Food gums
Food gums--A definition

- Non-starch, non-pectin carbohydrate polymers derived from land or sea plants, or microorganisms
  - Some representative gums include algin, furcellaran, ghatti, karaya, psyllium seed, tamarind, xanthan, dextrans, modified celluloses, arabic, tragacanth, locust bean, guaran, agar, and carrageenan
Search for a clean label

HONEY, PASS ME THAT BAG OF PROPYLENE GLYCOL ALGINATE.

THAT'S NOT HOW MY MOM USED TO MAKE 'EM!

FLOUR, STARCH, CHOCOLATE & BUTTER...

INGREDIENTS WE KNOW AND LOVE... JUST LIKE WE'D FIND IN OUR CUPBOARD.
Gums--Food functions

• Principally gums do their jobs by controlling the structure and mobility of liquid water

• Gums can
  – alter water retention
  – reduce water evaporation
  – alter water freezing rate
  – modify ice crystal formation
  – participate in chemical reactions
Gums--Food functions

- Gums can control or determine the texture of many food products
Gums--General functions

- **Thickening**
  - All gums do this to some extent

- **Gelling**
  - Only a few gums (agar, algin, carrageenan, etc.) can do this
Gums--Specific functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesive</td>
<td>Bakery glaze</td>
</tr>
<tr>
<td>Crystallization</td>
<td>Ice cream</td>
</tr>
<tr>
<td>inhibitor</td>
<td></td>
</tr>
<tr>
<td>Cloud agent</td>
<td>Fruit juice</td>
</tr>
<tr>
<td>Emulsifier</td>
<td>Salad dressings</td>
</tr>
<tr>
<td>Film former</td>
<td>Sausage casings</td>
</tr>
<tr>
<td>Foam stabilizer</td>
<td>Beer, whipped toppings</td>
</tr>
<tr>
<td>Function</td>
<td>Application</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Gelling agent</td>
<td>Puddings</td>
</tr>
<tr>
<td>Suspending agent</td>
<td>Chocolate milk</td>
</tr>
<tr>
<td>Syneresis inhibitor</td>
<td>Cheese, frozen foods</td>
</tr>
<tr>
<td>Thickening agent</td>
<td>Sauces, gravies</td>
</tr>
</tbody>
</table>
Factors affecting gum properties

- Concentration
- Temperature
- Degree of dispersion
- Solvation
- Electrical charge
- Previous thermal treatment
- Previous chemical treatment
Factors affecting gum properties

- Previous mechanical treatment
- Presence of other hydrocolloids (synergism)
- Age of the dispersion
- Presence of electrolytes and non-electrolytes
Effect of molecular shape on viscosity

linear, high hydrodynamic radius, high viscosity

branched, lower hydrodynamic radius, lower viscosity
Gelation

• Sol $\rightarrow$ Gel
• To effect this transformation we may
  – Add a non-solvent
  – Evaporate the solvent
  – Add a cross-linking agent
  – Reduce solubility by chemical reaction
  – Change temperature
  – Change pH
Gelation

- Junction zone bonds include
  - Hydrogen bonds
  - Ionic bonds
  - Covalent bonds
Synergism

- Usually requires the combination of a gelling and a non-gelling polymer

Carrageenan  A brittle, crumbly gel

Add a small amount of locust bean gum

A gel is produced which is elastic, tender, and stronger than that of carrageenan alone
General applications

- **Emulsification (o/w or w/o)**
  - Salad dressing
    - arabic and tragacanth
- **Suspension/dispersion**
  - Chocolate milk
    - Carrageenan
- **Foams**
  - Whipped toppings
    - locust bean, karaya
General applications

• Crystallization control
  – Ice cream
    • many gums

• Flavor fixation
  – Powdered drink mixes
    • gum arabic
General applications

• Protective films
  – Sausage casings
  • Alginate

• Syneresis inhibitor
  – Processed cheeses
  • locust bean, guar
Gum classes

- Plant exudates
- Seed gums
- Seaweed gums
- Cellulose derivatives
- Bacterial gums
Gum arabic

- An exudate gum
- Source
  - *Acacia* trees in the Sudan and other African countries
Gum arabic
Gum arabic production

“Tapping” the Acacia tree
Gum arabic exudate
Gum arabic harvesting

Young woman collecting gum arabic from low branches of acacia tree in the Kordofan region of Sudan. Courtesy of the Gum Arabic Co., Ltd., Sudan
Sorting the gum
Packaging the gum

Packaged in 50 or 100 kg burlap bags
Gum arabic

• Structure
  – D-galactose, L-arabinose, L-rhamnose, D-glucuronic acid
  – MW 250,000 to 1,000,000
  – Very complex structure (slightly acidic)
Gum arabic

• Unique because of
  – High water solubility
  – Newtonian rheology up to 40% concentration
  – Flavor encapsulation

• Uses
  – Confectionary products
  – Ice cream
  – Flavor fixation
**Proposed structure of gum arabic**

\[
R = L-Rhap(1 \rightarrow), L-Araf(1 \rightarrow), D-Galp(1 \rightarrow 3)-L-Araf(1 \rightarrow), \text{ or } L-Arap(1 \rightarrow 3)-L-Araf(1 \rightarrow)
\]

