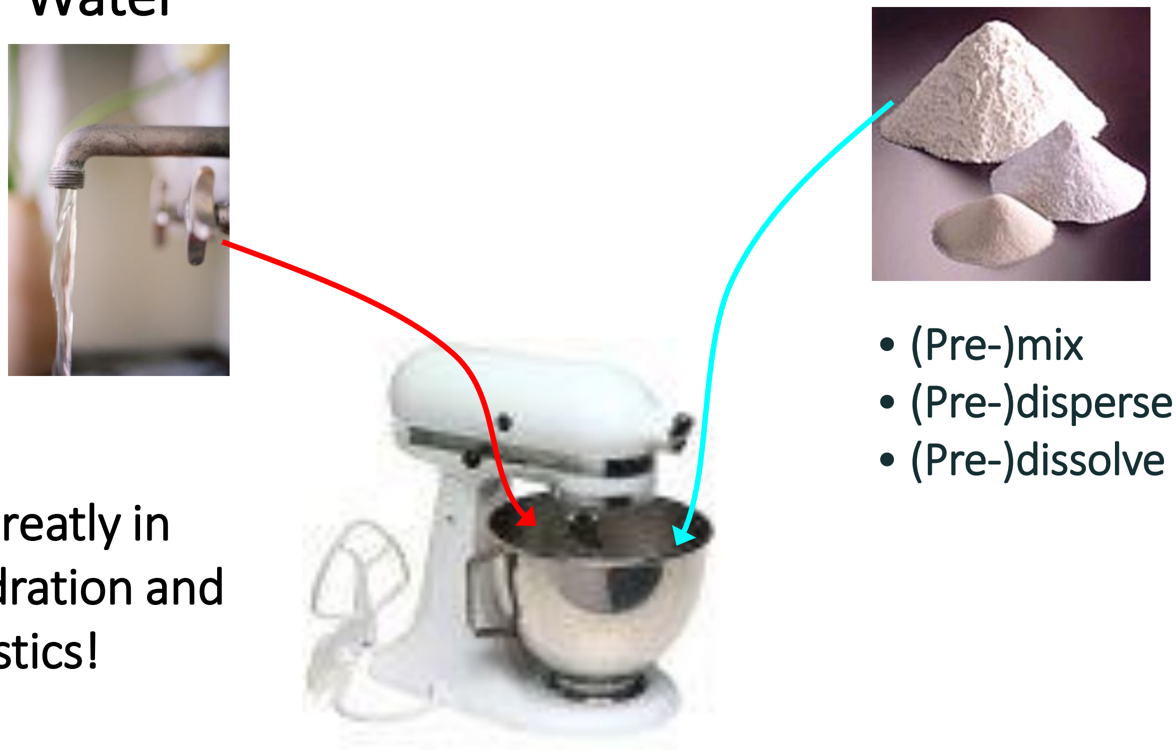
It consists of ß-D- fructofuranosyl units linked by 2-1 bonds.

chicory roots



yams

Dispersion Properties
Some Factors to Consider



Water

Biopolymer

- (Pre-)mix
- (Pre-)disperse
- (Pre-)dissolve

Biopolymers differ greatly in their dispersion, hydration and solubility characteristics!

Temperature, Time, Mixing Speed, Mixing Method, Order of Addition

Concluding Comments

Understanding the functional properties of food biopolymers (hydrocolloids) requires:

An appreciation of the general principles of polymer science

An appreciation of the unique structure, chemistry and behavior of each specific biopolymer

Amylose

Amylopectin