What is the best diet for maintaining optimal gut health?

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(www.ilsi.org/SEA_Region)
What is optimal to gut health?

Good bowel habit: prevention of constipation (4-20% of population).

Prevention of common Functional gut disorders: Irritable bowel syndrome (IBS) (15% of population)

Prevention of inflammatory bowel disease: (UC & Crohn’s)

Prevention of Colorectal cancer: (second most common cancer in both men and women).
The best diet?

Eat a diet rich in fresh fruit and vegetables, whole grains, cereals and maintain a healthy weight.
What is ‘dietary fibre’ (FSANZ)

- **dietary fibre** means that fraction of the edible part of plants or their extracts, or synthetic analogues that –

  (a) are resistant to the digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine; and

  (b) promote one or more of the following beneficial physiological effects –

  (i) laxation;

  (ii) reduction in blood cholesterol;

  (iii) modulation of blood glucose;

- includes **polysaccharides, oligosaccharides** (degree of polymerisation DP > 2) and lignins
‘Dietary Fibre’ - major types

**Oligosaccharides DP3-9**
*(SCC or low MW Oligos)*
- Galacto-oligosaccharides (GOS)
- Fructans (FOS - fructo-oligosaccharides)

**Polysaccharides (DP 9->1000)**
- Inulin (DP 10-90)
- Resistant starch (RS1-4)
- NSP (cellulose, hemicellulose, pectins, glucans, gums, brans)
What happens to ‘dietary fibre’ in the large intestine? = Colonic Fermentation.

- **Gases**: $\text{CO}_2$, $\text{CH}_4$, $\text{H}_2$
- **Short Chain Fatty Acids**: acetate, butyrate, propionate
- **Selective growth of certain bacteria**
- **Absorption of Ca, Zn, Mg**
- **luminal pH**
- **bulking & laxation effect**
- **Toxic by-products of protein Fermentation ammonia & phenols**
There are ‘fibre specialists’. Different fibre types have different effects—

Isolated ‘fibres’ that have been extensively studied.
- fructans (FOS/inulin), GOS
- RS (Himaize), pectin, guar gum
- psyllium, oats
- wheat bran
- cellulose, sterculia
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<tbody>
<tr>
<td>Laxation</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
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<tr>
<td>Transit time</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Balance of bacteria</td>
<td>+++ bifido</td>
<td>++ RS-butyrate-producing</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>SCFA</td>
<td>+++</td>
<td>+++ RS butyrate</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Lower Amm/phenol</td>
<td>?</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>‘Fibre’ Types</td>
<td>Fructans / FOS, GOS</td>
<td>RS Himaize, pectin, guar</td>
<td>psyllium/Ispaghula, oats.</td>
<td>wheat bran,</td>
<td>cellulose, sterculia,</td>
</tr>
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No single ‘Fibre Supplement’ does everything we want: Need to combine different fibre types.
Combining Wheat Bran with RS: Effects on faecal markers relevant to improved bowel habit and colorectal cancer risk.

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<td>+</td>
<td>+</td>
<td>+++</td>
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<tr>
<td>Transit time</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Balance of bacteria (bifido)</td>
<td>+++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>SCFA</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
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<td>‘Fibre’ Types</td>
<td>FOS, GOS</td>
<td>RS,</td>
<td>psyllium/Isphagula,</td>
<td>Wheat bran,</td>
<td>cellulose,</td>
</tr>
<tr>
<td>Lower Ammonia/phenols</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sterculia,</td>
</tr>
</tbody>
</table>
Location of fermentation events and relevance to CRC: RS

RS only

Rats: Young et al Gastroenterology 1996; Pigs: Govers et al Gut 1999, Muir et al (1)
Location of fermentation events and relevance to CRC: RS

RS only

Distal colon misses benefits of RS fermentation

Rats: Young et al Gastroenterology 1996; Pigs: Govers et al Gut 1999,
Location of fermentation events and relevance to CRC: RS+WheatBran

