The Impact of Diet on the Gastrointestinal Microbiome

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About Me

- BS in Food Science and Human Nutrition – Dietetics
  - University of Illinois at Urbana-Champaign – 2015
- MS in Clinical Nutrition/Dietetic Internship
  - Rush University Medical Center – 2017
- Interim
  - Nutrition Research Intern – National Dairy Council
  - Research Technician – Nutrition and Human Microbiome Laboratory
- Current Position
  - 3rd Year PhD Candidate in the Division of Nutritional Sciences
Learning Objectives

- Identify dietary factors that impact the human gastrointestinal (GI) microbiota.

- Compare and contract how different types of foods, which contain fiber, differentially impact the GI microbiota.

- Establish a connection between the GI microbiota and health.
**Definitions and Overview**

Microbiome - a collection of microbial genomes

Microbiota – a collection of microbes

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

The composition of the diet impacts digestive secretions, transit time, and absorption.

Diet provides a source of nutrients for us and the GI microbiota.

Diet provides a source of microbes.
Nutrient composition affects GI secretions & transit time

**Colon**
- Neutral pH
- Slow Transit
- Minimal Bile Acids
- Anaerobic
- Thick Mucin Layer

**Stomach**
- Acidic pH
- Oxygen

**Duodenum**
- Neutral pH
- Rapid Transit
- Bile Acids

**Jejunum & Ileum**
- Bile Acids
- Reduced Oxygen
- Mucin Layer
Diet affects GI microbiota composition

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

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

**Jejunum & Ileum**
- $10^4 - 10^8$ CFU/mL
- *Bacteroides*
- *Streptococcus*
- *Lactobacillus*
- *Bifidobacteria*
- *Fusobacteria*
A Deeper Dive Into Diet & Microbiota
Habitual diet is related to the composition of the GI microbiota.¹

Acute changes in macronutrient composition can rapidly (within 2-4 days) change the composition and function of gut microbes.²

Individuals that consume more plants have greater GI bacterial diversity.³

Dietary fiber and prebiotic intake differentially impacts GI microbiota composition and function.⁴

Cross-sectional analysis of > 10,000 fecal samples from participants in the US, UK, and Australia

Individuals completed health status and dietary questionnaires
Plants & Microbiota Diversity

INDIVIDUALS THAT CONSUMED MORE PLANTS HAD GREATER GI BACTERIAL DIVERSITY

- Individuals that consumed more plants had greater GI bacterial diversity.

Which type of fibers are in these foods? Fructans, pectins, cellulose, β-glucans, hemicelluloses

Which of these are fermentable? Soluble? Insoluble? Viscous?
- **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

Soluble, non-viscous, fermentable:
- Fructooligosaccharides (FOS)
- Galactooligosaccharides (GOS)
- Inulin
- Polydextrose

Accumulating data on health benefits
Dietary intervention trials allow for characterization of the impact of foods on the GI microbiota
Inulin Type Fibers

Plant Sources
- Wheat
- Bananas
- Garlic
- Onion
- Agave
- Chicory root

Food Sources
- Bars
- Cereals
- Yogurt
- Ice cream

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
Microbiota-Derived Signaling

SCFAs

Peptide YY
GLP-1

Inflammation

Serotonin

Microbial

- 16 g/d inulin and oligofructose (50/50) for 12 wk increased *Bifidobacteria spp.* and *Faecalibacterium prausnitzii*¹

- 5 & 7.5 g/d agave inulin increased *Bifidobacteria spp.* and SCFA²

- Positive relations between *Faecalibacterium spp.* and butyrate concentrations²

- 12 g/d inulin increased *Bifidobacteria spp.* and decreased *Bilophila spp.*, no change in SCFA¹

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### Inulin: Phenotypic Responses

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**LEGEND** (\% change)

- ◼ 0 to 0.9% increase
- ◼◼ 1.0 to 4.9% increase
- ◼◼◼ 5.0 to 9.9% increase
- ◼◼◼◼ 10 to 14.9% increase
- ◼◼◼◼◼ >15% increase
- ○ 0 to 0.9% decrease
- ◼ 1 to 5% decrease
Inulin-Type Fibers & Health

- **Immunomodulation**
  - Reduced high-sensitivity CRP, IL-6 and/or TNF-α, and endotoxin\(^1\)
  - 10 g/d for 60 days decreased IL-6 and TNF-α \(^2\)

- **Appetite and Food Intake**
  - 21 g/d for 12 wk increased PYY, decreased ghrelin, and reduced food intake.\(^3\)
  - 16 g/d for 2 wk increased plasma glucagon-like peptide 1 and PYY.\(^4\)

