Carbohydrate nutrition, dietary fiber, bulking agents and fat mimetics

Dietary carbohydrates

- Classes
  - Digestible
    - 4 kcal/gram
  - Partly digestible
  - Non-digestible

Dietary carbohydrate properties

- Bulk
- Thickness
- Creaminess
- Pulpiness
- Fattiness
Carbohydrate nutrition

- Only monosaccharides are absorbed in the small intestine
- Oligo- and polysaccharides are broken down to monosaccharides by digestive enzymes in the brush border membrane
  - sucrase
  - lactase
  - α-amylase
  - maltase

Digestible and absorbable CHO in the diet

<table>
<thead>
<tr>
<th>CHO</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>~60%</td>
</tr>
<tr>
<td>Sucrose</td>
<td>~30%</td>
</tr>
<tr>
<td>Lactose*</td>
<td>~7%</td>
</tr>
<tr>
<td>Glucose and others</td>
<td>~5%</td>
</tr>
</tbody>
</table>

*Not everyone can completely digest lactose

Brush border membrane

[Diagram of brush border membrane with blood vessels, villi, and capillaries]
Carbohydrate nutrition

- If polysaccharides are digested and absorbed, they are caloric
- But, most food gums pass through the small intestine unchanged
- However, in the large gut (colon) they may be degraded to produce gases and volatile fatty acids (VFAs, e.g. propionic, butyric)
  - These VFAs may be absorbed in the colon and metabolized in the liver for energy (approximately 7% of human energy is produced this way)

Glycemic response, glycemic index, glycemic load, and glycemic impact

- Glycemic response: change in blood glucose induced by ingested food
- Glycemic index: classification of a food based on the blood glucose-raising effect of a standard amount of it (50g of available carbohydrate) compared to white bread of glucose

Glycemic response curves

![Glycemic response curves](image)
Glycemic response curves

GI depends on

- Rate of gastric emptying
- Viscosity of intestinal contents
- Physical form of food being consumed
- Preparation or processing of food being consumed
- Time of consumption
- Meal frequency
- Other foods eaten with (or before) food being consumed
- The person consuming the food

Because of these dependencies, the measurement of GI is imprecise and subject to laboratory-to-laboratory variation
Glycemic load and glycemic impact

- GL is the product of GI times the number of grams of carbohydrate in a serving and dividing the result by 100
- Glycemic impact is the response in blood glucose concentration of a serving of a food relative to that of an equivalent weight of glucose

Post-prandial hyperglycemia

- This rise in blood glucose has significant consequences
- For non-diabetics it results in hyperinsulinemia which can increase liver and muscle glycogen and synthesis and storage of fat
- For diabetics the hyperglycemia presents problems for complications of the disease

Effects of low GI foods

- Consumption of low GI foods by a diabetic results in reduction of serum lipids and increased insulin sensitivity
- In non-diabetics, it is associated with weight loss, reduced body fat, increased HDL and reduced risk for diabetes and cardiovascular disease
Dietary fiber definition

- Dietary fiber is the edible parts of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and or blood glucose attenuation.

Dietary fiber: physiological effects

- Prebiotics: Substances not digested in the small gut and provide beneficial physiological effects in the colon by stimulating the growth of healthy bacteria (e.g., Bifidobacterium and Lactobacillus)
- Many oligosaccharides have been studied for prebiotic activity (see Table 16.2 in BeMiller)

Nutritional function of dietary fiber

- GI health and motility
- Decreased stool transit time
- Decreased incidence of colon cancer
- Increased fecal bulk
- Decreased serum cholesterol
**Dietary fiber sources**

- **Plant cell walls/whole grains**
  - Cellulose, hemicellulose, pectic substances

- **Hemicelluloses**
  - 20-30% of plant cell walls
  - Sometimes referred to as pentosans
  - Xylans and arabinoxylans in wheat
  - These are great water absorbers and important in determining baked good properties. Usually less is better to provide better gluten formation.

