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Dept. Food Sciences
University of Parma, Italy

Glycemic Impact:
Eat the Right Carbs, not “No Carbs”

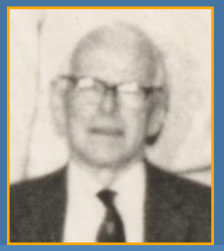
Carbohydrate foods

- **Main energy sources for human diets**
- **Are Different in**:
  - *Ratio and nature of Starch and Sugars*
  - *Amount and nature of Dietary Fibre*
  - *Nature and bioactivity of Non-carbohydrate by-passengers*
- **Act Differently on:**
  - *Glycemic impact*
  - *Blood lipids*
  - *Satiety and energy regulation*
  - *Laxation*
  - *Hormones, incretins and inflammation mediators*
  - *Oxidative stress, platelet aggregation, endothelial function*
  - *Microbiota composition and activity*

CHO quality: a long story

Vahouny Symposium on Dietary Fibre.
Washington DC, May 1988

Dietary Fibre



Denis Burkitt

Vahouny Symposium on Dietary Fibre.
Washington DC, May 1988

1950

1970

"Dietary fibre are the remnant of plant components that are resistant to hydrolysis by human alimentary enzymes"

- Hipsley EH, *BMJ, 1953, (2):420-22*;
- Burkitt et al. *Lancet, 1972, 1408-12*;
- Trowell HC, *Lancet, 1972, 503*

The concept evolves….

1985

“Edible plant material not hydrolysed by the endogenous enzymes of the human digestive tract”: method of analysis (Prosky et al., 1985) **accepted by AOAC** (AOAC method 985.29 and following)

The concept evolves….

2000

"Dietary fiber is the edible parts of plants or 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". *(AACC), 2000*

The concept evolves….

2001

"1. ***Dietary Fiber*** consists of **non-digestible carbohydrates and lignin** that are intrinsic and intact in plants.

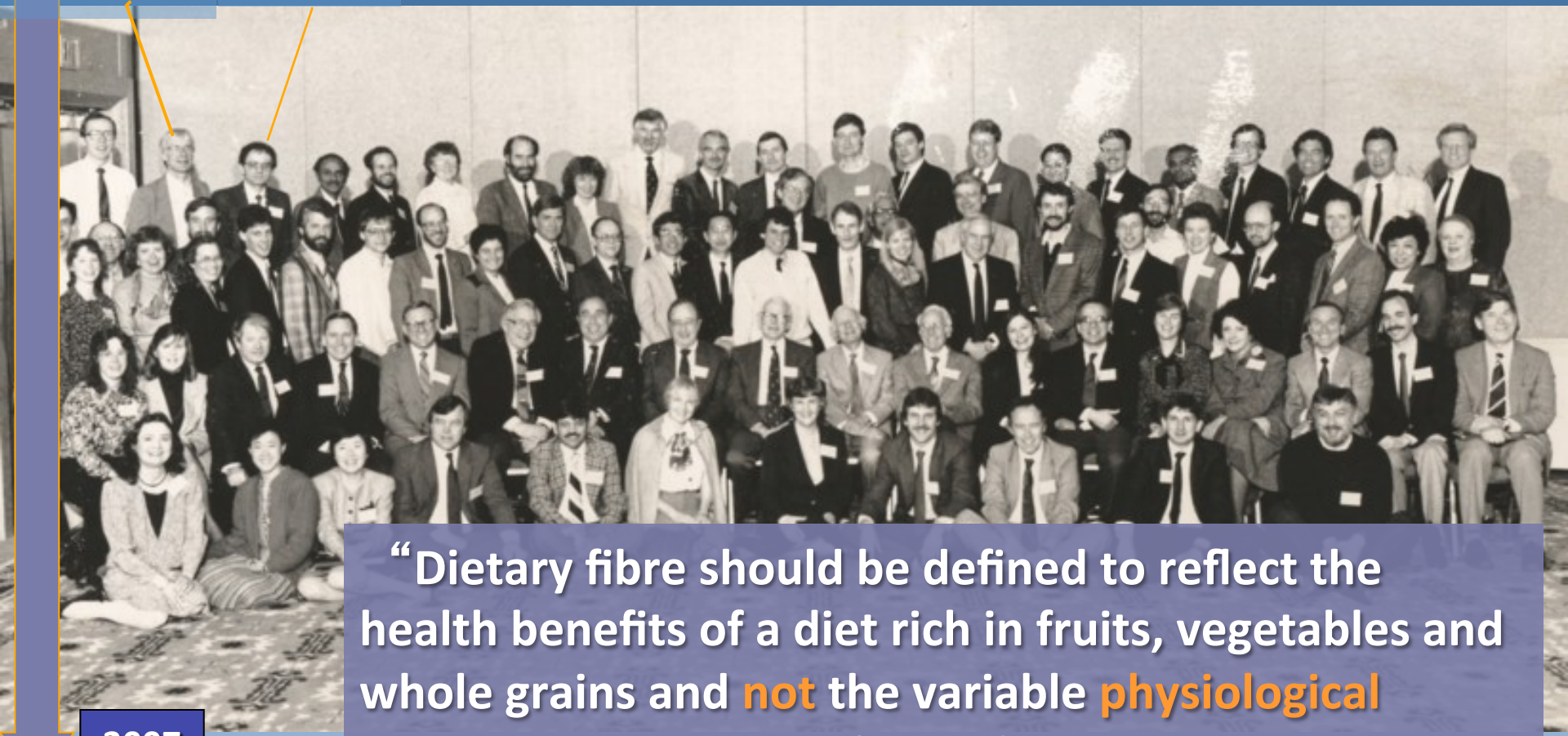
2. ***Added Fiber*** consists of **isolated, non-digestible carbohydrates** that have beneficial physiological effects in humans.

3. ***Total Fiber*** is the sum of ***Dietary Fiber*** and ***Added Fiber.***". *(I.O.M.), 2001*

…then goes back to the origin

John Cummings

Hans Englyst



2007

"Dietary fibre should be defined to reflect the health benefits of a diet rich in fruits, vegetables and whole grains and **not** the variable **physiological properties** or health effects of the various carbohydrate types." *(FAO/WHO), 2007*

Average consumer

Dietary carbohydrate quality:

- It's all about veggies and whole grains?
- Is dietary fibre the only marker of healthy carbs?

From DF to the Glycemic Index

Dietary fibres, fibre analogues, and glucose tolerance: importance of viscosity

DAVID J A JENKINS, THOMAS M S WOLEVER, ANTHONY R LEEDS, MIGUEL A GASSULL, PETER HAISMAN, JANG DILAWARI, DAVID V GOFF, GEOFFREY L METZ, K G M M ALBERTI

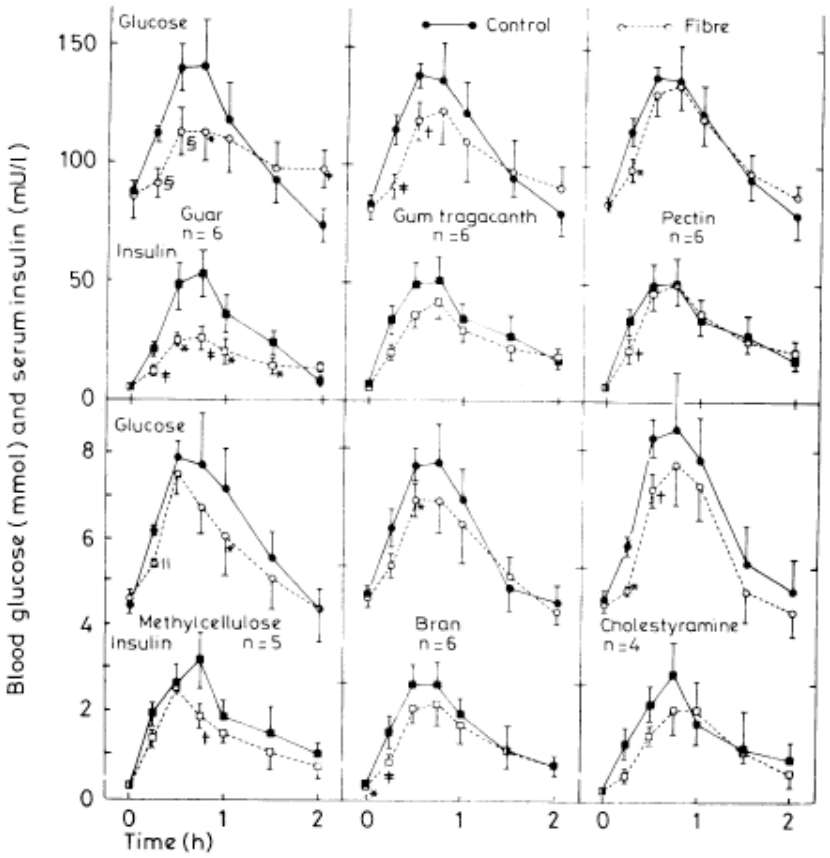


FIG 1—Mean blood glucose and serum insulin concentrations of volunteers after taking control and fibre-containing test meals. Difference from control: *P < 0·05; †P < 0·02; ‡P < 0·01; §P < 0·002; P < 0·001.

Conversion: SI to traditional units—Glucose: 1 mmol/l ≈ 18 mg/100 ml.

ISI top cited paper

The American Journal of Clinical Nutrition 34: MARCH 1981, pp. 362–366. Printed in U.S.A.

Glycemic index of foods: a physiological basis for carbohydrate exchange[1–3]

David J. A. Jenkins,[4] D.M., Thomas M. S. Wolever,[5] M.Sc., Rodney H. Taylor,[6] M.R.C.P., Helen Barker, B.Sc.,[6] S.R.D., Hashmein Fielden,[6] S.R.N., Janet M. Baldwin,[6] M.R.C.P., Allen C. Bowling,[5] Hillary C. Newman,[5] B.A., Alexandra L. Jenkins,[5] and David V. Goff,[5] M.Biol.

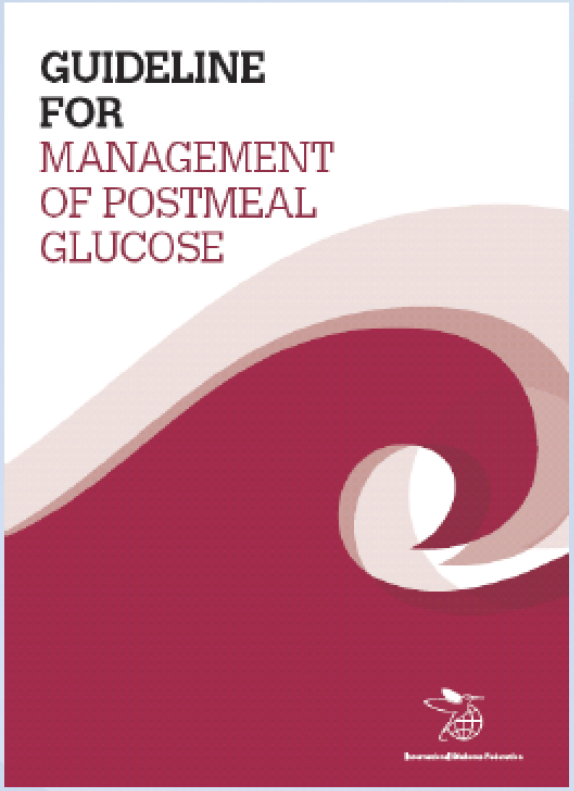
ABSTRACT To determine the effect of different foods on the blood glucose, 62 commonly eaten foods and sugars were fed individually to groups of 5 to 10 healthy fasting volunteers. Blood glucose levels were measured over 2 h, and expressed as a percentage of the area under the glucose response curve when the same amount of carbohydrate was taken as glucose. The largest rises were seen with vegetables (70 ± 5%), followed by breakfast cereals (65 ± 5%), cereals and biscuits (60 ± 3%), fruit (50 ± 5%), dairy products (35 ± 1%), and dried legumes (31 ± 3%). A significant negative relationship was seen between fat ($p < 0.01$) and protein ($p < 0.001$) and postprandial glucose rise but not with fiber or sugar content. *Am. J. Clin. Nutr.* 34: 362–366, 1981.

KEY WORDS Carbohydrate exchange, dietary carbohydrate, dietary fiber, blood glucose, diabetes

ISI top cited paper

Guideline for PPG management was published by the IDF in 2008

Updated in 2011



International Diabetes Federation

Is postprandial hyperglycaemia harmful?

