Dietary Fiber, Prebiotics, and Adult Health

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Disclosures

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The opinions reflected in this presentation are those of the speaker and independent of Nutricia North America.
Define dietary fiber and prebiotics.

Identify dietary fibers and prebiotics that can be fermented by the microbiota.

Establish a connection between the gastrointestinal microbiota and adult health:

- Compare and contrast fiber consumption and microbial connections.
- Discuss the ways fiber can be used to modulate GI microbes and adult health.
**Microbiome** - a collection of microbial genomes

**Microbiota** – a collection of microbes

- As many bacteria as host cells in human body¹

- > 150x more bacterial genes than our human genome²

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Microbiota Varies through GI Tract

**Stomach & Duodenum**
$10^1$ – $10^2$ CFU/mL
- *Helicobacter*
- *Streptococcus*

**Jejunum & Ileum**
$10^4$ – $10^8$ CFU/mL
- *Bacteroides*
- *Streptococcus*
- *Lactobacillus*
- *Bifidobacteria*
- *Fusobacteria*

**Colon**
$10^{10}$ – $10^{12}$ CFU/mL
- *Bacteroides*
- *Prevotella*
- *Faecalbacterium*
- *Ruminococcus*
- *Roseburia*
- *Clostridium*
- *Bifidobacteria*
- *Collinsella*
- *Desulfovibrio*
- *Bilophila*
- *Akkermansia*
- *Methanobrevibacter*

Adapted from: Krause’s Food & the Nutrition Care Process, 14th Ed.
GI Microbial Microenvironments

Lumen

Outer mucin layer

Inner mucin layer

Gut mucosa

GI Microbiota Functions

Metabolic functions
- Ferment nondigested food
  - Dietary fiber
  - Resistant starch
  - Protein
- Synthesize secondary bile acids
- Synthesize vitamins
  - B vitamins
  - Vitamin K
- Synthesize neurotransmitters
  - GABA
  - Serotonin

Protective functions
- Pathogen displacement
- Nutrient competition
- Immune stimulation
- Antimicrobial secretion

Systemic Influence of GI Microbiota

- Cognition & brain development
- Bone health
- Intestinal disease
- Obesity & insulin resistance
- Nonalcoholic fatty liver disease

Fiber, Prebiotics & the Gastrointestinal Microbiota
**Definitions: Fiber & Prebiotic**

**Dietary Fiber:** Non-digestible soluble and insoluble carbohydrates (≥ 3 monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (≥ 3 or more monomeric units) determined by FDA to have **physiological effects that are beneficial to human health**.¹

**Prebiotic:** A substrate that is selectively utilized by host microorganisms **conferring a health benefit.**²

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Different types of fibers in different types of plants

Physicochemical properties of fibers:

- **Solubility** - the ability of the fiber to dissolve in water (soluble) or remain as discrete particles (insoluble).
- **Viscosity** - the ability of some polysaccharides to thicken when hydrated (gel-forming).
- **Fermentability** - the degree to which fiber, after resisting digestion, can be broken down by the microbiota.

Dietary Fibers in Foods

Non-Starch Polysaccharides

- Cellulose
- Hemicelluloses
- β-glucans
- Pectins
- Fructans

Hemicelluloses:
- Arabinogalactans
- Glucans
- Arabinoxylans
- Glucuronoxylans
- Xyloglucans
- Galactomannans
- Pectic substances

Cellulose
- Brans
- Cereals
- Legumes
- Nuts
- Peas
- Extracted

Hemicelluloses:
- Brans
- Cereal grains
- Legumes
- Nuts
- Vegetables
- Fruit
- Functional fibers

β-glucans:
- Oat β-glucan
- Barley β-glucan

Pectins
- Fruits
- Vegetables
- Legumes
- Nuts
- Extracted

Fructans
- Inulin
- Oligofructose

Insoluble, poorly to moderately fermentable

Soluble, viscous, readily fermentable

Soluble, readily fermentable

Soluble, non-viscous, fermentable

Dietary Fiber Health Benefits

- **Insoluble (cellulose, bran)**
  - Laxative effect

- **Soluble, viscous, non-fermented (psyllium)**
  - Cholesterol-lowering, improve glycemia, weight loss, stool normalization

