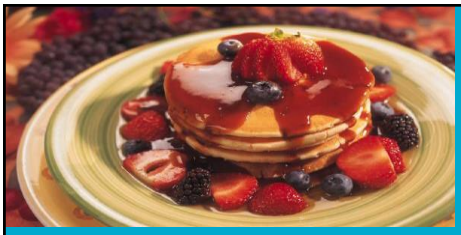

Dietary Fibre – Much More than Roughage

DAVID TOPPING, HEALTH AND BIOSECURITY
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Fibre and the Community

Diet/lifestyle-related conditions cause most premature morbidity and mortality which translates clinically to patient numbers.

These diseases are appearing very rapidly in developing countries – genetic factors are of minor importance and lifestyle is the dominant determinant.

Epidemiology shows that dietary fibre consumption lowers risk in obvious (eg colo-rectal cancer) conditions while the microbiome is involved in unexpected (eg autism, Parkinson's) ones.

The data show also that fibre consumption is generally sub-optimal which is why health agencies, world-wide, encourage eating more fibre-rich foods to lower risk.

Fibre – The New Paradigm

For over 40 years of health authorities have encouraged consumers to eat more fibre.

Australians in general have followed this advice and increased their consumption, largely from cereals and vegetables.

While fibre has proved to be an effective laxative, rates of serious diseases (notably bowel cancer) have gone up, contrary to expectations.

Fibre has been seen as an indigestible bulking agent, that idea is changing with recognition that important fibre components are fermented by the large bowel bacteria.

Many of the benefits ascribed to fibre are actually due to this fermentation and its products.

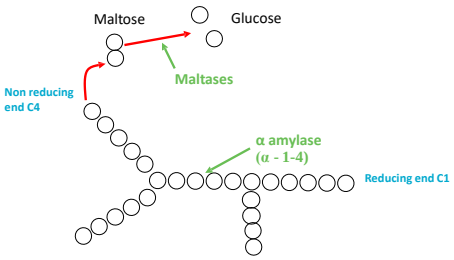
The Adult Digestive System

- The stomach and small intestine digest and absorb nutrients directly.
- The large bowel absorbs the products of bacterial fermentation.
- Fibre is not digested in the upper gut and enters the large bowel, explaining its faecal bulking action.

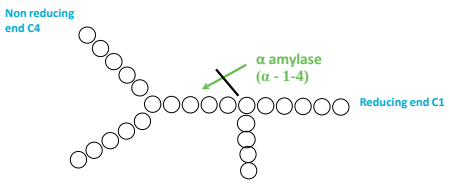
Dietary Fibre Components

- Human small intestinal enzymes can only digest one food polysaccharide - starch.
- This glucose polymer is hydrolysed in the upper gut and the glucose which is released is absorbed into circulation.
- Dietary fibre consists largely of plant non-digestible carbohydrates
  - Non-starch polysaccharides (NSP) – give plants structure
  - Resistant starches (RS) – starch not digested in the upper gut
  - Oligosaccharides – eg fructans used as prebiotics
- All of these pass through the small intestine into the large bowel.

Small Intestinal Starch Digestion



Small Intestinal NSP Digestion - None



The Fibre Hypothesis

- Populations (eg Africans) eating traditional whole grain foods (ie including the germ and bran) as staples have low rates of diet-related diseases – colo-rectal cancer (CRC), constipation, irritable bowel syndrome (IBS) etc.
- Early observational studies contrasted the high rates of these conditions in Europeans who ate highly refined (ie low fibre) foods.
- The analytical technology at the time only gave a measure of insoluble, structural fibres such as those found in cereal grain seed coats.
- The hypothesis was that a deficiency of fibre caused diet-related illnesses – largely through bulking ie "roughage".