- **D-GlcpA** = D-glucopyranosiduronic acid
- **D-Galp** = D-galactopyranose
- **L-Rhap** = L-rhamnopyranose
- **L-Arap** = L-arabinopyranose
- **L-Araf** = L-arabinofuranose
Gum tragacanth

- An exudate gum
- Source
  - *Astragalus* genus shrub. First described several centuries B.C. Grows in Asia Minor, Iran, Syria, Turkey. Hand collected, as is arabic.
- Structure
  - D-galacturonic acid, L-fucose, D-galactose, D-xylose, L-arabinose
  - MW about 840,000
Gum tragacanth

From “tragos” (goat) and “akantha” (horn)
Gum tragacanth
Gum tragacanth

- Tragacanth fractionation

Tragacanth

> Tragacanthin  
60-70% of gum  
water soluble

> demethylation

> Bassorin  
30-40% of gum  
water insoluble
Gum tragacanth

• Viscosity
  – High at low concentration (0.5%)
  – pH independent
  – Molecular dimensions (19 x 4500 Å) account for high viscosity
Gum tragacanth

• Uses
  – Salad dressings and sauces (acid stability)
  – Ice creams, ices, sherbets
  – Frozen pie fillings
Locust bean gum

- A seed gum
- Source
  - The carob tree (*Ceratonia siliqua*). Grows in the near East and Mediterranean
Locust bean gum

• Structure
  – A galactomannan (Man:Gal = 4:1)
  – MW 300,000 to 360,000
    • Contains long stretches of bare mannose backbone which is responsible for synergism
Locust bean gum

Alpha-1,6 linkage

Beta-1,4 linkage

Image courtesy of www.dicamp.univ.trieste.it/research/rheology/egc1/paper.htm
LBG--Structure and uses

The bare regions are responsible for the synergism between LBG and carrageenan

Uses
Ice cream, cheese products, meat products
Guar gum (guaran)

- A seed gum
- **Source**
  - *Cyamopsis tetragonolobus*, a plant not unlike soybeans. Grown in India, Pakistan, and the U.S. Guar gum is from the seed endosperm
- **Structure**
  - Mannose:Galactose = 2:1
  - MW = 1-2 x 10^6 daltons
Guar gum

A guar plant,
<br>
*Cyamopsis tetragonolobus*
Guar gum harvesting

In the US, this is done by machine, much like the harvesting of soybeans.
Guar gum--Structure

Image courtesy of www.dicamp.univ.trieste.it/research/rheology/egc1/paper.htm
Guar gum

- Hydrates rapidly in cold water to give highly viscous dispersions
- A new view of the structure shows that the mannan backbone is not uniformly substituted
Guar gum

• Uses
  – Processed cheese
  – Ice cream
  – Baked goods
  – Meat
  – Dressings and sauces
  – Beverages
Carrageenan

- A seaweed gum
- Source
  - Irish moss (*Chondrus crispus*), found on the coasts of Ireland, England, France, and Spain
- Structure
  - A complex mixture of sulfated polysaccharides
Carrageenan

- Irish moss -- *Chondrus crispus*

Image courtesy of seaweed.ucg.ie/seaweed/IrishSeaweed.html
Carrageenan structures

Two oddities:
1. Sulfate groups
2. 3,6-anhydro rings
Carrageenan gelation properties

<table>
<thead>
<tr>
<th></th>
<th>Kappa</th>
<th>Iota</th>
<th>Lambda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongest gels</td>
<td>With K⁺ ion</td>
<td>With Ca²⁺ ion</td>
<td>No gel</td>
</tr>
<tr>
<td>Gel texture</td>
<td>Brittle</td>
<td>Elastic</td>
<td>No gel</td>
</tr>
<tr>
<td>Regel after shear</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Syneresis</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Freeze-thaw stability</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Synergy LBG</td>
<td>Yes</td>
<td>No</td>
<td>no</td>
</tr>
</tbody>
</table>
Carrageenan gelation mechanism
Carrageenan-LBG synergism
Carrageenan-LBG interaction
Carrageenan properties

• Kappa, lambda, and iota are all different
  – Strongly anionic; associated with $K^+$, $Ca^{++}$, and $Na^+$
Carrageenan properties

- In water
  - Thickens (pseudoplastic) and gels
- In milk
  - Thickens, gel, and reacts with milk proteins to stabilize the colloidal system
Carrageenan properties

- Kappa forms a thermally reversible gel in the presence of K$^+$ ions
  - Gels are normally brittle and prone to syneresis. This can be remedied by the addition of a small amount of locust bean gum. Due to structural differences between the gums, only LBG will do this, guar will not.
Carrageenan uses