More starch survives to reach the distal colon (location of most tumours)

Distal colon benefits:

- ↑ SCFA
- ↑ butyrate
- ↓ pH
- ↓ ammonia
- ↓ phenols

RS+WB

Rats: Young et al Gastroenterology 1996; Pigs: Govers et al Gut 1999,
Hypothesis:

That wheat bran will act as a carrier to propel RS into the distal colon

benefits in luminal characteristics and on epithelial biomarkers of CRC risk
Aim:

To investigate in humans of combining wheat bran and RS(Hi-maize) on bowel habit and faecal markers relevant to colorectal cancer risk.
Experimental design: *randomised cross-over*

- **Day 0**: Control
- **Day 19**: +WB 10 g/d
- **Day 26**: +WB 10 g + RS 20 g/d

**Outcome measures**:
- Faecal bulk
- Transit time
- SCFA & butyrate
- Ammonia & phenols
- Starch
Subjects:

- $n = 20$
- 11 men, 9 women
- All had family history of CRC
Results:
Dietary intake (n=20, mean±SEM)

<table>
<thead>
<tr>
<th>(g/d)</th>
<th>Control</th>
<th>WB</th>
<th>WB+RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>92±4</td>
<td>94±4</td>
<td>94±4</td>
</tr>
<tr>
<td>Fat</td>
<td>67±4</td>
<td>70±4</td>
<td>64±3</td>
</tr>
<tr>
<td>Carbohydrate -Digestible</td>
<td>279±13</td>
<td>276±14</td>
<td>278±12</td>
</tr>
<tr>
<td>-‘dietary fibre’</td>
<td>22.5±1.2</td>
<td>29.7±1.4</td>
<td>29.5±1.2</td>
</tr>
<tr>
<td>- dietary fibre</td>
<td>2.5±0.1</td>
<td>1.8±0.1</td>
<td>21.6±1.1</td>
</tr>
<tr>
<td>- RS</td>
<td></td>
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</tbody>
</table>
Bowel-function questionnaire given at conclusion of each dietary period:

Symptoms rated from 0 to 10 (0=none, 3=mild, 6=moderate and 10=severe)
Ease of defecation rated from 0 to 10 (0=easier, 5=normal, 10=more difficult)
Effect of wheatbran (WB) and wheatbran plus resistant starch (WBRS) on faecal output.

* p < 0.05 cf control
Effect of wheatbran (WB) & wheatbran plus resistant starch (WBRS) on transit time & frequency.

mean±SEM, n=20

* P < 0.05 cf control
Effect of wheatbran (WB) & WB plus RS (WBRS) on Total SCFA and Butyrate.

**Total SCFAs**
- C
- WB
- WBRS

**Butyrate**
- *p<0.05 control mean; n=20
Effect of wheatbran (WB) & wheatbran plus resistant starch (WBRS) on faecal phenols and ammonia.

Phenols and Ammonia (conc)

- Total phenols (ug/g)
- Phenols (ug/g)
- p-cresol (ug/g)
- Ammonia (ug/g)

mean; n=20; * p<0.05
Conclusions

• These results show that combining these ‘fibre specialists’ (RS plus wheat bran) is a practical way of supplementing the diet to “improve” luminal conditions.

• **May have therapeutic and/or preventive roles**
  - improve bowel habit (laxation)
  - in diseases of the colonic epithelium (colorectal cancer and Inflammatory bowel disease)
What about gut microbiome: How best to manipulate it?
Prebiotics are "non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth/activity of a limited number of bacteria in the colon."