Conclusion	Evidence grade
Postprandial and postchallenge hyperglycaemia are independent risk factors for macrovascular disease	[Level 1+]
Postprandial hyperglycaemia is associated with: Increased risk of retinopathy, increased CIMT, decreased myocardial blood volume/blood flow, increased risk of cancer, impaired cognitive function in the elderly Postprandial hyperglycaemia causes oxidative stress, inflammation and endothelial dysfunction	[Level 2+]

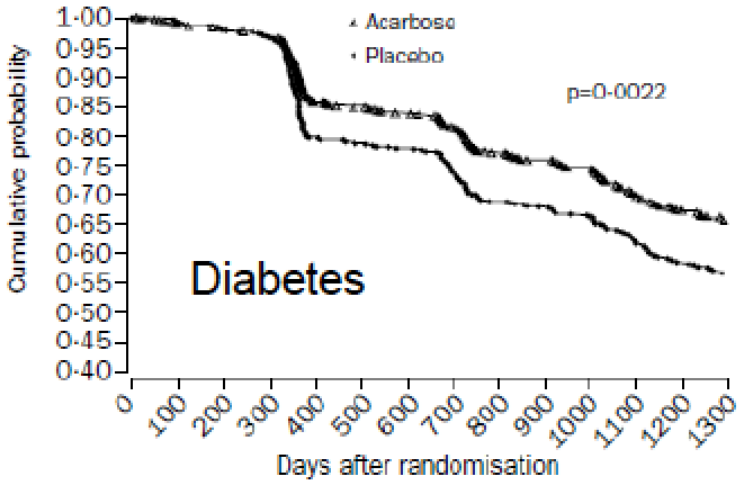
CIMT = carotid-intima-media thickness

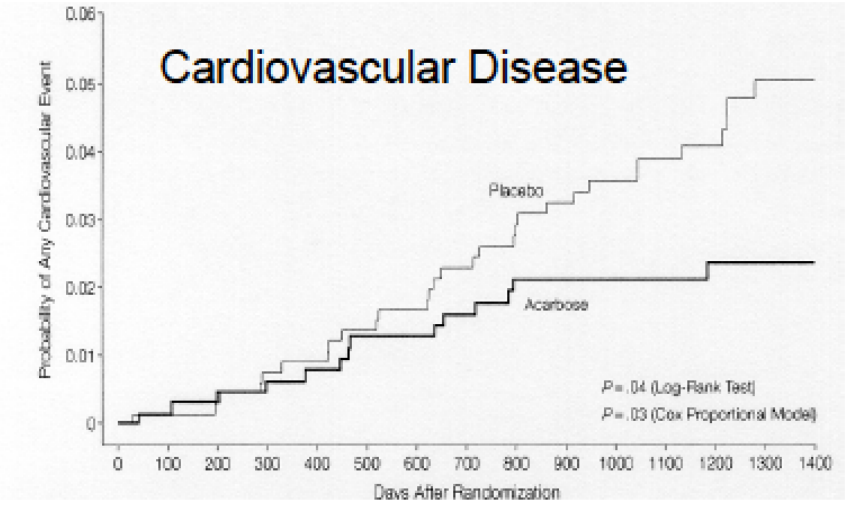
Which therapies are effective in controlling postprandial plasma glucose?

Conclusion	Evidence grade
Diets with a low glycaemic load are beneficial in improving glycaemic control	[Level 1+]
Several pharmacological agents preferentially lower postprandial plasma glucose	[Level 1++]

Treatment of IGT with:

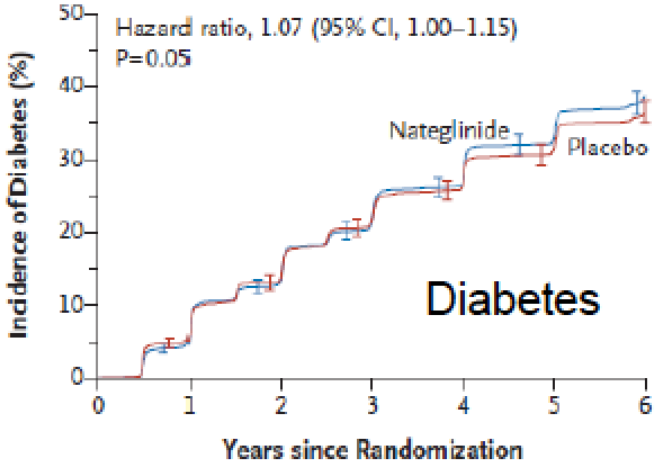
Acarbose

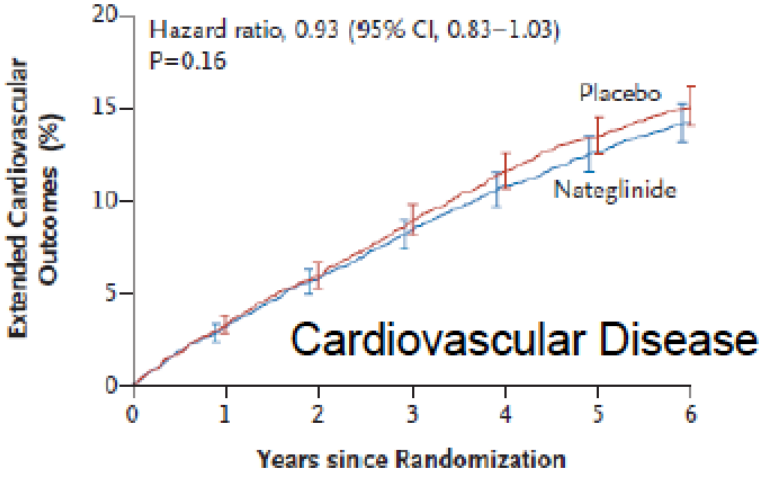




Lancet 2002;359:2072. & JAMA 2003;290:486.

Nateglinide





New Eng J Med 2010;362:1463.

Meta-analyses on fibre sources, GI/GL and health: Summary of main results

	Cancer	CVD	T2D	Total Mortality*
GI - GL	(some site) ✔✗ (GI/GL)	(F.) ✔ (GI) (M.) ✗	✔ (GI) ✔ (GL)	
FRUIT	(some site) ✔✗	✔	✗	
VEGETABLE	(some site) ✔✗	✔	✗ ✔(Green)	
WHOLE GRAINS	✗	✔	✔ (Grain) ✗ (Germ)	
TOTAL FIBRE	(some site) ✔✗			
FIBRE FROM FRUIT	✗			✗
FIBRE FROM VEGETABLES	✗			✗
FIBRE FROM GRAINS	✗			✔ (different causes)

Park Y. Et al. JAMA, 2005
Aune D. Et al. Gastroenterology, 2011
Gnagnarella P. Et al. AJCN 2008

Daucher L. Et al. J Nutr, 2006
Mellen P. Et al. NMCD, 2008
Mirrahimi A Et al. JAHA, 2012

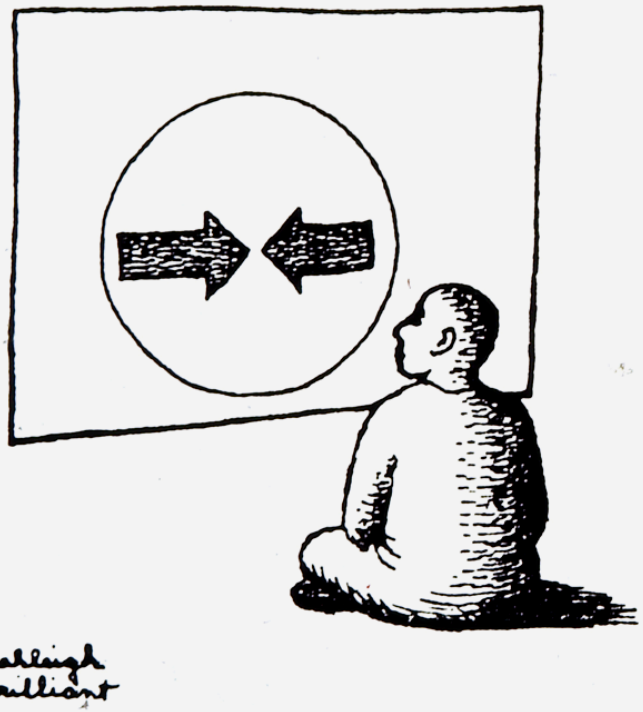
Munter J. Et al. PLOSMed, 2007
Carter P. Et al. BMJ, 2010
Barckay AW. Et al. AJCN, 2008
Livesey G. Et al. AJCN, 2013

*NIH-AARP
Diet and health study. 2011

GI and DF: how do they work?

- Quest for mechanisms

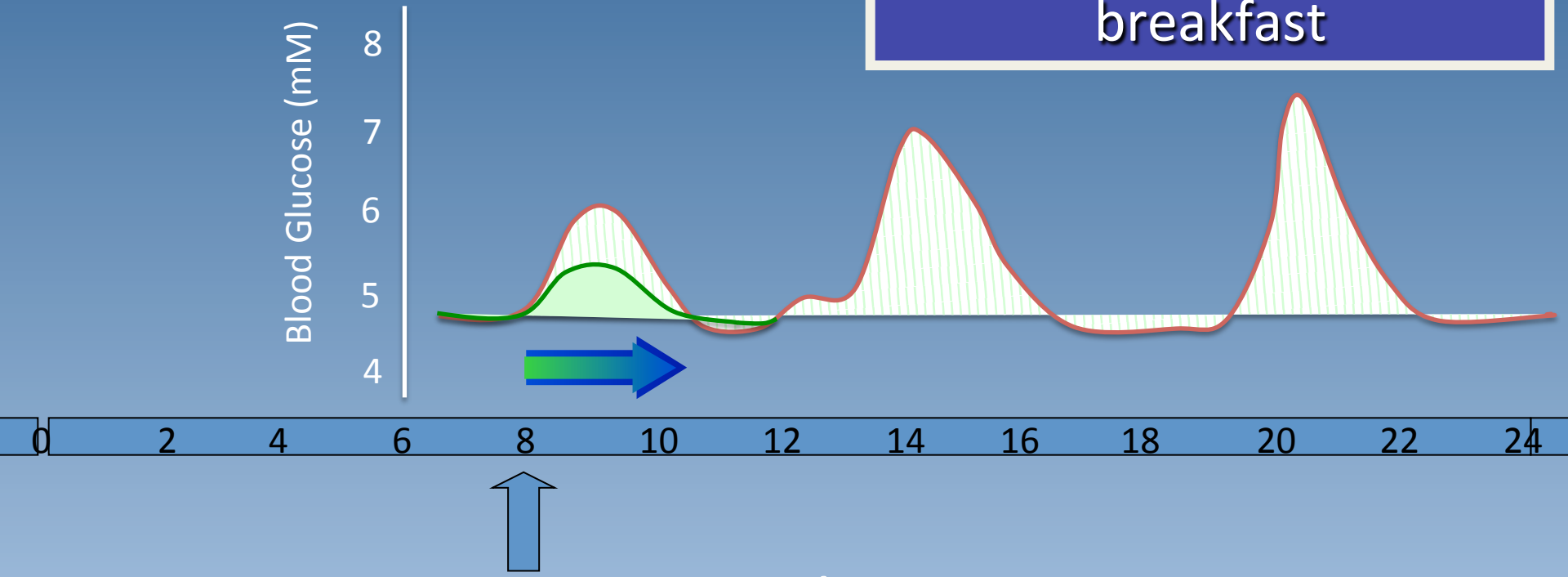
- Nutrient flux (digestion, absorption)
- Hormone response
- Incretin response
- Colonic fermentation
- Microbiota modulation
- Liver function
- Inflammation
- Glucose excursions vs. glucose levels



I don't have any solution, but I certainly admire the problem.