• Puddings
  – “Eggless” custards

• Chocolate milk
  – Particle suspension

• Cheese products
  – Prevents whey separation
Carrageenan uses

- **Ice cream**
  - Crystallization control

- **Meat**
  - Protective coating to prevent oxidative rancidity

- **Salad dressing**
  - Stabilizer
Alginate

• A seaweed gum
• Source
  – A brown seaweed, *Macrocystis pyriferia*
Alginate

- **Structure**
  - D-mannuronic acid, L-guluronic acid
  - Poly M blocks
  - Poly G blocks
  - Alternating M-G blocks
  - M/G ratio differs depending on the source
Macrocystis pyrifera

Image courtesy of www.pbs.org/oceanrealm/seadwellers/cathedraldwellers/kelp.html

Kelp forests
Harvesting giant kelp
Alginate structures

Poly-D-mannuronic acid segment of alginate

Poly-L-guluronic acid segment of alginate
Alginate properties

• Low MW fractions show nearly Newtonian flow
• Non-Newtonian behavior increases with
  – Increasing degree of polymerization (DP)
  – Increasing concentration
  – Presence of Ca$^{++}$ instead of Na$^+$
Alginate properties

• As temperature increases, viscosity decreases
Alginate properties

- Good stability in the pH range 5-10
  - Maximum viscosity occurs between pH 6-8
  - Degradation occurs at low pH (1-4)

- Alginate is fairly resistant to microorganisms
Alginate gelation

- Ca\textsuperscript{++} gels
- Acid gels
- Combination gels

- These are all called chemically set gels
Add 1% alginate to 5% CaCl₂

This reaction produces an instant gel
Alginate uses

- Food applications
  - Ice cream
  - Bakery icings
  - Bakery jelly
  - Meringues
  - Salad dressings
  - Pimento stuffed olives
  - Frozen reformed onion rings
Microcrystalline cellulose

• A cellulose derivative
• Preparation

Pure alpha cellulose \textbf{acid}
fibrous, does not absorb water

\textbf{Microcrystalline cellulose, non-fibrous, absorbs water}
Microcrystalline cellulose

• Properties
  – MW = 30,000 to 50,000
  – Water insoluble but dispersible; undergoes some swelling on dispersion
Microcrystalline cellulose

• Uses
  – Salad dressings
  – Frozen desserts
  – Provides body, bite resistance, chewiness
    (McDonald’s milk shakes)
MCC micrograph
Sodium carboxymethylcellulose (CMC)

- A cellulose derivative
- Preparation

Cellulose $\xrightarrow{\text{NaOH}}$ chloroacetate $\xrightarrow{\text{CMC}}$
CMC structure

Image courtesy of www-fst.ag.ohio-state.edu/FST605/lectures/lect20.html
Sodium carboxymethylcellulose (CMC)

- Degree of substitution (DS) for food use = 1.0

- Properties
  - Water soluble
  - Pseudoplastic dispersions
  - Stable at pH 5-10, best at 7-9
Sodium carboxymethylcellulose (CMC)

- Monovalent salts, soluble
- Divalent salts, hazy
- Trivalent salts, gel or precipitate
- Reacts with proteins (e.g. gelatin) to increase viscosity of dispersion
CMC uses

- Pie fillings
  - Prevents syneresis
- Breads
  - Has an anti-staling effect
- Dietetic foods
  - Provides bulk and body to replace that normally given by sucrose
Methylcellulose

- A cellulose derivative

Cellulose $\xrightarrow{\text{NaOH}}$ Methylcellulose

Methyl chloride
Methylcellulose structure

Image courtesy of www-fst.ag.ohio-state.edu/FST605/lectures/lect20.html
Methylcellulose

- **Properties**
  - DS = 1.64-1.92 provides maximum water solubility
  - Dispersions are pseudoplastic; degree of pseudoplasticity is determined by length of chain (DP)
  - Exhibits thermogelation
Thermogelation

Temperature

Viscosity

Start heating

Finish cooling

Gelation
Mechanism of thermogelation
Methylcellulose uses

• Baked goods
  – Promotes water retention
  – Provides resistance to oil absorption (doughnuts)

• Dietetic foods
  – Provides structure and texture in gluten-free products
Methylcellulose uses

• Frozen foods
  – Syneresis inhibition (provides good freeze-thaw stability)

• Salad dressing
  – Emulsifier/stabilizer/thickener
Xanthan gum

- A bacterial gum
- Source
  - *Xanthomonas campestris*, a bacteria
- Structure
  - Basically a derivatized cellulose
Xanthan gum structure

Cellulose backbone

Sidechain
Xanthan properties

- Xanthan is soluble in hot or cold water to produce dispersion of high viscosity at low concentration.
- The dispersions are highly pseudoplastic (shear-thinning).
Viscosity behavior

- Viscosity vs. Temperature
  - RT to 200°F

- Viscosity vs. pH
  - pH 1 to 13
Uses

• **Beverages**
  – Good flavor release (due to shear-thinning)
  – Cloud stabilizer

• **Frozen foods**
  – Pie fillings-increases freeze-thaw stability

• **Relishes**
  – Good acid stability (0.1%)

• **Xanthan-LBG gels and puddings**
  – Instant gels and puddings