‘Prebiotics are dietary fibres, but not all dietary fibres are prebiotics.’
**Table: Studies FOS/inulin GOS effects**

<table>
<thead>
<tr>
<th>Prebiotic</th>
<th>Daily dose &amp; duration</th>
<th>No. of subject</th>
<th>Study design</th>
<th>Microflora modulation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inulin (long-chain)</td>
<td>8 g/day, 14 days</td>
<td>9</td>
<td>Placebo controlled, cross-over</td>
<td>Increase in bifidobacteria, small increase in clostridia</td>
<td>Tuohy et al. (2001) [170]</td>
</tr>
<tr>
<td>Inulin</td>
<td>Up to 34g/d 64 days</td>
<td>8</td>
<td>Feeding study</td>
<td>Increase in bifidobacteria</td>
<td>Kruse et al. (1999) [163]</td>
</tr>
<tr>
<td>Inulin</td>
<td>15 g/day 15 days</td>
<td>4</td>
<td>Placebo controlled cross-over</td>
<td>Increase in bifidobacteria</td>
<td>Gibson et al. (1995) [28]</td>
</tr>
<tr>
<td>Inulin</td>
<td>20-40 g/d 19 days</td>
<td>25 elderly</td>
<td>Parallel placebo controlled</td>
<td>Increase in bifidobacteria, decrease in enterococci and enterobacteria</td>
<td>Kleessen et al. (1997) [164]</td>
</tr>
<tr>
<td>FOS</td>
<td>15 g/day 15 days</td>
<td>48</td>
<td>Placebo controlled cross-over</td>
<td>Increase in bifidobacteria, decrease in <em>Bacteroides</em>, clostridia &amp; fusobacteria</td>
<td>Gibson et al. (1995) [28]</td>
</tr>
<tr>
<td>FOS &amp; PHGG biscuits</td>
<td>6.6 g/day FOS 3.4 g/d PHGG for 21 days</td>
<td>31</td>
<td>Placebo controlled, cross-over</td>
<td>Increase in bifidobacteria</td>
<td>Tuohy et al. (2001) [30]</td>
</tr>
<tr>
<td>FOS</td>
<td>0-20 g/day 7 days</td>
<td>40</td>
<td>Placebo controlled parallel</td>
<td>Increase in bifidobacteria (optimal dose 10g/day)</td>
<td>Boulhnik et al. (1999) [156]</td>
</tr>
<tr>
<td>FOS</td>
<td>4 g/d 42 days</td>
<td>12</td>
<td>Feeding study</td>
<td>Increase in bifidobacteria</td>
<td>Buddington et al. (1996) [166]</td>
</tr>
</tbody>
</table>
Prebiotic Effects:

- All studies carried out using purified supplements (FOS, inulin, GOS).
- Major effects are on the increase of *bifido* bacteria.
- Few studies look at the natural sources of ‘prebiotics’ indeed it is generally thought that ‘natural prebiotics (eg. FOS/ GOS) are only present in trace amounts in food’!
Measuring ‘natural prebiotics in food’.

• While establishing our food database for quantifying FODMAPs in food- we have also accumulated a large database on the ‘natural prebiotics’ in food.

• It is clear from our research that fructans/ FOS and GOS are present in significant amounts in many foods.
Natural sources of prebiotics (Oligos)

<table>
<thead>
<tr>
<th>Fruit</th>
<th>GOS</th>
<th>FRUCTAN</th>
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</thead>
<tbody>
<tr>
<td>Watermelon (1 slice)</td>
<td></td>
<td></td>
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<tr>
<td>Custard apple (½ cup)</td>
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<td></td>
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<tr>
<td>Persimmon (1 fruit)</td>
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<td></td>
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<tr>
<td>Grapefruit (1 medium)</td>
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<td></td>
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<tr>
<td>Jerusalem artichoke (1 artichoke)</td>
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<tr>
<td>Leek bulb (½ cup, chopped)</td>
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<td></td>
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<tr>
<td>Onion (½ onion)</td>
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<tr>
<td>Garlic (1 clove)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>GOS</th>
<th>FRUCTAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Split peas, boiled (½ cup)</td>
<td></td>
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<tr>
<td>Baked beans (½ cup)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red kidney beans, boiled (½ cup)</td>
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<td></td>
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<tr>
<td>Cashews (20 nuts)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Nuts and legumes</th>
<th>GOS</th>
<th>FRUCTAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumpernickel bread (2 slices)</td>
<td></td>
<td></td>
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<tr>
<td>Dark rye bread (2 slices)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gnocchi (1 cup, cooked)</td>
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<td></td>
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<tr>
<td>All bran (½ cup)</td>
<td></td>
<td></td>
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<tr>
<td>Cous cous (1 cup, cooked)</td>
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<td></td>
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<tr>
<td>Weet bix (2 biscuits)</td>
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</table>