The Fibre Concept Then

Dietary Fibre and Improved Regularity in Older People

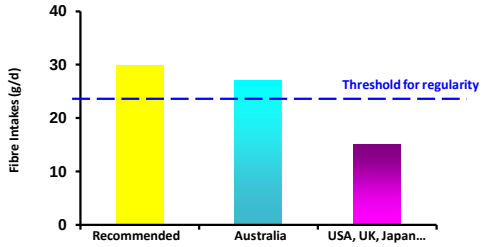
	Fibre	Aperients	Bowel Actions	Average time to stop aperient use
	(g/d)	(no/d)	(no/d)	(wk)
Baseline	13.9	1.3	0.9	
End	25.4	0	1.4	5.4

Source: Baghurst et al (1984)

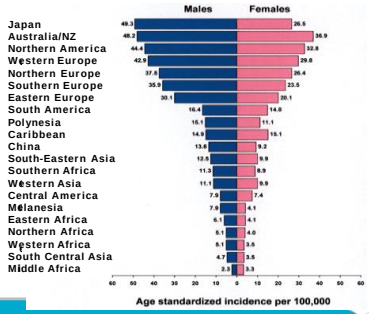
The Australian Fibre Experience

- Australian consumers have taken to fibre concept in a big way with relatively high population levels of intake.
- Colo-rectal cancer (CRC) is an epithelial malignancy, >80% of new cases are sporadic.
- Fibre was believed to protect by lowering cell exposure to carcinogens by diluting and binding of toxic agents.
- However, despite our high intakes, largely of cereal and vegetable fibre, our CRC rates are high and rising – the Australian fibre paradox.
- Fibre promotes laxation very well but for most other conditions the "roughage" model is a big disappointment.

Population Fibre Intakes



Global Colorectal Cancer Rates



Source: Global cancer statistics 2002

So What Went Wrong?

- Applying modern, enzymatic/chromatographic analytical procedures shows that the Africans ate little fibre (probably14 g/person/day) but it is the way they consumed their staple whole grain maize or sorghum flour that counts.
- Like many agrarian societies, starchy cereal foods are staples which they cook in water to make them digestible but then allow them to cool (ie staling).
- This storage lets the starch chains reassociate making them resistant to human small intestinal digestion.
- The starch which passes into the large bowel is resistant starch (RS) which is fermented extensively by the microbiota generating short chain fatty acids (SCFA).
- SCFA are important metabolic fuels for the viscera and modern convenience foods are generally highly refined and are processed fresh and so are low in RS.
- This results in an SCFA deficiency so the aim is to feed a hungry microbiome through providing RS.

The Human Large Bowel Microbiome

- Colonic bacteria are significant contributors to the human digestive system and their numbers exceed those of the human host, probably 10-fold.
- Colonisation occurs at birth.
- Fermentation profile differs with lifecycle stage:
  - Breast fed infants – liquid phase fermentation of milk oligosaccharides, facultative anaerobes, little or no propionate and butyrate.
  - Post weaning – solid and liquid phase fermentation of fibre polysaccharides (and other dietary components), anaerobes, short chain fatty acids (SCFA) as key products.

Essentials of SCFA production

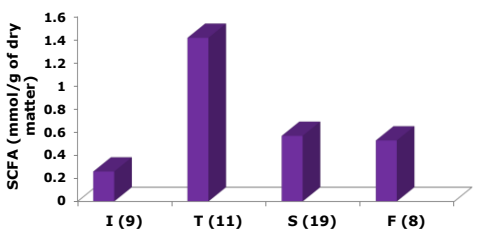
- SCFA supply virtually all energy for obligate herbivores .
- Large bowel SCFA concentrations are as high in omnivores (eg rats and pigs) as in the rumen.
- SCFA levels are also high in human stomal effluent making them important visceral fuels.
- The bacteria are anaerobes and oxygen is lethal to them, gas production (ie flatus) is essential for their survival by excluding oxygen.
- Humans do not make gas, it is a bacterial product.
- Fibres are fermented to different degrees
  - Highly fermentable – lentils, navy beans
  - Poorly fermented – psyllium, cereal brans