- **Soluble, viscous, readily fermented (β-glucan, pectin)**
  - Cholesterol-lowering, improve glycemia
Dietary Fiber Health Benefits

- **Soluble, non-viscous, fermentable:**
  - Fructooligosaccharides (FOS)
  - Galactooligosaccharides (GOS)
  - Inulin
  - Polydextrose
  - Soluble Corn Fiber
  - Resistant Starch

- Accumulating data on health benefits

Different types of fibers in different types of plants

Synthesized fibers

- Physicochemical properties
- Chemical structure

Microbes in the human gut are able to ferment specific fibers

- Cellulose
- Psyllium
- Inulin
- Polydextrose

Fermentability - The degree to which dietary fiber, after resisting digestion by human digestive enzymes, can be broken down (fermented) by the gut microbiota to produce short-chain fatty acids (acetate, propionate, and butyrate).

- Different types of fibers in different types of plants
- Different botanical origins and chemical structure
  - FOS
  - Inulin
  - Polydextrose (PDX)

**Microbes Ferment Dietary Fiber**

*Amylose*: $\alpha$-1,4 glucosidic bonds

*Cellulose*: $\beta$-1,4 glucosidic bonds

*$\beta$-Glucan*: mixed $\beta$-1,3 and $\beta$-1,4 glucosidic bonds
Diet-Microbiota Interactions

Low fiber and microbiota diversity changes fermentation profiles

*Polydextrose*  *Cellulose*  *Inulin*

**Increased access to complex carbohydrates**

*Increased diversity and Metabolic output*

- Acetate $\uparrow$
- Propionate $\uparrow$
- Butyrate $\uparrow$

**Decreased fiber complexity**

*Decreased diversity*

- Acetate $\downarrow$
- Propionate $\uparrow$
- Butyrate $\downarrow$

Microbiota-Derived Signaling

SCFAs

- Peptide YY (PYY)
- GLP-1
- Inflammation
- Serotonin
- Appetite
- Anti-Cancer
- Gut Motility
- Metabolism

Define dietary fiber and prebiotics

**True or False?** Dietary fiber is defined as:

Non-digestible soluble and insoluble carbohydrates (≥ 3 monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (≥ 3 or more monomeric units).
Dietary Fiber: Non-digestible soluble and insoluble carbohydrates (≥ 3 monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (≥ 3 or more monomeric units) determined by FDA to have physiological effects that are beneficial to human health.”

Prebiotic – a substrate that is selectively utilized by host microorganisms conferring a health benefit.

Identify dietary fibers and prebiotics that can be fermented by the microbiota. **Select all that apply.**

a) **Cellulose**  
b) **Psyllium**  
c) **Inulin**  
d) **Polydextrose**
 Identify dietary fibers and prebiotics that can be fermented by the microbiota.

a) Cellulose
b) Psyllium
c) Inulin
d) Polydextrose
**Food Sources**

- Chicory root
- Onion
- Artichoke
- Agave
- Wheat
- Bananas
- Garlic

**Structures**

- Fructose polymer linked by $\beta-2,1$ linkages
- Varying degrees of polymerization (2-60)
- Fructooligosaccharides (FOS) $\rightarrow$ Inulin

**Microbial**

- 16 g/d inulin and oligofructose (50/50) for 12 wk increased *Bifidobacterium* and *Faecalibacterium prausnitzii*\(^1\)
- 5 & 7.5 g/d agave inulin increased *Bifidobacteria* and SCFA\(^2\)
- Positive correlation between *Faecalibacterium* and butyrate concentrations\(^2\)
- 12 g/d inulin increased *Bifidobacterium* and decreased *Bilophila*, no change in SCFA\(^1\)

