Carbohydrate Chemistry
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Overview

• Carbohydrate chemistry
  – General characteristics
  – Sugar chemistry
  – Starch chemistry

• 10 minute break

• Iodine test for Starch
General Features

- Carbo + hydrate
- General structure $C_x(H_2O)_x$
- -ose suffix is very common
- Classification based on nutritional use or chemical characteristics

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<th>Nutritional Classifications</th>
<th>Chemical Classifications</th>
<th>Degree of Polymerization (DP)</th>
<th>Common Uses</th>
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<td>Complex Carbohydrates</td>
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<td>Polysaccharides</td>
<td>Up to 15,000</td>
<td>Thickeners</td>
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Monosaccharides

- 3 to 6 carbons
- Building blocks for larger polymers
- Common monosaccharides
  - Glucose, “blood sugar”
  - Fructose, “fruit sugar”
  - Galactose

Disaccharides

- Condensation reaction between two monosaccharides
- Most have $\alpha (1 \rightarrow 4)$ link; sucrose has $\alpha (1 \rightarrow 2)$
  - We’ll talk about why that’s important in a minute…
- Common disaccharides
  - Maltose, “malt sugar”
  - Sucrose, “table sugar”
  - Lactose, “milk sugar”
Chemical Reactions of Sugars

- Hydrolysis
  - Acid, heat, or combination
  - Enzymes

- Caramelization
  - Brown colors formed from sugar only
  - Hydrolysis, degradation, polymerization

Condensation
Hydrolysis

Chemical Reactions of Sugars

- Maillard Browning
  - Brown colors formed from reducing sugar and amino acid
  - Multi-step process, leads to nitrogen-containing polymers
  - Accelerated by temperature
  - Favored at high pH and intermediate moisture
Monosaccharides are Reducing Sugars

Starch and Most Disaccharides are Reducing Sugars
Sucrose IS NOT a Reducing Sugar
Caramelization or Maillard Browning?

- Browned cornstarch
- Bread crust
- Toffee
- Caramels or caramel sauce
- Seared meat (how?)

Polysaccharides—Starch

Amylose

- Straight chain
- $\alpha (1 \rightarrow 4)$ linked glucose units
- $MW \sim 10^6$
- Chains take on a helical structure
Polysaccharides—Starch

Amylopectin

- Branched chain
- $\alpha (1 \rightarrow 4)$ chains and $\alpha (1 \rightarrow 6)$ branches
- MW $10^7$ to $10^8$
- Branches take on a helical structure
Amylose

Amylopectin

Gelatinization

• UNIQUE TO STARCHES!!!
  – Absorption of water
  – Swelling as even more water is imbibed
  – Leaching of amylose

• Amylopectin portion can:
  – Stay – “granule ghost”
  – Leave—“pasting”

**Look up Play-doh® at www.howstuffworks.com for an explanation of gelatinization**
Gelatinization

- Temperature of gelatinization is unique to each starch source
- Starches vary with their ability to thicken
- Some starches are more translucent than others
- Starch pastes vary in texture

All are related to **amylose / amylopectin ratio**!

Gelation

- Gelation ≠ Gelatinization!
- Gelation of starch requires amylose
  - Forms junction zones
- Potato, tapioca, and rice starches do not form gels
- Arrowroot forms a soft gel
- Corn, wheat starches form strong gels
- Flours form weaker gels than starches
Retrogradation

• Reversion of gelatinized starch components to an organized crystal structure
• Amylose retrogrades at a much faster rate than amylopectin!
• Can be reversed with heat
• Retrogradation is fastest at refrigeration temperatures

Time for a Break!
Let’s take 10 minutes
Iodine Test for Starch

- Triiodide interacts with helical starch structure
- Triiodide must be made from Iodine molecule and iodide ion
- $I_2 + I^- \leftrightarrow I_3^-$

Triiodide/Starch Interaction

- Longer helices hold more triiodide
- More extensive triiodide interactions create a blue-purple color
- Less extensive triiodide interactions create a red-purple color
Iodine Test for Starch

- Foods high in amylose turn bluish-purple
  - Cornstarch, flour, potato starch, dextrins with low DE

Iodine Test for Starch

- Foods high in amylopectin turn reddish-purple
  - Waxy starches, some short-grain rice, dextrins with mid-range DE
Iodine Test for Starch

- Foods high in sugars do not cause a color change
  - Iodine will stain it light brown or yellow
  - Sugar, corn syrup, dextrins with high DE

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Materials Available

- Triiodide solution (1.25% I₂/2.5% KI)
  - Use 1 drop!
- Cornstarch and maltodextrins of varying sizes
- Sugar, powdered sugar, and sucralose sweetener
- Potato flakes and pearls
- Marshmallows
Where to Find Triiodide

• Make it yourself: Iodine (1%) and KI (2%)
• Solutions are available through lab supply stores
  – *Lugol solution* is used for Gram staining in microbiology
  – Dilute it 1:10 for starch test (1 part Lugol + 9 parts water)
• First aid iodine contains a stabilized version
  – Lasts longer, but might affect the color reaction you see
  – Most kinds also contain hydrogen peroxide

Questions?

Thank you for your attention!