Acute meal studies (i.e. the postprandial phase)

GI typically measured as acute effect after a standardized 50g CHO breakfast



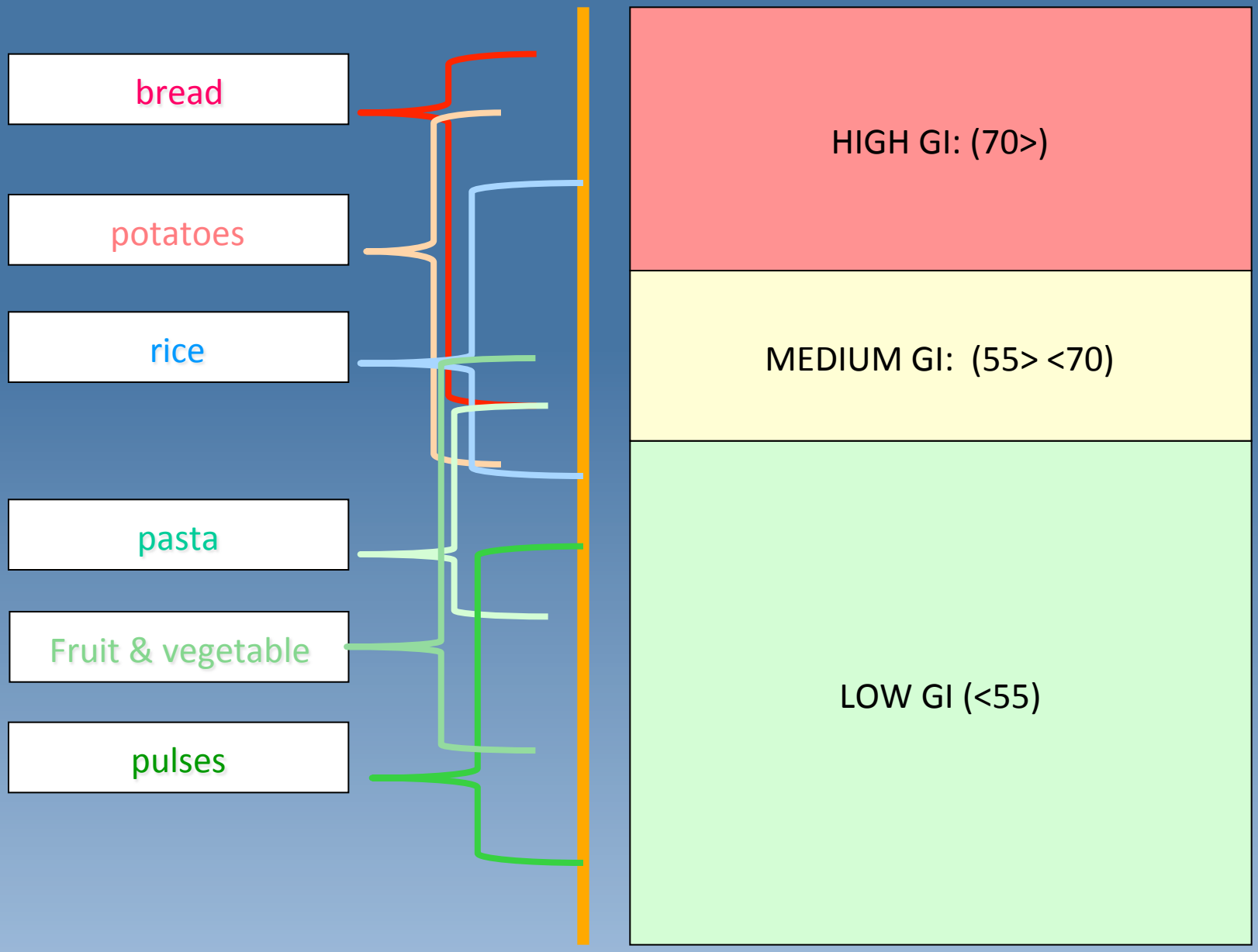
GI = IAUC test / control (glucose) %

Remember: Methods *do* matter

- GI is precisely defined by the **ISO** (International Organization for Standardization) **method 26642:2010**
- The GI is both a **standardized** glycemic response (based on an equal amount of available carbohydrate) and a **relative** glycemic response (relative to a referent food).
- Therefore, GI is a **property of the food** itself .
- Carbohydrate foods that are digested, absorbed and metabolized quickly are considered **high GI foods (GI≥70 on the glucose scale)** whereas those that are digested, absorbed and metabolized slowly are considered **low GI foods (GI≤55 on the glucose scale).**

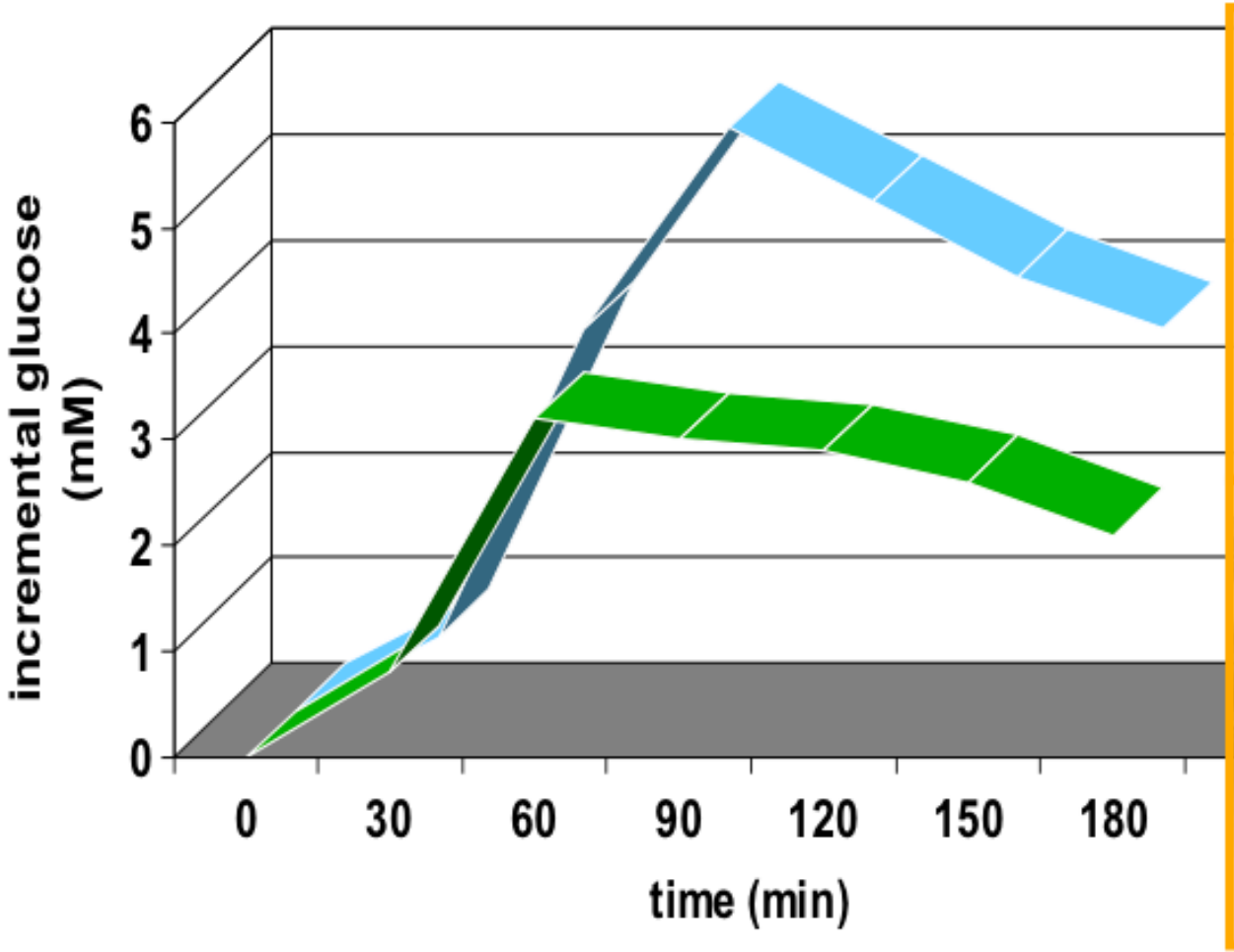
From Glycemic Index to Glycemic Load

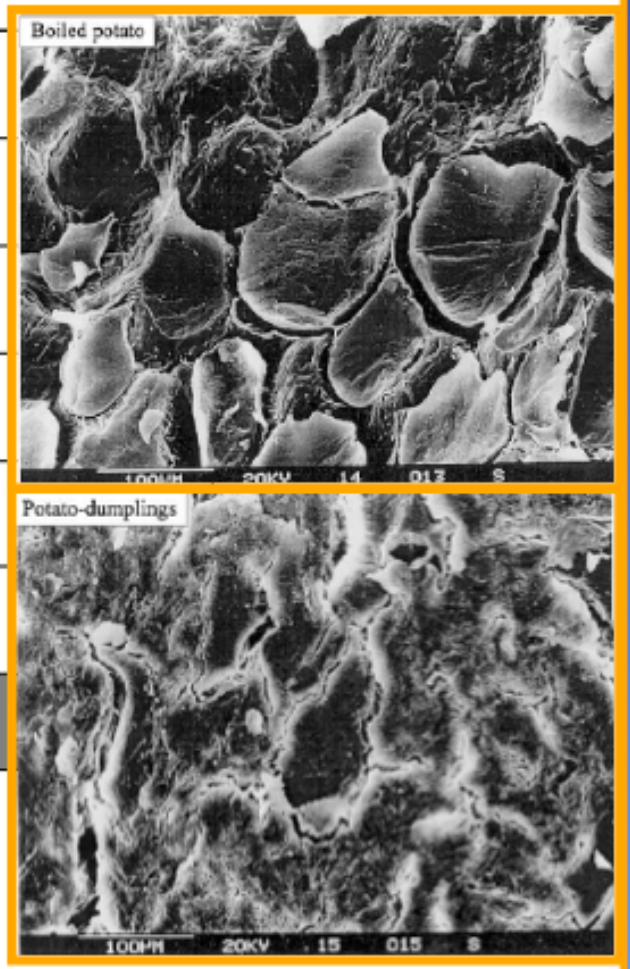
- GL = **GI x available carbohydrate/given amount of food**.
- Available carbohydrates can have different modes of expression: g per serving, g per 100g food, g per day intake, and g per 1000 kJ or 1000 kcal.
- Thus GL has corresponding units of g per serving, g per 100 g food, and g per 1000 kJ or 1000 kcal, **dependent on the context in which GL is used**
- To reduce GL, you may either **reduce CHO or reduce GI.**
- Guess what: the two strategies are **not** equivalent….


bread
potatoes
rice
pasta
Fruit & vegetable
pulses
HIGH GI: (70>)
MEDIUM GI: (55> <70)
LOW GI (<55)

Food processing

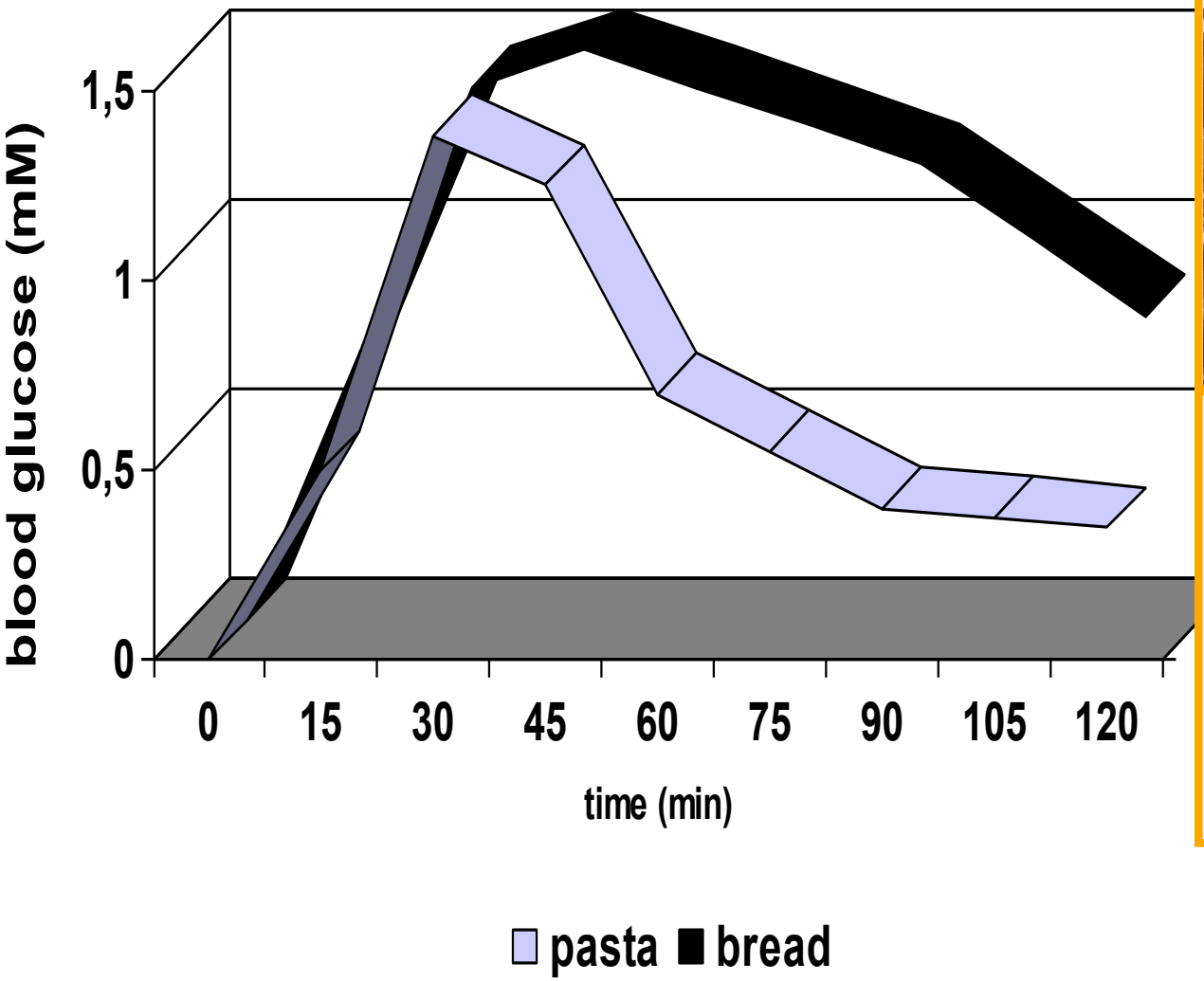
Processing, either industrial or domestic, affects food structure..

