Cellulosics

- Cellulose— the principal cell wall component of higher plants
- The most abundant organic compound on earth

Cellulose

- High molecular weight
- Linear
- Water insoluble
- β-1,4-linkages
Cellulose properties

- Not digested—0 kcal/mole (dietary fiber)
- Physical reason plus little β-glucosidase in the human gut

Cellulose source

- Cotton linters
- Wood pulp

Cellulose from cotton linters

Cotton fiber

Treat with hot NaOH, removes protein, pectic substances, waxes

High quality cellulose
Cotton from wood pulp

Wood (50% cellulose, 30% hemicellulose, 20% lignin)

Pulping

1) alkali
2) alkaline NaOCl

Cellulose

Pulping processes

- Digestion with calcium bisulfite and sulfur dioxide (bisulfite process)
- Digest with alkaline sodium sulfide (sulfate process)
- Digest with sodium hydroxide (soda process)
  - Soda process is most often used to make cellulose for conversion to water soluble derivatives

Powdered cellulose

- Specially purified for use in foods
- Quality is determined by $\alpha$-cellulose content
  - $\alpha$-Cellulose is insoluble in 18% alkali
  - $\beta$-Cellulose dissolves in 18% alkali but precipitates on neutralization
  - $\gamma$-Cellulose remains soluble after neutralization
  - If $\alpha$-cellulose content is greater than 99%, we regard it as pure $\beta$-1,4-glucan
Characteristics

- Bland flavor
- Little color
- Little microbial contamination
- Fiber length 0.5-4.0 mm
- Fiber width 0.005-0.35 mm

Uses

- Bread and other baked goods
  - Non-caloric bulking agent
- Frozen novelties (ice pops)
  - Freeze-thaw stability
- Sauces
  - Smooth, creamy texture
  - Increases cling and viscosity
- Synergistic with
  - Guar, CMC, and xanthan

Microcrystalline cellulose

- Preparation

  Pure alpha cellulose (fibrous, does not absorb water) → Microcrystalline cellulose (non-fibrous, absorbs water) → acid
MCC preparation

Acid attacks the amorphous regions and hydrolyze it
Crystallites (fringed micelles) are left
This is MCC

Microcrystalline cellulose

Properties
- DP about 3000
- MW = 30,000 to 50,000
- Water insoluble but dispersible; undergoes some swelling on dispersion
**Types**

- **Powdered MCC**
  - Spray dried
  - Aggregates of microcrystals, they are porous and sponge-like (20-90 micrometers)
- **Uses**
  - Anticaking agent/flavor carrier in cheese
  - Calorie reducer in baked goods
  - Stabilizes dispersed oil
  - Extrusion aid for expanded snacks (e.g., Cheetos) and frozen French fries

---

**Types**

- **Colloidal MCC**
  - Water dispersible
  - Properties similar to water soluble gums
- **Preparation**
  - Apply mechanical pressure to tear fibers apart
  - Then add CMC to aid in re-bonding of colloidal fibers during drying
  - CMC also aids in re-dispersion and stabilizes fibril dispersions

---

**Colloidal MCC**

[Diagram of MCC and CMC]
Viscosity development depends on high shear to disperse the particles
Viscosity continues to increase over 12-24 hours
Viscosity may increase 10-fold during hydration
Dispersions show thixotropic rheology

It is possible to modify the rheology and stability of MCC dispersions by interaction with other gums
- Xanthan, CMC, hydroxypropylcellulose
MCC relatively stable to heat and acid
Major MCC functions

- Stabilizes foams and emulsions
- Stabilizes starch and pectin gel to heat
- Improves adhesion
- Controls ice crystal growth
- Forms thixotropic gels
- Modifies textures
- Replaces fat and oil

Colloidal MCC in ice cream

- 0.2-0.4%
- Suspending agent
- Enhances stiffness
- Decrease ice crystal growth

Colloidal MCC in salad dressings

- Improves uniformity
- Improves stability
- Improves pasteurizability
- Improves spreadability
  - Not an emulsifier but does collect at the oil/water interface and thickens the mixture and improves mouthfeel
Other MCC uses