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Phenotypic Responses

Metabolic

- 21 g/d for 12 wk reduced body weight, fat mass and trunk fat\(^1\)
- 16 g/d for 2 wk decreased postprandial glucose responses after a standardized meal\(^2\)
- 16 g/d inulin and oligofructose (50/50) for 12 wk did not significantly change body composition, although fat mass tended to decrease\(^3\)
- 10 g/d oligofructose-enriched inulin for 8 weeks reduced glucose, A1C, IL-6, TNFa, and LPS in women with overweight/obesity and type 2 diabetes\(^4\)
- 12.5 g/d for 17 wk reduced total body weight, BMI, waist circumference, fasting insulin, and HOMA in women with obesity\(^5\)

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2. Cani PD (2009). Gut microbiota fermentation of prebiotics increases satietogenic and incretin gut peptide production with consequences for appetite sensation & glucose response after a meal. AJCN;90(5),1236-43
**Appetite, food intake, and satiety**

- 21 g/d for 12 wk increased PYY, decreased ghrelin, & reduced food intake
- 16 g/d for 2 wk increased glucagon-like peptide 1 and PYY
- 12.5 g/d for 17 week improved satiety in women with obesity
- 8 g/d for 2 weeks increased satiety following breakfast and dinner, reduced energy intake at breakfast and lunch, overall 5% reduction in energy intake

- **Food Sources**
  - Synthesized and added to enteral formulations

- **Structures**
  - β-(1,4) linked galactose oligomer, attached to glucose by β-(1,4) bond

GOS & Health

- **Microbial**
  - 5- to 10-fold increases in *Bifidobacteria*\(^1\)
  - Increased *Bacteroides, Bifidobacteria*, and fecal lactate\(^2\)

- **Immunomodulation**
  - 5.5 g/d for 10 wk increased IL-10, IL-8, natural killer cell activity and reduced IL-1 \(\beta\)\(^2\)
  - 5.5 g/d for 12 wk increased fecal secretory IgA and decreased calprotectin, decreased plasma CRP in overweight adults\(^3\)

- **Psychological**
  - 5.5 g/day for 3 wk reduced waking salivary cortisol and increased attentional vigilance in the processing of positive versus negative stimuli\(^4\)

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Polydextrose (PDX)

- **Food Sources**
  - Synthesized fiber that is a multi-purpose food ingredient found in baked goods, dairy products, and beverages

- **Structures**
  - Highly branched, randomly bonded glucose polysaccharide units with DP of 2-120 (average 12). Glucose linked by α- and β-linked 1,2, 1,3, 1,4, and 1,6 glycosidic linkages.  

Microbial

- Up to 40% fermented, up to 60% excreted
- Increased *Parabacteroides* and reduced *Eubacterium*, *Ruminococcus*, and *Roseburia*¹
- Reduced ammonia, phenols, indoles, branched-chain fatty acids and butyrate¹

Microbiota: PDX & Soluble Corn Fiber (SCF)

Microbiome Changes with Daily PDX & SCF

**Gastrointestinal**
- 3.6 g/d reduced transit time in adults with constipation
- 8 g/d reduced transit time in adults with constipation
- 8 g/d reduced abdominal discomfort and tended to reduce stool hardness

**Metabolic**
- 12.5 or 15 g/d decreased postprandial triglyceride response to high fat meal
- 56.7 g/d tended to reduce peak glucose response and significantly reduced insulin response

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**Appetite, satiety, and food intake**

- 8 g/d PDX for 21 day reduced snack consumption and increased butyrate producing bacteria in healthy adults.
- 6.25 g or 12.5 g PDX 90 min prior to meals decreased hunger. 12.5 g decreased energy intake in healthy adults.
- 12 g PDX 60 min prior reduced energy intake at ad-libitum lunch in healthy males.
- 6.25, 12.5, and 25 g PDX 90 min prior to ad-libitum lunch decreased energy intake in healthy adults.
- 15 g PDX decreased hunger and increased satiety and GLP-1 concentrations postprandial in non-diabetic, obese adults.