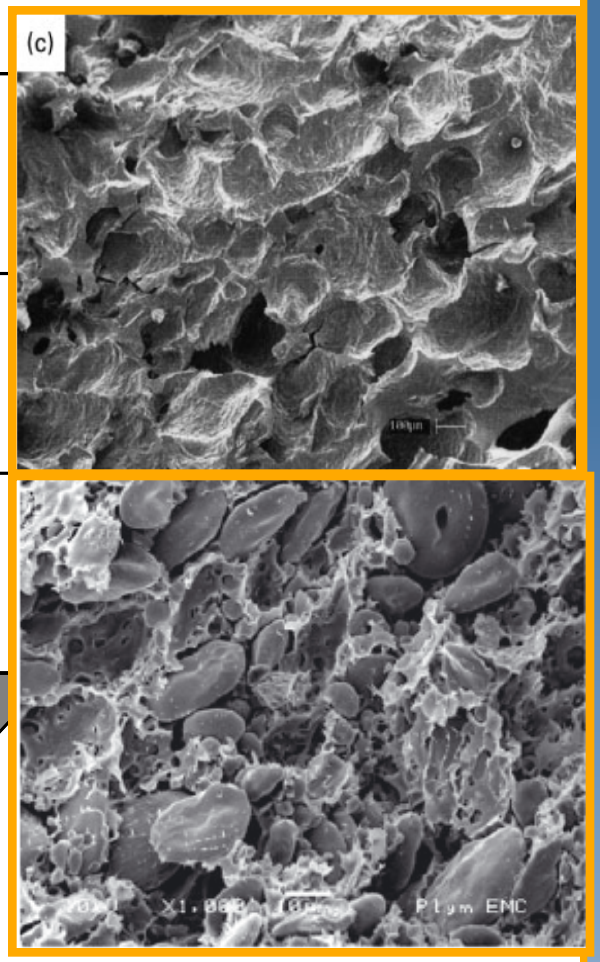




Adapted from Riccardi et al, *nutr Rev* 2003; (61): s56-s60

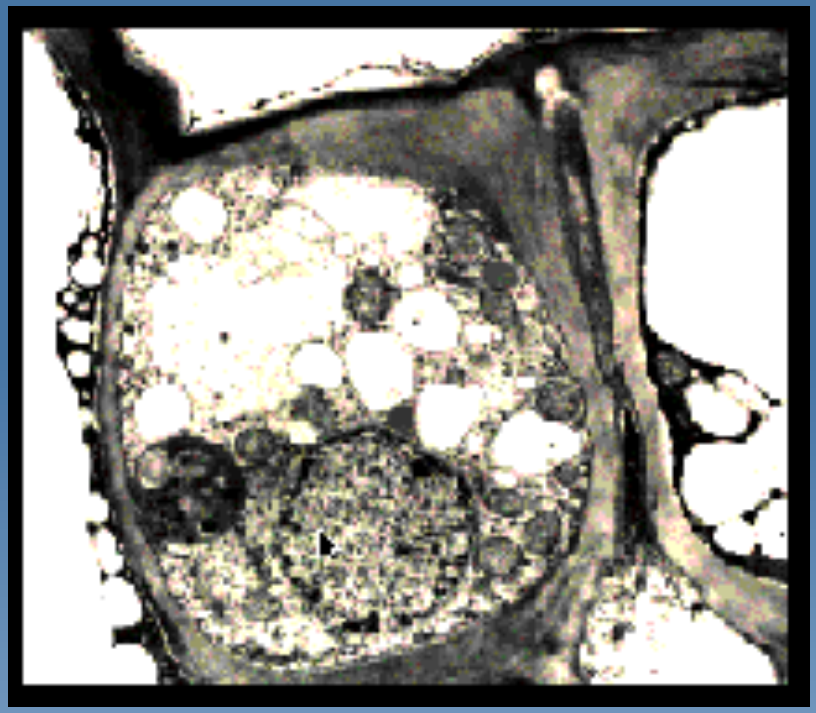
From Giacco *et al*, *Br J Nutr* 2001; 85: 33-40





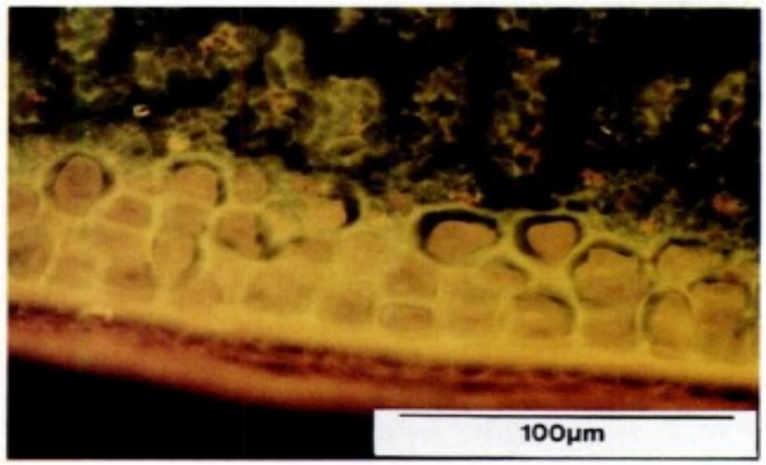
From Cleary & Brennan, *Int J Food Sci Tec* 2006; 41: 910-18

Effect of maintaining intact plant cell wall



Plant cell wall reduces starch accessibility to α-amylase (RS_1).....

Barley / legumes cell-wall (Ileostomists studies)



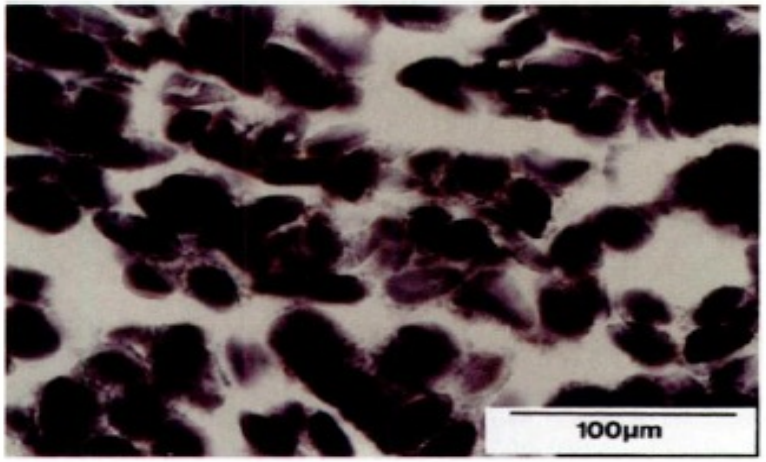
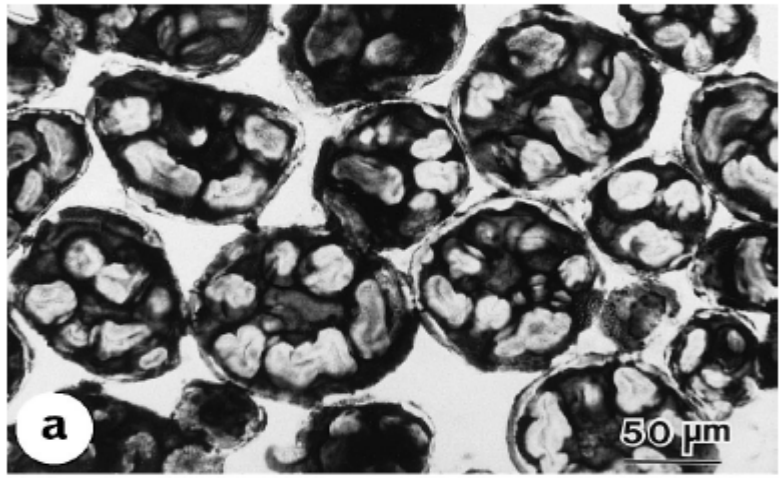


FIG 4. Light micrograph of cereal remnant in ileostomy effluent after flaked barley was eaten. Top: remnant stained with acridine orange showing granules of starch inside cereal endosperm cells, with three tissue layers from bottom to top being the bran, aleurone, and endosperm. Bottom: a similar remnant stained with iodine to identify the granules as starch.

Livesey et al. Am J Clin Nutr 1995; (61): 75-81



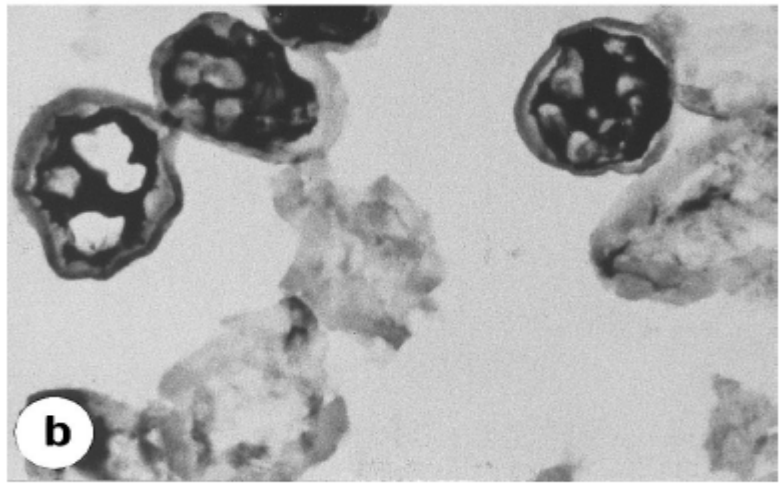


FIGURE 1 Light microscopy pictures of cotyledonar cells from (*a*) cooked beans and (*b*) from human ileal content recovered 3 h after ingestion of the beans.

Noah et al. J Nutr 1998; (128): 977-85

…. and the rate of starch digestion

Whole and ground kidney beans + bread made with whole and ground wheat kernels

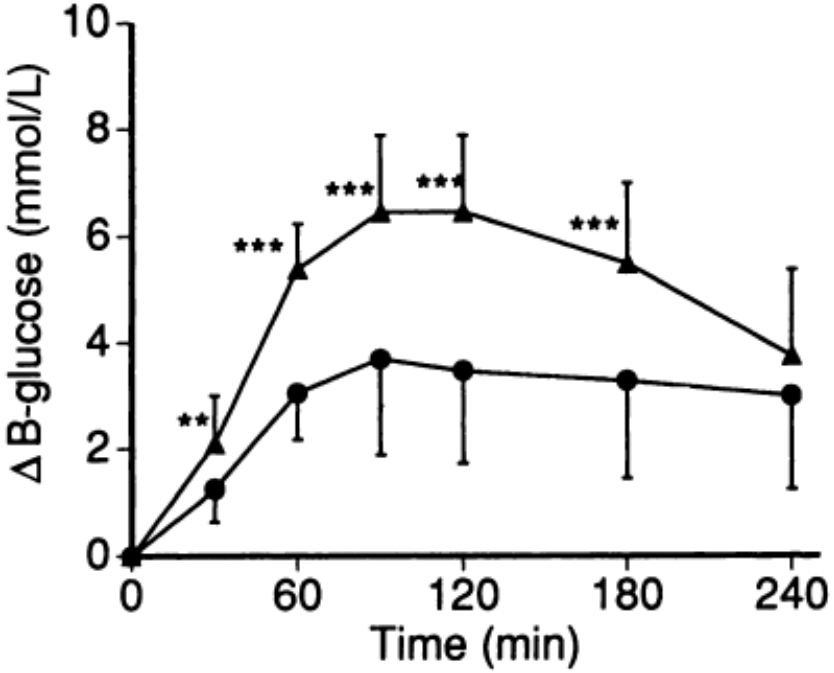


FIGURE 3. Increments of blood glucose in patients with non-insulin-dependent diabetes mellitus after consumption of the low-GI cereal/bean meal (●——●) compared with the high-GI cereal/bean meal (▲——▲). Areas under the curve (area units) for the low-GI cereal/bean meal and the high-GI cereal/bean meal were 93 ± 37 and 160 ± 32, respectively. $\bar{x}$ ± SD. ** $P < 0.01$, *** $P < 0.001$.