**β-Glucans**

- **Source**: cereal bran (especially from oats and barley)

- **Structure**
  - 1→3 linked segments of 1→4 linked cellotriosyl or cellotetraosyl units

**β-Glucans**

- May be used as a fat mimetic
- Treating with water and high shear will produce a fat like gel that has been used to replace fat in ground beef, hot dogs, cheeses, cookies, muffins, etc.
Effect of consumption

- Decreased post-prandial D-glucose response
- Decreased insulin response
- Decreased serum cholesterol

Larch arabinogalactan

- Extracted from *Larix occidentalis*
- Beta-1-3-linked galactopyranose units, each of which is substituted with galactobiosyl or arabinofuranosyl units
- Prebiotic and immune system stimulant

Psyllium seed gum

- From psyllium seed hulls
- High water binding properties
- Consumption may reduce risk of heart disease by reducing cholesterol levels
Resistant starch

- May be resistant due to
  - Physical inaccessibility (RS1)
  - Degree of gelatinization (RS2)
  - Granule size
  - Amylose content (RS3)
  - Starch-protein interaction
  - Starch-lipid complexes
  - Degree of crystallinity
  - Chemical modification (RS4)

Resistant starch

- Fresh cooked starch is always the most digestible
- Freezing-thawing cycles increase the proportion of resistant starch

Polydextrose
Polydextrose

- Analyzes as 90% dietary fiber
- About 1 Kcal/gram
- Used as non-sweet bulking agent in sugar replacement
- Also, a body agent and humectant
- Used in candies, frostings, toppings
- Has some fat sparing properties

Other dietary fibers

- Inulin
- Hydrolyzed guar gum
  - Benefiber
- Pectin
- Chitosan
- Recommended intake in US is 25-30 grams per day

Dietary fiber as a food ingredient

- Some difficulties can occur as added fiber can cause undesirable changes in foods such as gumminess, off flavors, increased viscosity, changes in gelation behavior, differences in oil binding and/or color changes
Bulking agents

- Dietary fiber
  - Soluble
  - Insoluble
- Resistant starch
  - Highly retrograded
- Low molecular weight bulking agents
  - Starch dextrins
    - Used in coffee whiteners and high intensity sweeteners
  - Polydextrose

Bulking agent functionality

- Ability to increase product volume
- Humectancy
- Reduced aw
- Extension of shelf life
- Provision of appropriate viscosity or gelling characteristics
- Effects on crumb texture
- Delay of starch gelatinization

Bulking agent functionality

- Appropriate spread (cookies)
- Appropriate surface cracking (cookies)
- Surface glaze properties
- Appropriate color
- Appropriate effect on taste
- Proper crystallization
- Effects on freezing point depression
Fat mimetics

- **Rationale**
  - In the US, 37% of calories in the diet come from fat
  - Recommendation is no more than 30%

- **Problems with fat removal**
  - Sensory problems and consumer non-acceptance

Fat characteristics

- **Fat provides**
  - Lubricity
  - Flavor
  - Aroma
  - Spreadability
  - Aeration

- The ideal fat replacer does not exist at present

Fat sensory sensation

- The fatty sensation depends strongly on dispersion rheology and particle size and less on the chemical nature of the material being used
Fat mimetics

- Protein aggregates
  - Simplesse
  - Milk whey + egg white + xanthan gum
  - Particle size = 0.1-3.0 μm
- Starch hydrolysis products
  - Stellar, Paselli, Maltrin, etc.
- Microcrystalline cellulose

Fat mimetics

- Small granule starches
  - Amaranth starch
  - 1-2 μm
  - Some modified (treated with fatty acids or fatty acid chlorides) amaranth starches are useful fat replacers in frozen dessert systems
- Sugar polyesters
  - Olestra

Olestra
Caprenin

Not well absorbed
5 kcal/gram

Salatrim

4.5-6.0 kcal/gram