Identify dietary fibers and prebiotics that can be fermented by gut microbiota.

**True or False?** All fibers and prebiotics change the composition of the microbiome in the same way.
False

Fibers and prebiotics differentially change the composition of the microbiome. Inulin, FOS, and GOS can increase *Bifidobacterium*, while PDX increases the abundances of Bacteroidetes.
## Prebiotic Health Effects

<table>
<thead>
<tr>
<th>Health end point</th>
<th>Prebiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satiety</td>
<td>Fructooligosaccharide (FOS)</td>
</tr>
<tr>
<td>Calcium and other mineral absorption, bone health</td>
<td>FOS</td>
</tr>
<tr>
<td>Stimulation of neurochemical-producing bacteria in the gut</td>
<td>Galactooligosaccharide (GOS)</td>
</tr>
<tr>
<td>Urogenital health</td>
<td>GOS</td>
</tr>
<tr>
<td>Irritable Bowel Syndrome (IBS)</td>
<td>GOS</td>
</tr>
<tr>
<td>Skin health, improved water retention and reduced erythema</td>
<td>GOS</td>
</tr>
<tr>
<td>Traveler’s diarrhea</td>
<td>GOS</td>
</tr>
<tr>
<td>Allergy</td>
<td>FOS, GOS</td>
</tr>
<tr>
<td>Metabolic health: glycemia, dyslipidemia, inflammation</td>
<td>FOS, GOS</td>
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<tr>
<td>Bowel habit and general gut health in infants</td>
<td>FOS, GOS</td>
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<tr>
<td>Infections and vaccine response</td>
<td>FOS, GOS, and PDX</td>
</tr>
<tr>
<td>Necrotizing enterocolitis</td>
<td>FOS, GOS</td>
</tr>
</tbody>
</table>

**Prebiotics and health end points in clinical trials** *(adapted from Table 1)*

1. RF McLoughlin, et al. Short-chain fatty acids, prebiotics, synbiotics, and systemic inflammation: a systematic review and meta-analysis. AJCN. 2017

- 14 of 29 prebiotic and 13 of 26 synbiotic studies reported a decrease in ≥ 1 marker of systemic inflammation
  - Meta-analyses indicated that prebiotics and synbiotics reduce CRP
- 60 mM acetate enema reduced TNFα
- 200 mL mixture of acetate, propionate, & butyrate (200 mM) reduced fasting IL-1β

- Prebiotics reduced total and LDL cholesterol
- Soluble, fermentable, and non-viscous fiber treatments reduced postprandial glucose and insulin

- Prebiotics reduced total and LDL cholesterol
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- Soluble fiber reduced **BMI, body weight, percent body fat, fasting glucose, and fasting insulin**

- Insoluble and soluble fiber interventions resulted in **weight loss** with 14 g/d of additional dietary fiber

- Glucomannan **reduced fasting glucose and body weight**

- Soluble fiber treatments **decreased energy intake** and **appetite** more frequently than insoluble fiber treatments

- Soluble, fermentable, and non-viscous fiber treatments **reduced postprandial glucose and insulin**

- Prebiotics **reduced total and LDL cholesterol**

Dietary Fiber Database

Developed by an expert team at Tufts University led by Dr. Nicola McKeown
Version 3 released 12/31/2016
Containing 983 entries capturing new literature through May 2016

1. Total and LDL cholesterol
2. Post-prandial glucose & insulin
3. Blood pressure
4. Increased fecal bulk and laxation
5. Transit time

6. Colonic fermentation & short chain fatty acid production
7. Modulation of colonic microbiota
8. Weight loss, maintenance, and reduction in adiposity
9. Satiety
10. Bone health

Database and user manual are available at the ILSI North America site (http://ilsina.org/our-work/nutrition/carbohydrates/).
Dietary fibers and prebiotics differentially impact health and the human gastrointestinal microbiota.

Connections between the microbiota and adult health include gastrointestinal as well as metabolic and psychological health.
Questions?
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