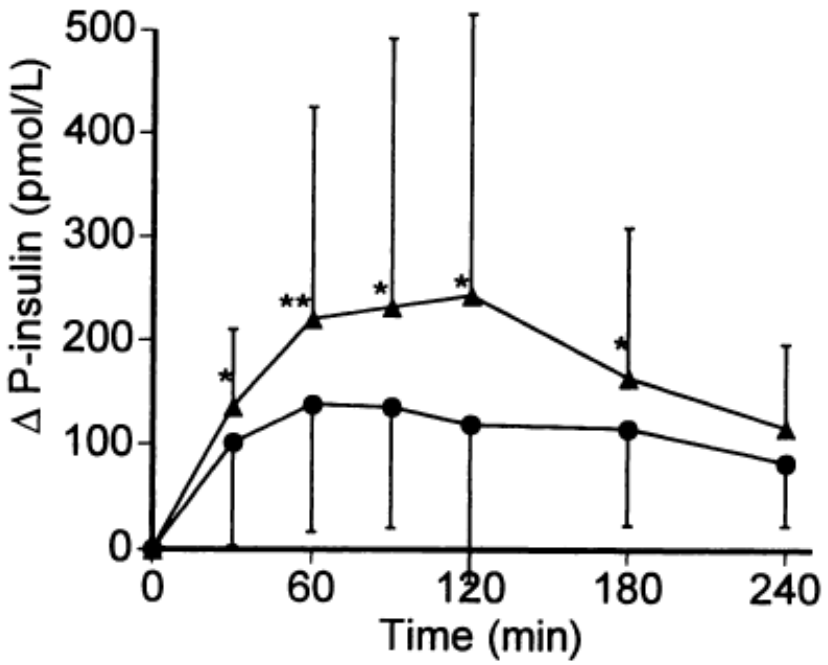
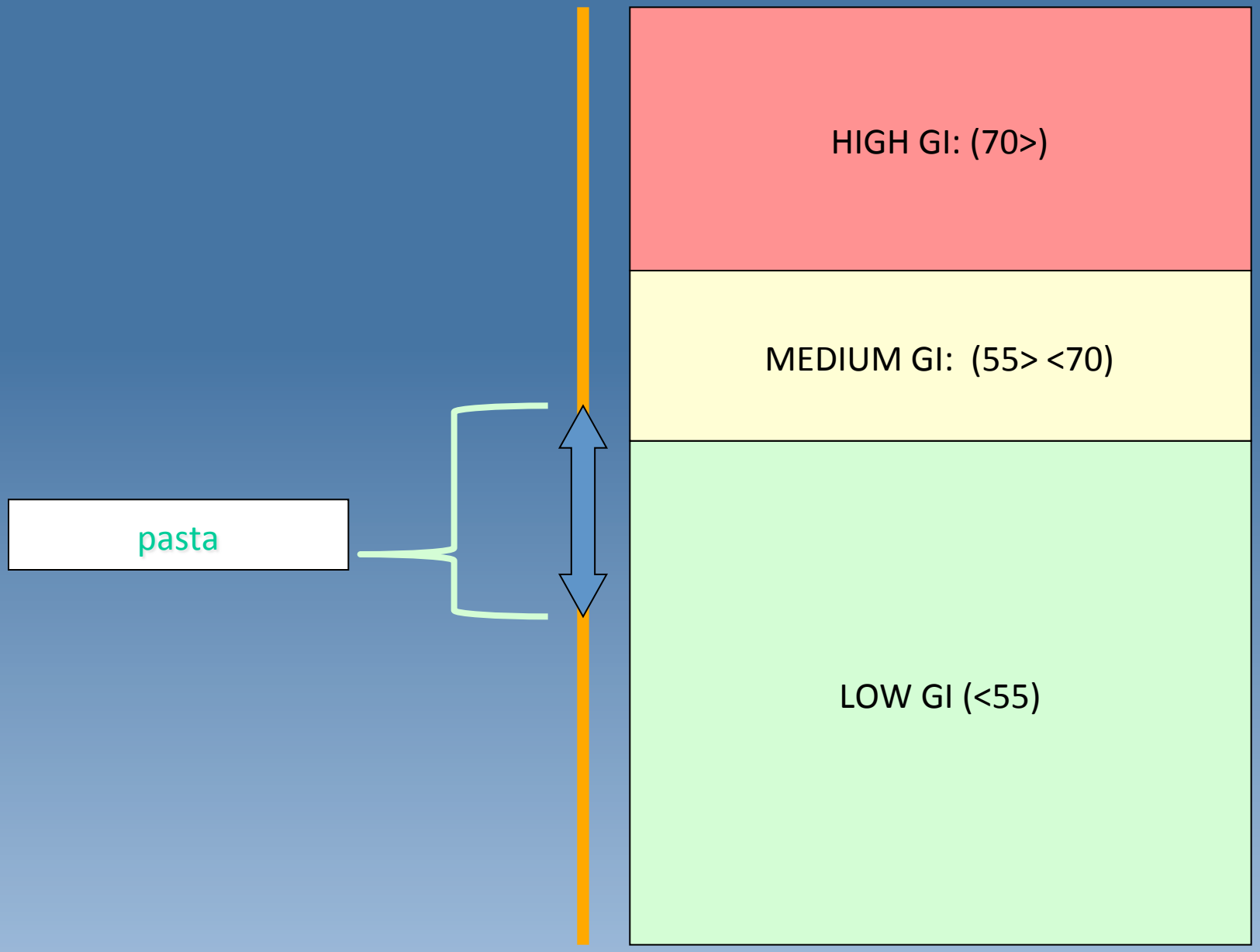
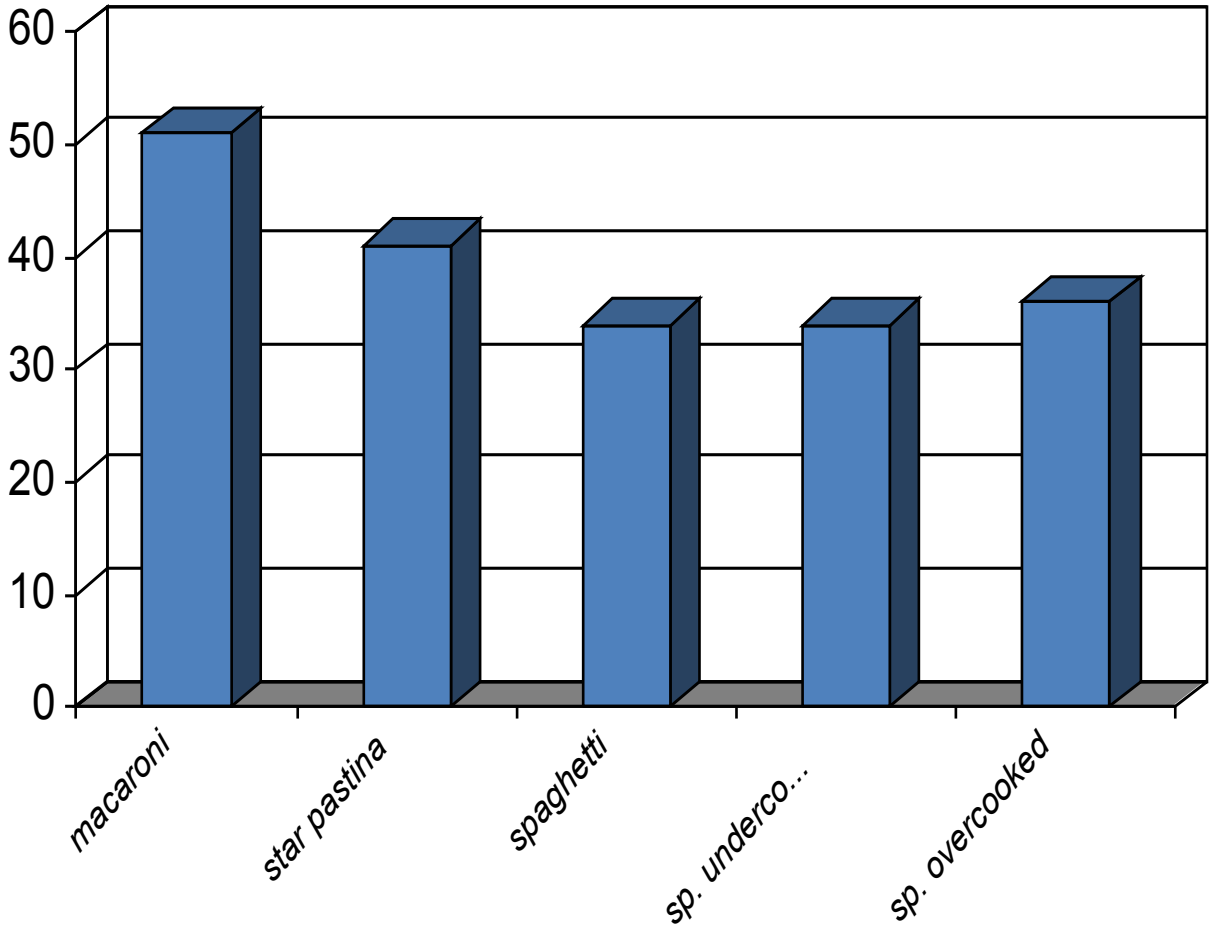


FIGURE 4. Increments of plasma insulin in patients with non-insulin-dependent diabetes mellitus after consumption of the low-GI cereal/bean meal (●——●) compared with the high-GI cereal/bean meal (▲——▲). Areas under the curve (area units) for the low-GI durum meal and the high-GI durum meal were 600 ± 504 and 987 ± 937, respectively. $\bar{x}$ ± SD. * $P < 0.05$, ** $P < 0.01$.

Asp et al. Am J Clin Nutr 1995; (61): 837-42


HIGH GI: (70>)
MEDIUM GI: (55> <70)
LOW GI (<55)
pasta

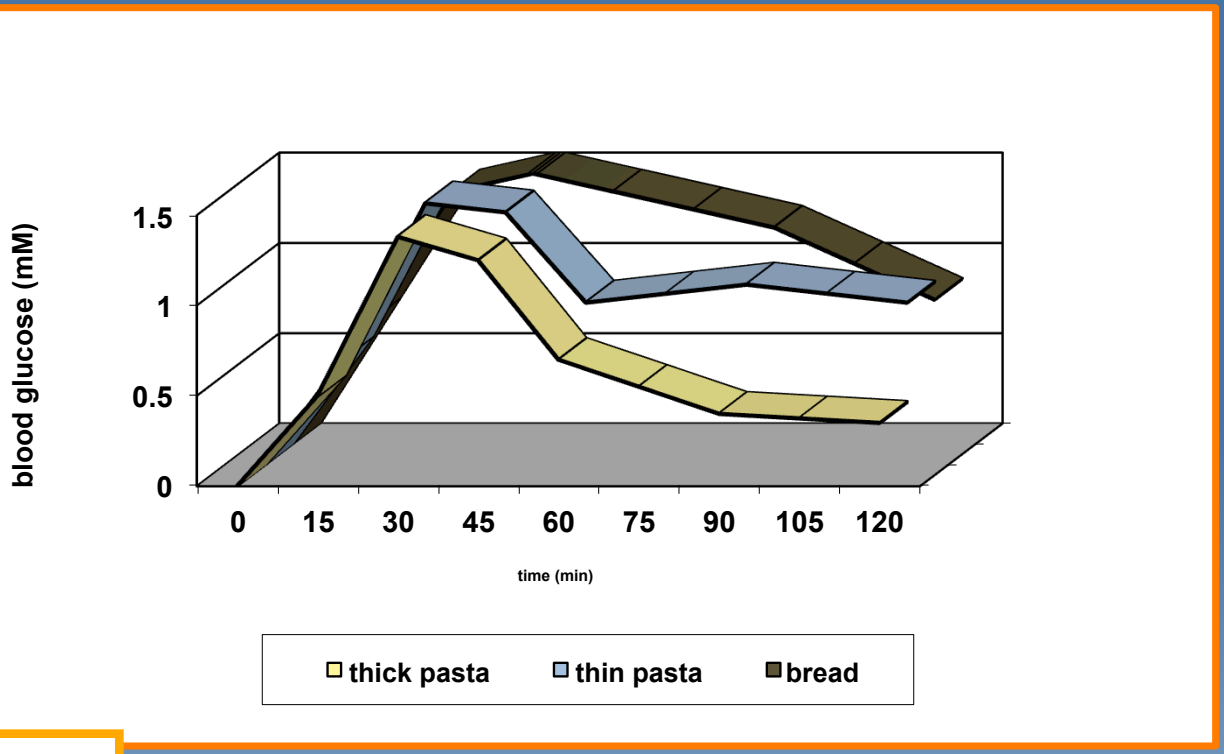
Different types of pasta may produce different glycemic responses but these are not necessarily related to differences in cooking time