- Improves cling in sauces
- Thickens and masks flavors in starch systems
- Improves body, texture, and stability in vegetable fat whipped toppings (20-27% fat)
- For other typical uses, see Table 7.2 in W&B

MCC synergism

- MCC-guar and MCC-alginate
  - Contributes fat-like mouth feel to non-fat/lowfat products

PrimaCel (Nutrasweet)

- Microfibrous cellulose
- Fiber diameter = 0.1 micrometer (normal 20-90 micrometer)
- Up to 200x more surface area than MCC
- Odd behavior: Thickens up to a certain point with increasing temperature, then viscosity drops off
- IFT National meeting, 1997
Labeling

- Microcrystalline cellulose or cellulose gel

Sodium carboxymethylcellulose (CMC)

- Preparation

\[
\text{Cellulose} \xrightarrow{\text{NaOH, chloroacetate}} \text{CMC}
\]

CMC structure
Sodium carboxymethylcellulose (CMC)

- **Degree of substitution (DS) for food use = 0.4-0.8 (max = 1.5)**

- **Properties**
  - Water soluble
  - Thixotropic dispersions
  - Stable at pH 5-10, best at 7-9

CMC characteristics

- **Substitution at O2, O3, and O6**
  - Ratio = 2.14:1.00:1.58
- **Non-uniform substitution along cellulose backbone leads to thixotropic flow and increased interaction with MCC**
- **Available in a wide variety of viscosity types (viscosity is proportional to average molecular weight)**

CMC viscosity types

<table>
<thead>
<tr>
<th>Viscosity</th>
<th>Average DP</th>
<th>Average MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>3,200</td>
<td>700,000</td>
</tr>
<tr>
<td>Medium</td>
<td>1,100</td>
<td>250,000</td>
</tr>
<tr>
<td>Low</td>
<td>400</td>
<td>90,000</td>
</tr>
</tbody>
</table>
CMC dispersions

- CMC is fully extended in its shape to decrease Coulombic repulsion
- This produces
  - Monodisperse solutions (dispersions)
  - High viscosity
  - High stability

CMC at low pH

- At pH less than 4, ionization is repressed, association increases, and viscosity increases
- At pH 3, CMC is insoluble
- CMC is acid unstable, especially if heat is applied
  - Hydrolysis will decrease viscosity

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
- Also, stabilizes protein dispersions near their pI
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

CMC labeling

- Sodium carboxymethylcellulose
- Sodium carboxymethyl cellulose
- Carboxymethylcellulose
- Carboxymethyl cellulose
- CMC
- Sodium CMC
- Cellulose gum

Methylcellulose and hydroxypropyl methylcellulose

Cellulose derivatives

- Cellulose $\xrightarrow{\text{NaOH}}$ Methylcellulose
- Methylcellulose $\xrightarrow{\text{Methyl chloride}}$ Hydroxypropyl methylcellulose
- Methylcellulose $\xrightarrow{\text{Propylene oxide}}$ Hydroxypropyl methylcellulose
Methylcellulose structure

Properties
- Cold water soluble
- Enzyme (cellulase) resistant
- DS for methylcellulose = 1.1-2.2
- Molar substitution level (HPMC) = 0.02-0.03
- Dispersions are pseudoplastic; degree of pseudoplasticity is determined by length of chain (DP)
- Exhibits thermogelation

Thermogelation

Start

Viscosity

Temperature

Heat

Gelation

Cooling

Finish
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
MC and HPMC functions

- Generally, they reduce fat in foods
  - They impart fat-like properties to the foods themselves
  - They decrease fat absorption in deep-fried products

Other food characteristics

- Richness/creaminess
- Lubricity
- Structure/body
- Foam stability
- Moisture retention in baked goods
- Gas retention in baked goods
- Low MW methylcellulose is synergistic with hydroxypropylstarch

HPMC uses

- Foam stabilizer in non-dairy whipped toppings (at a level of about 0.5%)
- Improves whipping characteristics
- Prevents phase separation
- Provides freeze-thaw stability
MC labeling

- Methylcellulose
- Methyl cellulose
- Modified vegetable gum (occasionally)

HPMC labeling

- Hydroxypropylmethylcellulose
- Hydroxypropyl methylcellulose
- Hydroxypropyl methyl cellulose
- Carbohydrate gum (occasionally)