- **Body Composition**
  - 21 g/d oligofructose for 12 wk reduced body weight, fat mass and trunk fat.\(^3\)
  - 16 g/d combination of inulin and oligofructose for 12 wk did not change body composition, fat mass tended to decrease.\(^5\)

- **Glycemia**
  - 16 g/d for 2 wk decreased postprandial glucose responses after a meal.\(^4\)

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Walnuts

Randomized, controlled, cross-over design

8 Female | 10 Male

Age: 53 y (35-67 y)
BMI: 28.8 kg/m² (20-35 kg/m²)

Base Diet
Typical American Diet

3-wk intervention with 1-week washout

Base Diet (scaled down) +
1.5 servings/d (42 g/d)
walnut pieces

Walnuts Impacted GI Microbiota

Faecalibacterium

Roseburia

Dialister

% of sequences

Control
Walnut

*P<0.05

Holscher HD, et al., J. Nutr 2018
Walnuts Reduced Secondary Bile Acids

Deoxycholic acid
Lithocholic acid

**P<0.05**

Holscher HD, et al., *J. Nutr* 2018
Walnuts Reduced Secondary Bile Acids

Roseburia (% of sequences) vs. Lithocholic Acid (µg/mg)

$r = -0.42; P = 0.08$

Holscher HD, et al., J. Nutr 2018
Randomized, controlled, cross-over design

n=18
Age: 57 y (33-72 y)
BMI: 30 kg/m² (22-36 kg/m²)

3 Week Treatment

Control
Whole Almonds
Roasted Almonds
Chopped Almonds
Almond Butter

Wash Out Period

Holscher HD, et al., Almond consumption and processing affects the composition of the gastrointestinal microbiota of healthy adult men and women: a randomized controlled trial. *Nutrients* 2018; 10 (2): 126
Almonds Impact GI Microbiota

*P<0.05

Holscher HD, et al., *Nutrients* 2018
Chopped Almonds Increased *Roseburia*

- Control
- Chopped Almonds
- Whole Almonds
- Almond Butter
- Whole Roasted

*P<0.05

Holscher HD, et al., *Nutrients* 2018
Randomized, controlled, cross-over design

Healthy Adults
N=18

Age (y)=57 (37-65)

BMI (kg/m²)=26.2 (19.0-36.6)

INTERVENTION
200 g Broccoli + 20 g radish
16 days

CONTROL
0 g Broccoli/radish
16 days

14 DAY WASHOUT

CONTROL
0 g Broccoli/radish
16 days

Broccoli Increased *Bacteroides*

Kaczmarek JL, et al., *J Nutr Bioc* 2019
- **7-day menu cycle** of standard American diet items

- **Treatments included** cereal, granola, trail mix, and fruit cereal bars

### Healthy Adults (n=68)

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<tr>
<th>Group</th>
<th>Baseline Visit</th>
<th>Post-Treatment Visit</th>
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<tr>
<td><strong>CONTROL</strong> (n=21)</td>
<td>0.8 servings per 1800kcal</td>
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<tr>
<td><strong>OATS</strong> (n=23)</td>
<td>4.4 servings per 1800kcal</td>
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<tr>
<td><strong>BARLEY</strong> (n=24)</td>
<td>4.4 servings per 1800kcal</td>
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Whole Grain Oats & Barley
Whole Grain Barley Increased *Roseburia*

Δ from Baseline

![Graph showing the increase in Roseburia with whole grain barley compared to control and oats](image)

- **Control**: Black bar
- **Oats**: Orange bar
- **Barley**: Light brown bar

Thompson, S.V et al., *FASEB* 2016
Which macronutrients can impact the GI microbiota?
Eating a diet rich in different types and sources of fibers helps support a more diverse GI microbiota.

Diet & GI Microbiota

Food (fiber) source, dose, & form matter

- **Agave inulin**¹
  - ↑ **Bifidobacteria**

- **Oats & Barley**⁵
  - ↑ **Roseburia**

- **Broccoli**⁴
  - ↑ **Bacteroides**

- **Almonds**³
  - ↑ **Roseburia**
  - ↑ **Dialister**

- **Walnuts**²
  - ↑ **Faecalibacterium**
  - ↑ **Roseburia**

1. **Diet** impacts the human GI microbiota.

2. Consumption of different types of **foods, which contain fiber,** differentially impact the GI microbiota.

3. Increasingly, microbes and microbial metabolites are linked to **human health.**
Collaborators: George Fahey, PhD, Elizabeth Jeffery, PhD, Kelly Swanson, PhD, Michael Miller, PhD, David Baer, PhD, Janet Novotny, PhD, Craig Charron, PhD, American Gut Consortium

Funding: Ingredion, USDA, California Walnut Commission, Almond Board of California, Kellogg Company

Questions?