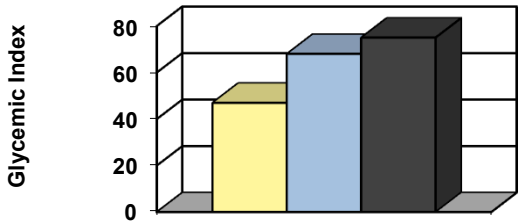
Adapted from: Wolever *et al.* Diabetes Care, 1986; 9(4): 401-4

In vivo GI of two pastas of same format but different thickness

Thick vs. thin pasta

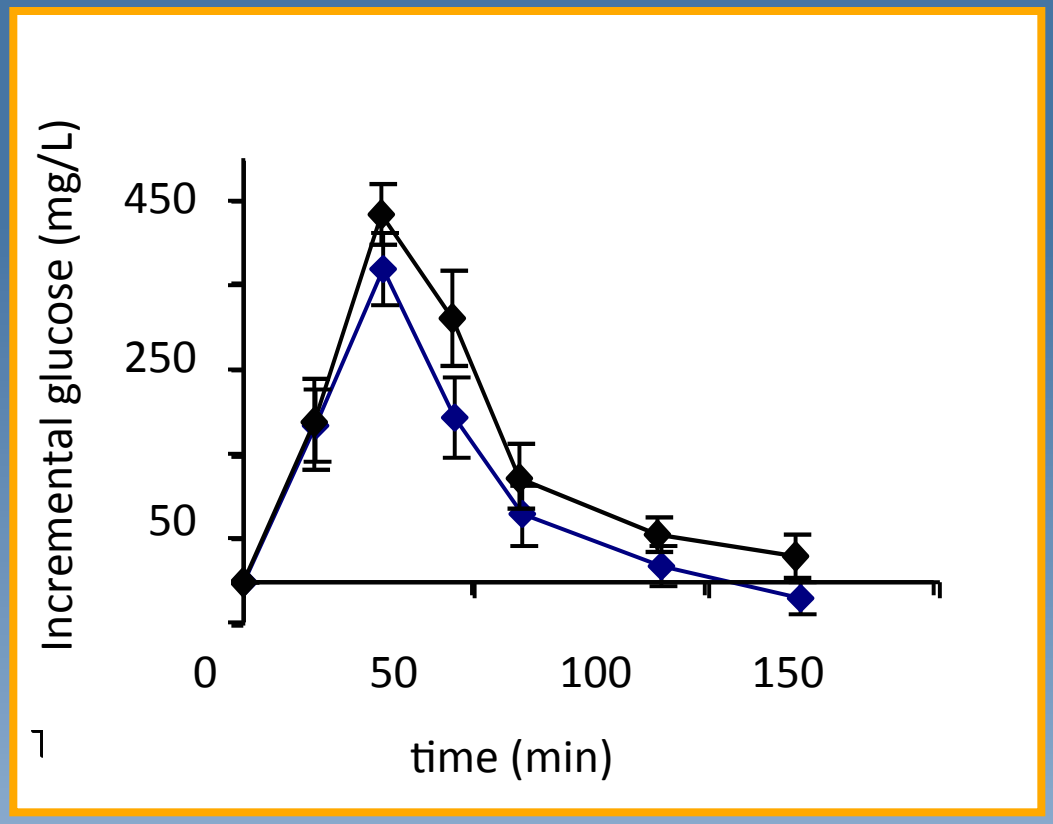


+ 45%



Total meal surface area (after chewing) may partly explain differences in postprandial response to pasta. Thin formats may increase pasta GI.

Effect of bran enrichment in short pasta



White penne

Whole wheat penne

Wheat fibre, if any, negatively affects glycemic response, at least in short pasta formats. This could be due to changes in pasta structure or in water penetration kinetics during cooking.

The effects of fiber enrichment of pasta and fat content on gastric emptying, GLP-1, glucose, and insulin responses to a meal

GS Frost[1]*, AE Brynes[1], WS Dhillo[3], SR Bloom[3] and MI McBurney[2]

European Journal of Clinical Nutrition (2003) 57, 293–298

0954-3007/03 $25.00

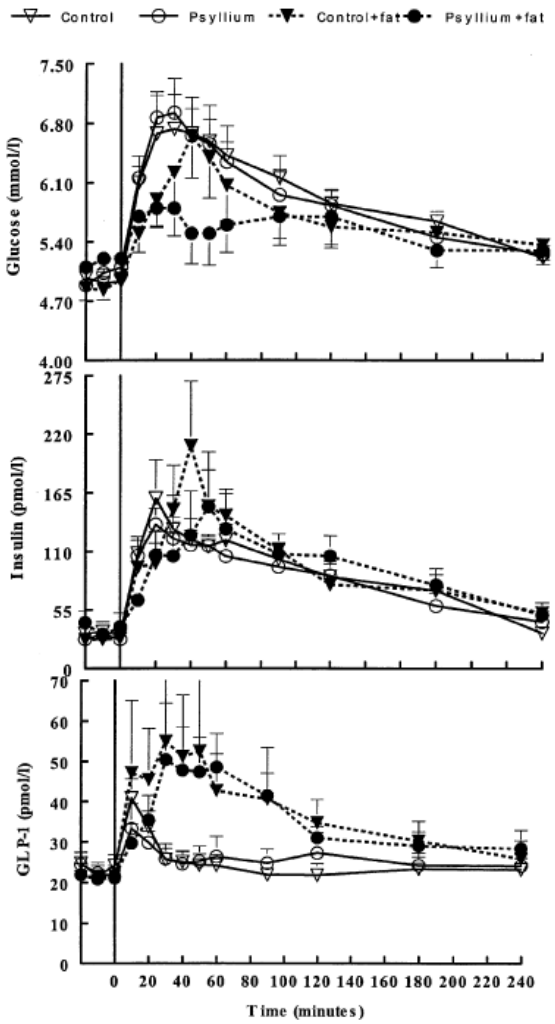


Figure 1 Circulating plasma glucose, insulin and GLP-1 response to four pasta-based test meals in healthy volunteers ($n=9$).

Added soluble fibre (psyllium) do not significantly affect gastric emptying and postprandial gluco-insulinemic response whereas fat does.

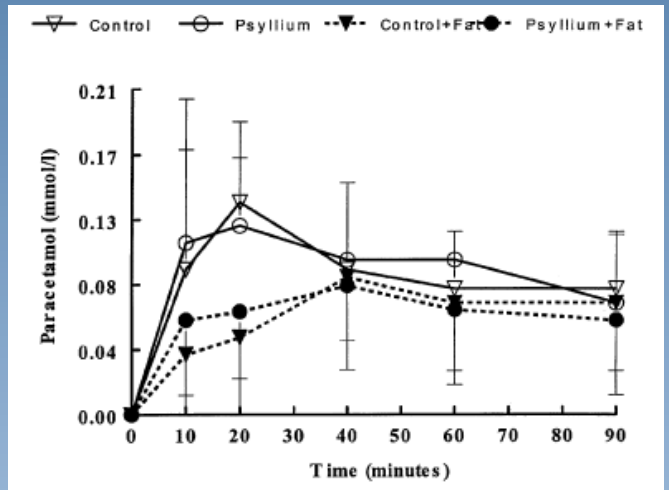


Figure 2 The paracetamol absorption test demonstrating that the addition of fat delayed gastric emptying in both the control test meal and the psyllium test meal ($P<0.01$). There was no significant difference between the control only meal and the psyllium-only meal.

European Journal of Clinical Nutrition (2006) 60, 763–769

0954-3007/06 $30.00
www.nature.com/ejcn

ORIGINAL ARTICLE

The impact of the addition of toppings/fillings on the glycaemic response to commonly consumed carbohydrate foods

CJK Henry[1], HJ Lightowler[1], FL Kendall[1] and M Storey[2]

[1]*Nutrition and Food Science Group, School of Biological and Molecular Sciences, Oxford Brookes University, Oxford, UK and* [2]*British Potato Council, Oxford Business Park South, Oxford, UK*

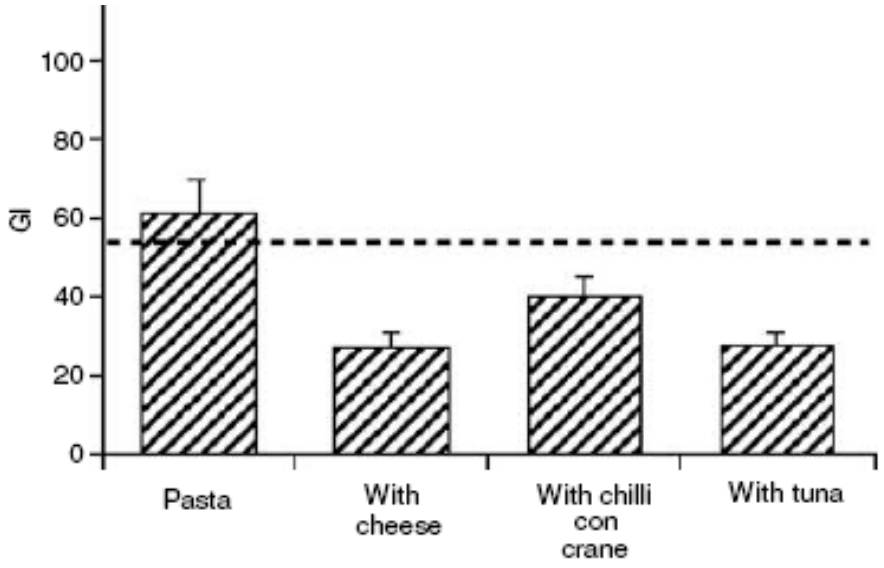
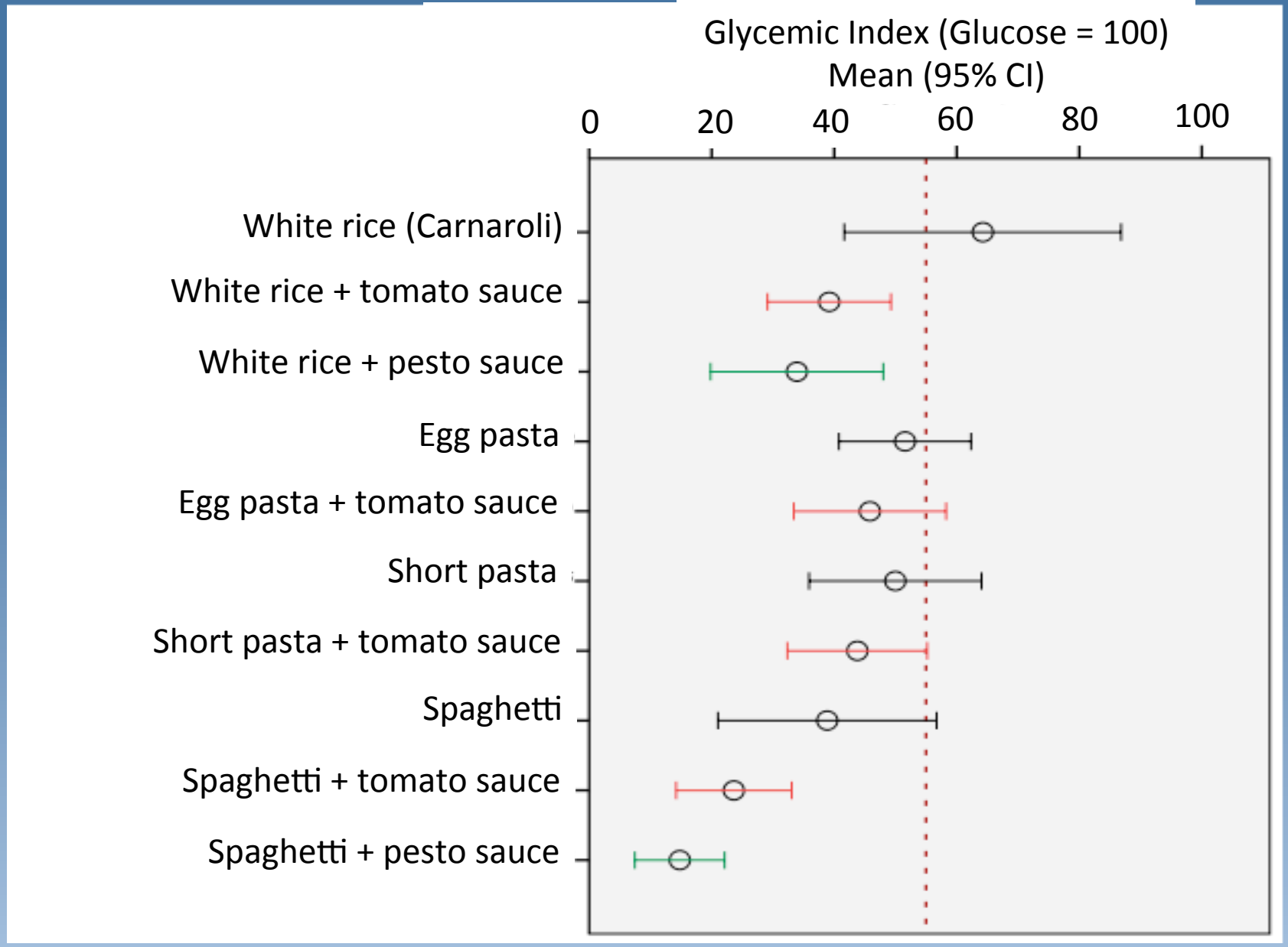