$C_x(H_2O)_y + N +$ Bacteria

↓

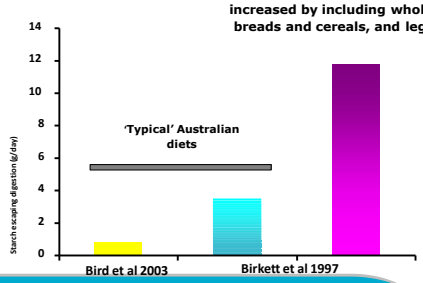
Acetate, Propionate and Butyrate + CO_2 + H_2+ CH_4 + More Bacteria + H_2O

SCFA in Human Stomal Effluent and Faeces



Modern Diets are low in RS

Modified diet – Resistant starch increased by including wholegrain breads and cereals, and legumes



SCFA and Gut Health

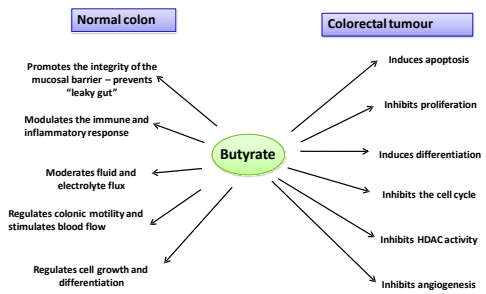
- Collectively, SCFA improve the colonic environment but the major acids have more specific effects.
  - Acetate (2 carbons) – assists in controlling pathogen overgrowth and diarrhoea.
  - Propionate (3 carbons) – modulates colonic muscular activity.
  - Butyrate (4 carbons) – investigated the most with a wealth of experimental data showing great promise, RS fermentation favours its production.
- While these are promising for long term risk reduction, data of clinical benefit are accumulating and no major adverse effects have been reported.
- Butyrate may be of benefit in IBS and mood disorders
- Probiotics are important in early life but do not raise butyrate in adults – this is why reported benefits are inconsistent.
- Most current prebiotics (eg inulin, FOS) do not stimulate the bacteria which produce butyrate.

Faecal SCFA in pigs fed *B animalis* and a low or high amylose starch with or without FOS

SCFA	Low amylose starch		High amylose starch	
(mmol/kg)	- *FOS*	+ *FOS*	- *FOS*	+ FOS
Total	88.0	85.4	125.0	111.5
Acetate	51.6	50.9	60.2	54.5
Propionate	21.7	20.9	37.3	33.1
Butyrate	11.3	10.2	18.9	16.2

Mean of 11 observations per group

Butyrate and the Colon



Feeding a Hungry Microbiome

- Modern foods are generally low in fermentable fibre but new grains are being developed as ingredients to fill the gap.
- Current foods and ingredients include
  - BARLEYMax
  - Greenwheat freekeh
  - Whole grains – brown rice, stone ground wheat, rye, sourdough breads
  - Cooked and cooled starchy foods – polenta, potatoes, spaghetti
  - Legumes – baked (navy) beans, hummous, lentils, chickpeas
  - Unripe bananas and green banana flour
- Fibre mixtures work better than single ones (ie fermentable + other types).

Human Feeding Study - Faecal SCFA Output

Diet	Faecal SCFA excretion (mmol/d)			
	Acetate	Propionate	Butyrate	Total
Refined wheat	9.2[a]	1.8[a]	2.8[a]	14.4[a]
Wholemeal wheat	10.7[ab]	2.3[ab]	3.8[a]	17.3[ab]
BARLEYmax™	13.7[b]	2.7[b]	5.4[b]	22.6[b]

Take Home Messages

- Fibre has established benefits for regularity.
- The emphasis is shifting away from fibre only as roughage with more emphasis on fermentable fibres.
- Eating more foods to feed the microbiome promises extra benefits through SCFA production.
- Large bowel production of CO_2+, H_2 and CH_4 ensures survival of the microbiome.
- These gases do not smell, any bad odours such as H_2S come from non-carbohydrate sources eg protein.
  - Crepitation – noisy but harmless
  - Flatulence – silent but deadly
- For more information Google the animation "The Hungry Microbiome".