Short-chain carbohydrate content (g/serving)
NSP, RS and oligos (fructan/GOS) are present in foods:

- White bread
- Multi-grain bread
- Rye bread
- Pasta
- Cornflakes
- Kidney beans
- White rice
How we currently measure ‘dietary fibre’ will not include all of these.

- The definition of ‘Dietary Fibre’ includes polysaccharides, oligosaccharides (degree of polymerisation > 2) and lignins.
- The common AOAC approved methods mostly in use do not measure all of these.
Total dietary fibre analysis

Classic AOAC 985.29/991.43 method

Non-starch polysaccharides

Resistant Starch (RS)

Low MW oligosaccharides

DIETARY FIBRE (DF)

Insoluble HMW (IHMWDF)
- Cellulose
- Lignin
- Insoluble pentosan
- Insoluble pectin
- β-glucans (yeast/moulds)
- ...

Soluble HMW (SHMWDF)
- Hydrocolloids
  - Carrageenan
  - Gums
    - Guar
    - Locust bean
    - Cassia
    - Arabic
    - ...
- Soluble pentosans
- Soluble pectins
- Cereal β-glucan

RS 1
Physical inaccessible starch

RS 2
Resistant starch granules

RS 3
Retrograded Starch

RS 4
Chemically modified starch

Inulin

Fructose oligosaccharide (FOS)

Galactose oligosaccharide (GOS)

Polydextrose

Resistant Maltodextrin
Total dietary fibre analysis

DIETARY FIBRE (DF)

AOAC 2009.01

High Molar Weighth (HMWDF)

- Insoluble HMW (IHMWDF)
  - Cellulose
  - Lignin
  - Insoluble pentosan
  - Insoluble pectin
  - β-glucans (yeast/moulds)
  - ...

- Soluble HMW (SHMWDF)
  - Hydrocolloids
    - Carrageenan
  - Gums
    - Guar
    - Locust bean
    - Cassia
    - Arabic
    - ...
  - Soluble pentosans
  - Soluble pectins
  - Cereal β-glucan

Resistant Starch (RS)

- RS 1
  - Physical inaccessible starch
- RS2
  - Resistant starch granules
- RS3
  - Retrograded Starch
- RS4
  - Chemically modified starch

Low Molar Weight (LMWDF = prebiotic)

- Inulin
- Fructose oligosaccharide (FOS)
- Galactose oligosaccharide (GOS)
- Polydextrose
- Resistant Maltodextrin
CONCLUDE: How much of these ‘dietary fibres’ do you need for health benefits?

**RECOMMENDED**
Dietary fibre 25-30g/d

**NO SET RECOMMENDED LEVEL**
- RS \( \sim 15-20g/d \) to get physiological benefits
- FOS, inulin, GOS (selective growth of bacterial species) \( \sim 4-15 \) gm

Individuals who limit their intake of cereal and grains while following certain diets: e.g., Gluten-free diet, paleo- diet, Low FODMAP diet – may not be getting enough ‘prebiotic fibre’
Conclusions:

Whole foods contain all fibre types. More research is required using whole foods.

Super Foods that are naturally high in dietary fibre, RS and prebiotics include; rye, barley and legumes, legumes....

Re-think about the way we measure dietary fibre—So that all of these ‘fibres’ in foods can be included.
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