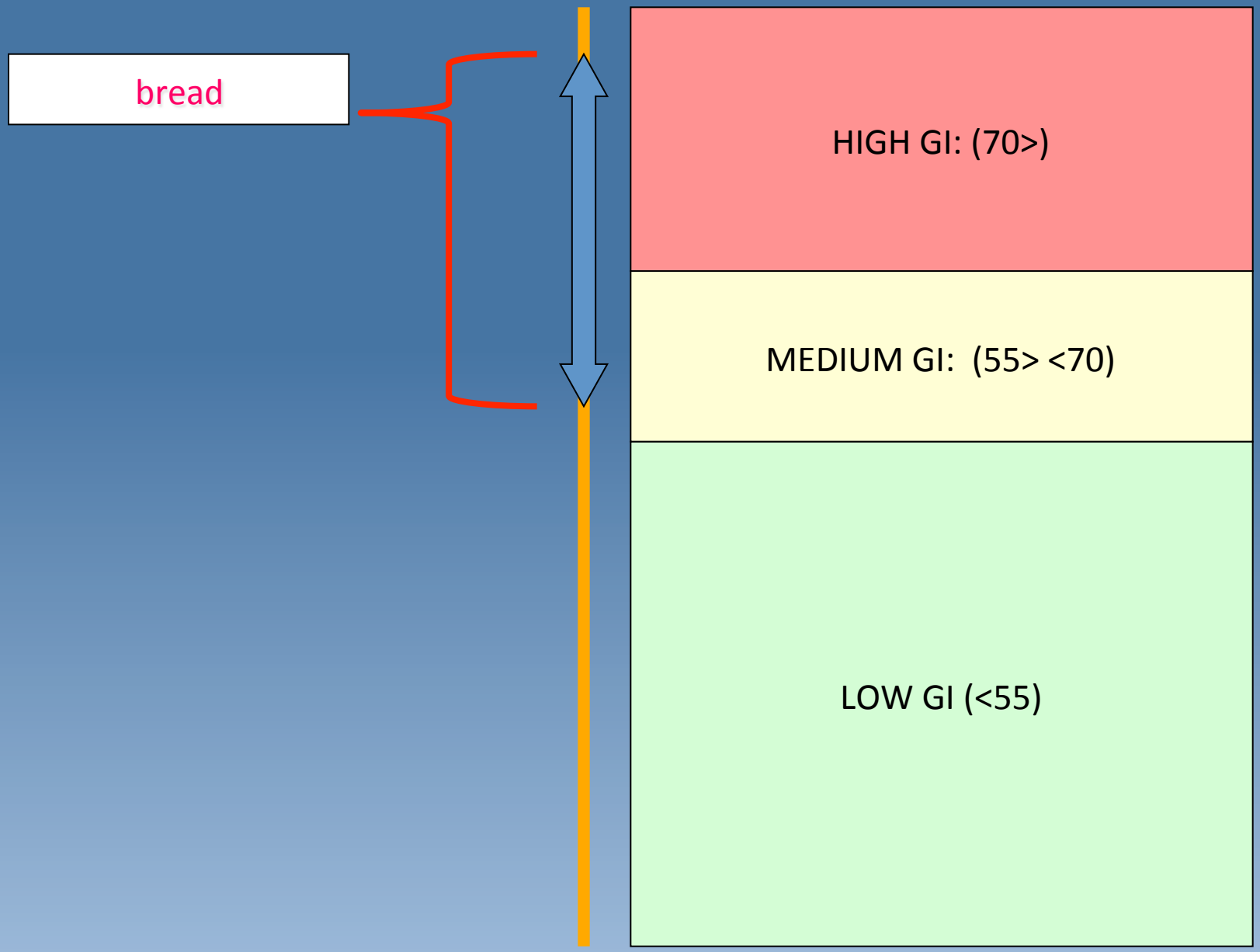
Figure 3 GI of the test meals (--- GI = 55). Values are the mean ± s.e.m.

Addition of toppings significantly decreases the glycemic index of pasta.

What about pasta dressing with tomato or other traditional sauces?

Dressing proportionally reduces GI of rice and pasta meals




bread
HIGH GI: (70>)
MEDIUM GI: (55> <70)
LOW GI (<55)

DF, Sourdough leavening and glycemic response

A) WHOLE WHEAT leavened with *S.cerevisiae*

B) WHOLE WHEAT sourdough

C) WHITE WHEAT leavened with *S.cerevisiae*

D) WHITE WHEAT sourdough

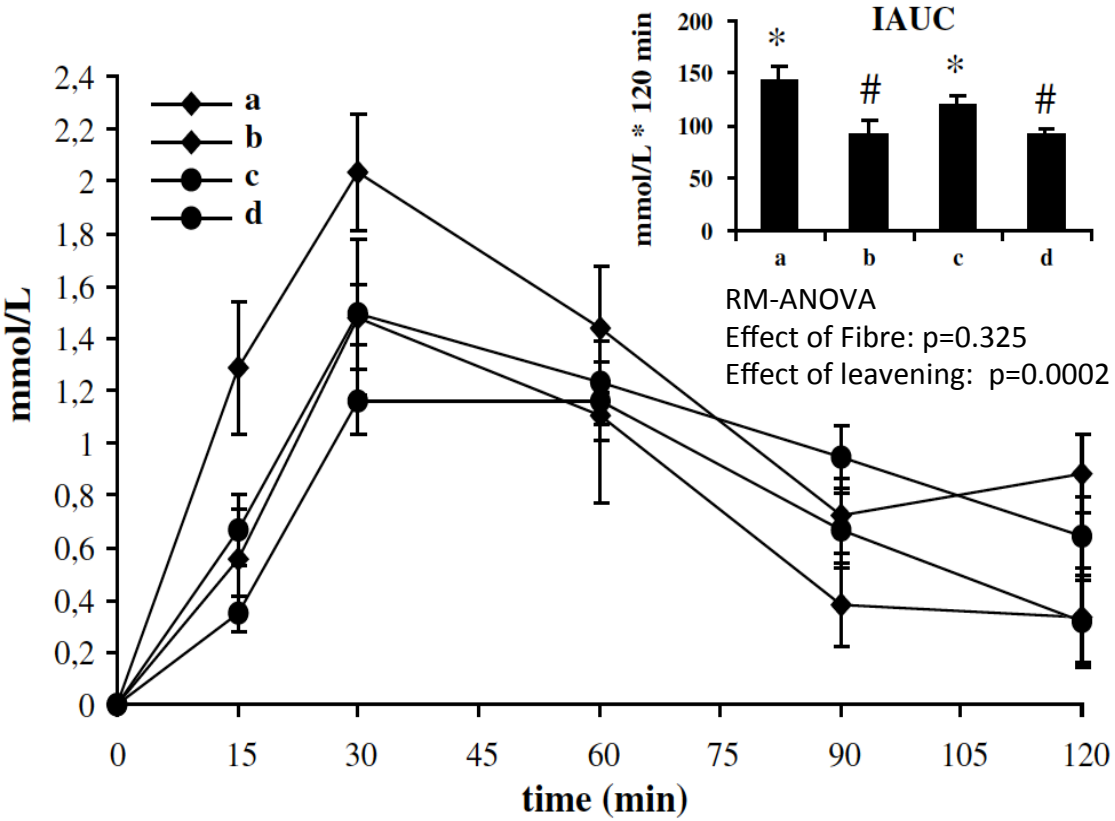


Fig. 3. Incremental blood glucose curves and incremental areas under the curves (IAUC) of postprandial glycemia (**a** = whole *S. cerevisiae*; **b** = whole sourdough; **c** = white *S. cerevisiae*; d = white sourdough). Bars with different symbols are significantly different ($p < 0.001$).

Scazzina et al. Journal of Cereal Science, 2009: 49(3) 419-421

Organic acids/pH – effect of vinegar

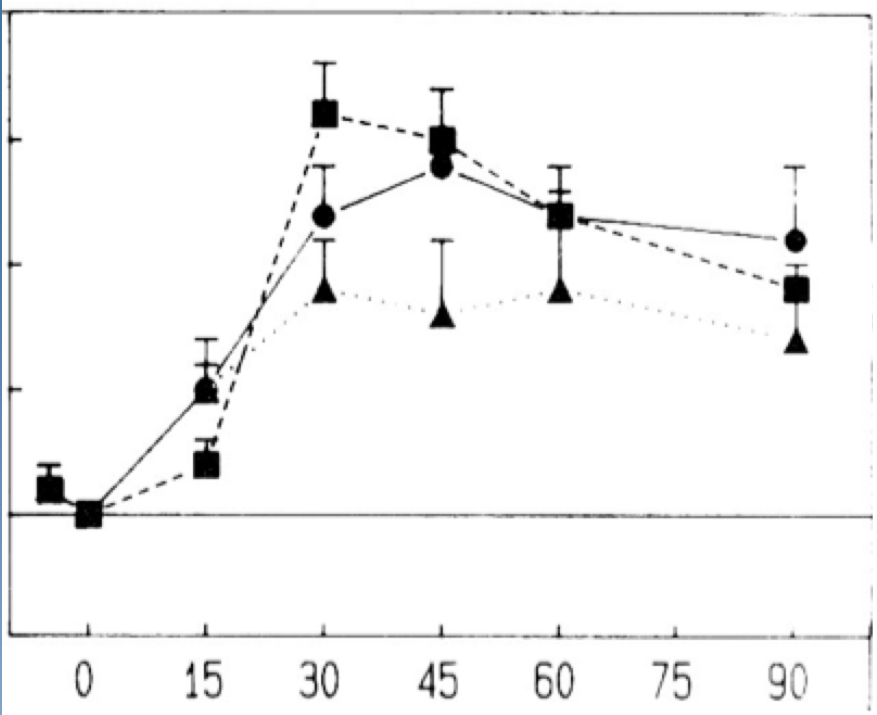


Figure 1 Changes in plasma glucose (top) and plasma a

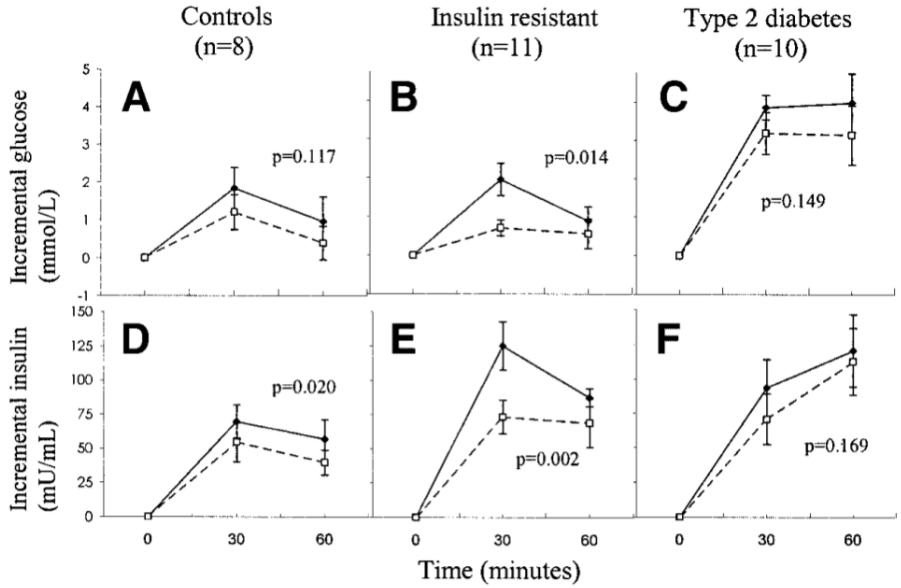


Figure 1—*Effects of vinegar (□) and placebo (◆) on plasma glucose (A– C) and insulin (D– F) responses after a standard meal in control subjects, insulin-resistant subjects, and subjects with type 2 diabetes. Values are means ± SE. The P values represent a significant effect of treatment (multivariate ANOVA repeated-measures test).*

Brighenti F et al;
EJCN, 1995 vol. 49 (4):242-7

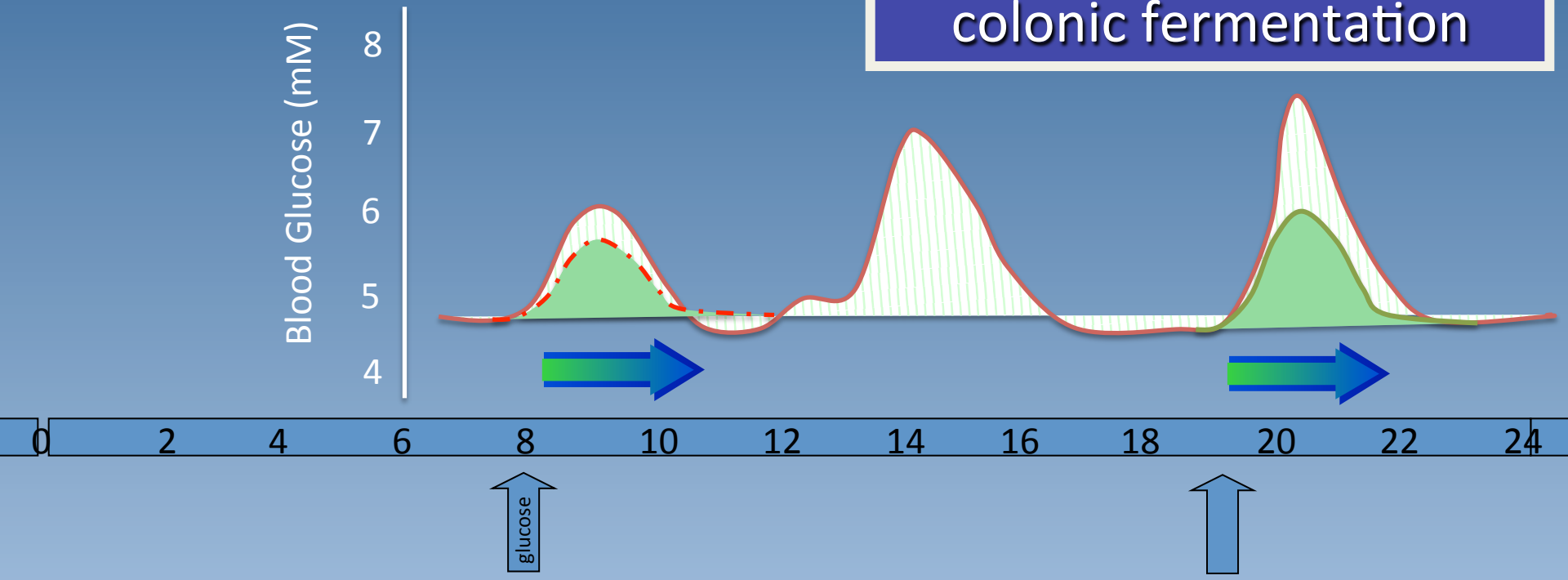
Johnston C et al;
Diabetes Care, 2004 vol. 27 (1): 281-2

Organic acids/pH – effect of vinegar

Organic acids either present or added to foods modulate glucose response…What about SCFAs endogenously derived?...

Second-meal studies (i.e. the colonic phase)

The second-meal effect is induced by low-GI fibre-rich foods that stimulate colonic fermentation



Colonic fermentation of indigestible carbohydrates contributes to the second-meal effect[1–4]

Furio Brighenti, Luigi Benini, Daniele Del Rio, Cristina Casiraghi. Nicoletta Pellegrini. Francesca Scazzina. David JA Jenkins, and Italo Vantini

Am J Clin Nutr 2006;83:817–22. Printed in USA. © 2006 American Society for Nutrition

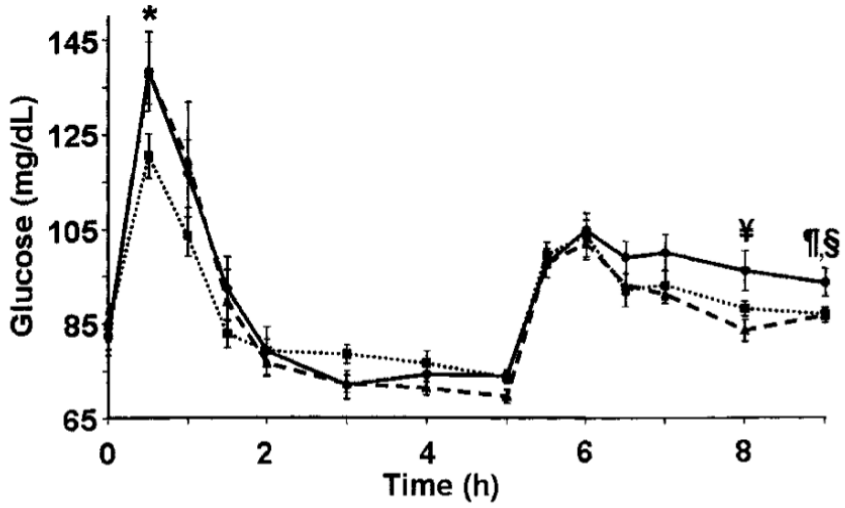


FIGURE 1. Mean (±SE) glucose concentrations during the test period after the high-glycemic-index (HGI; ●), low-glycemic-index (LGI; ■), and HGI with lactulose (HGI-Lac; ▲) breakfasts. $n = 10$. Effect of treatment, $P < 0.005$; time × treatment interaction, $P < 0.02$ (both: repeated-measures ANOVA). $^{*}P < 0.03$: differences between the HGI and HGI-Lac breakfasts and between the HGI and LGI breakfasts; $^{¥}P < 0.01$: difference between the HGI and HGI-Lac breakfasts; $^{§}P < 0.05$: difference between the HGI and LGI breakfasts; $^{¶}P < 0.05$: difference between the HGI and HGI-Lac breakfasts (all: Tukey's honestly significant differences post hoc test).

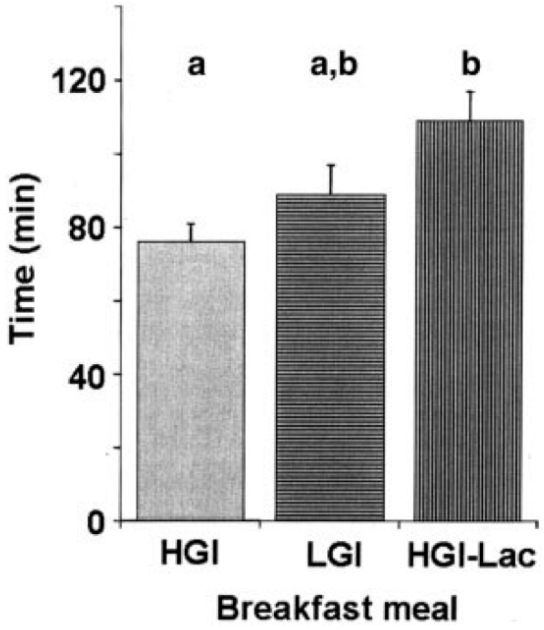


FIGURE 5. Mean (±SE) ultrasonographic gastric half-emptying times (min) of the second meal preceded by the different breakfast meals. $n = 10$. Bars with different letters are significantly different, $P < 0.05$ (repeated-measures ANOVA followed by Tukey's honestly significant differences post hoc test).

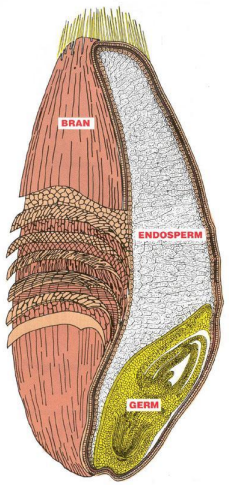
What next?

- Displacement of negative dietary components
- Energy balance, Overweight/obesity
- Glucose control, Insulin / IGF / Insulin sensitivity
- Plasma lipids
- Blood pressure
- Endothelial function

  - Magnesium
  - Vitamin C, carotenoids
  - DF metabolites (SCFAs)
  - Polyphenols and P. metabolites
  - Hormones, incretines and inflammation mediators
  - Microbiota composition and activity

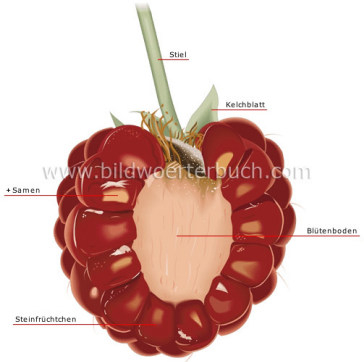
Non-carbohydrate by-passengers

Cereals, fruit and vegetables largely differ in the type and amounts of non-carbohydrate components associated to DF.



- Phenolics
  - Flavanols
  - Flavones
  - Catechins
  - Lignans
  - Phytosterols
  - Phenolic acids
  - Alkylresorcinols
  - Salycilates
- Methyl donors
  - Betaine
  - Choline
- Fats

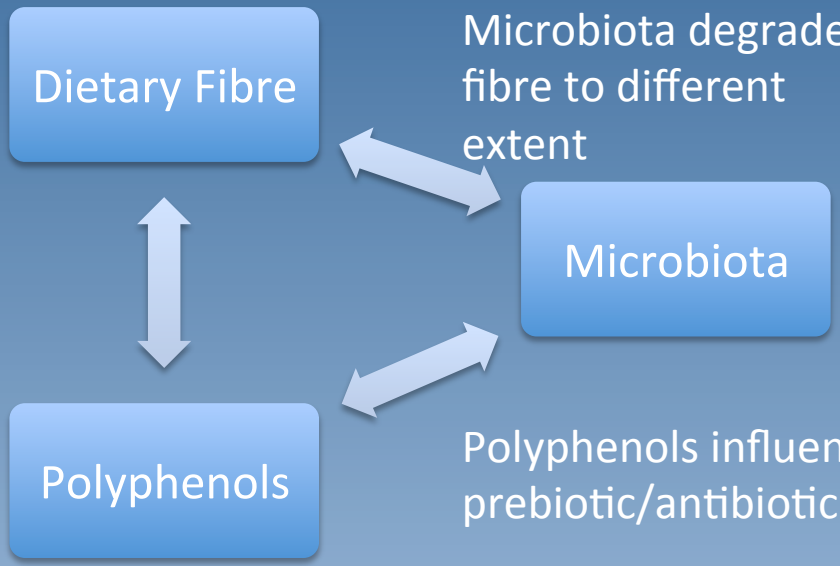
- Vitamins
  - Ascorbate
  - Carotenoids
  - Niacin
  - Folates
  - Vitamin K
  - tocopherols
- Organic acids
  - Citrate
  - Malate
  - Oxalate
- Minerals
  - Magnesium
  - Selenium
  - Potassium



Metabolic gut: Multiple relationships

DF influences polyphenols (i.e. chemical link and presence in foods)

Polyphenols change fibre nature (e.g. digestibility)



DF influences microbiota (i.e. prebiotic effect)

Microbiota degrades fibre to different extent

Polyphenols influence microbiota (i.e. prebiotic/antibiotic effect)

Microbiota converts polyphenols to different extent

Vahouny Symposium on Dietary Fibre. Washington DC, May 1988

THANKS FOR YOUR ATTENTION