The glycemic index of foods

Glucose and insulin responses
Why are they relevant?

- Treatment of diabetes
  - hyperglycaemia and hypoglycaemia
- Prevention of type 2 diabetes
- Prevention of coronary heart disease
- Appetite control, weight reduction
- Sporting performance

Postprandial glycaemia
Determined by:

- Individual's metabolism
- The amount of carbohydrate in the meal
- The nature of the carbohydrates (GI)

How is the GI measured?

- Feed 50g CHO portion of the food to 10 subjects
  eg 200g spaghetti
- Measure blood sugar at regular intervals
  0, 15, 30, 45, 60, 90 and 120 mins
- Calculate 'area under the curve'
- Compare with area after reference food
  This is tested at another time - express as %
- Calculate the average value for all 10 individuals

The nature of the carbohydrate
The glycemic index of foods

- Ability to raise blood glucose level
- Compares CHO on a gram for gram basis
- Reference food has a GI of 100
- The published GI of a food is the average GI in ~10 subjects

Starch
Slowly digested

Starch
Rapidly digested

Blood glucose rise
Most starchy foods have a high glycaemic index

<table>
<thead>
<tr>
<th>Food</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>70</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>69</td>
</tr>
<tr>
<td>Dark rye bread</td>
<td>86</td>
</tr>
<tr>
<td>Potatoes (boiled)</td>
<td>88</td>
</tr>
<tr>
<td>Cornflakes</td>
<td>84</td>
</tr>
<tr>
<td>Rice (Calrose brown)</td>
<td>87</td>
</tr>
<tr>
<td>Weetbix</td>
<td>69</td>
</tr>
</tbody>
</table>

(Glucose = 100)

Relatively few starchy foods have a low GI

<table>
<thead>
<tr>
<th>Food</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>25</td>
</tr>
<tr>
<td>Legumes</td>
<td>30’s</td>
</tr>
<tr>
<td>Pastas</td>
<td>40’s</td>
</tr>
<tr>
<td>Heavy grain bread</td>
<td>40’s</td>
</tr>
<tr>
<td>Allbran™</td>
<td>42</td>
</tr>
<tr>
<td>Porridge oats</td>
<td>50</td>
</tr>
</tbody>
</table>

(Glucose = 100)

Sugary foods have a moderate GI

<table>
<thead>
<tr>
<th>Food</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose solution</td>
<td>65</td>
</tr>
<tr>
<td>Fanta™</td>
<td>68</td>
</tr>
<tr>
<td>Muesli bars</td>
<td>61</td>
</tr>
<tr>
<td>Life Savers™</td>
<td>70</td>
</tr>
<tr>
<td>Chocolate milk (low fat)</td>
<td>34</td>
</tr>
<tr>
<td>Yogurt (sweetened)</td>
<td>33</td>
</tr>
<tr>
<td>Icecream (low fat)</td>
<td>50</td>
</tr>
</tbody>
</table>

Median (range, 39 foods) = 58 (33 - 80)

Factors influencing the GI

- Fat, protein, soluble fibre and anti-nutrients influence the GI of a food
- But the most important factors are:
  1. nature of the starch
     its physical state after preparation and processing
  2. nature of the monosaccharide
     Glucose is very glycemic
     Fructose has little effect on glycemia
     Galactose has little effect on glycemia

Effect of processing

Wheat

![Graph showing effect of processing on glucose levels](Holt and Brand Miller EJCN 1994; 48:496)

Effect of amylose: amylpectin ratio

Rice varieties

![Graph showing effect of amylose ratio on glycaemic index](Brand Miller et al 1992; 56:1034)
Physical state of starch in foods

Determines rate of starch digestion

- Raw starch
- Swollen
- Gelatinised
- Disrupted
- Dispersed
- Enzymatically degraded

Faster

Slower

Raw cereals
Cooked legumes
Cooked grains, pasta
Extruded products, popped cereals

New classification of starches

<table>
<thead>
<tr>
<th>Classification</th>
<th>Rapidly digested</th>
<th>Slowly digested</th>
<th>Resistant starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose released in 20 mins</td>
<td>Glucose released within 20 to 100 min</td>
<td>Starch not hydrolysed after 120 min</td>
<td></td>
</tr>
<tr>
<td>* Bread</td>
<td>* Raw cereals</td>
<td>* Cooled potato</td>
<td></td>
</tr>
<tr>
<td>* Potatoes (warm)</td>
<td>* Pasta</td>
<td>* Raw banana</td>
<td></td>
</tr>
<tr>
<td>* Flours</td>
<td>* Legumes</td>
<td>* Amylose</td>
<td></td>
</tr>
<tr>
<td>Amylopectin (cooked)</td>
<td>* High amylose starches (cooked)</td>
<td>(ungelatinised)</td>
<td></td>
</tr>
</tbody>
</table>


Effect of sugar vs cornflakes

50 g carbohydrate portions

- Soft drink (sucrose)
- Cornflakes (starch)

Blood glucose mM

Time (min)


Starches vs sucrose

- 50 g starch = 50 g glucose eq.
- 50 g sucrose = 25 g glucose eq. + 25 g fructose eq

Can be rapidly or slowly digested and absorbed
GI unpredictable

GI of sucrose = -(100 + 20)/2 = 60

Effect of food acids

Vinegar slows down stomach emptying
Sour dough breads have a lower GI

Blood glucose mM

Time (min)

Proven benefits of low GI diets

- lower day-long glucose levels
- lower day-long insulin levels
- higher HDL levels
- lower triglycerides (blood and muscle)
- lower risk of developing diabetes and heart disease (Harvard studies)
- higher satiety, weight reduction
- Improved sports performance
Substituting low for high GI foods

High GI
- Bread white or w’meal
- Most breakfast cereals
- Potato
- Rice (low amylose)
- Biscuits
- Tropical fruits – melons, pineapple

Low GI
- Heavy grain breads
- Porridge, muesli, All Bran
- Sweet potato, pasta
- Basmati (high amylose)
- Oat-based, fruit-based
- Temperate fruits – apples, oranges

Low GI meals reduce blood glucose

Low GI vs high GI meals over 10 hours


Low GI foods reduce insulin levels

Low vs high GI meals over 10 hours


HbA1c is lower on low GI diet

16 Type 2 subjects, 2 x 12 wk crossover


HbA1c = a measure of average blood glucose levels

Brand et al. Diabetes Care 1991;14:95

HbA1c correlates with GI of diet

EURODIAB study in 31 diabetes clinics throughout Europe

Buyken et al. 2001 Am J Clin Nutr 73; 574

Low GI diet improves insulin sensitivity

4 week crossover, 12 type 2 diabetic men, weight maintaining

Rickall et al. Diabetes Care 2004; 27:1866-1872
GI and the insulin resistance syndrome

Framingham Offspring Cohort, n = 2834

Glycemic load and risk of diabetes

Melbourne Collaborative Cohort Study, 37,000 subjects

GI as a determinant of HDL-cholesterol

1986-87 Survey of British Adults (n = 1420)

High glycaemic load increases heart attack

Nurses Health Study 10 years of follow-up in 65,000 women

Slowly digested = higher satiety

Six cereal breakfasts, same amount of carbohydrate

Low GI meals are more satiating

Voluntary food intake in 12 obese teenage boys following test breakfast and lunch of varying GI

A/Prof. Jennie Brand-Miller, University of Sydney
**Change in body fat mass**

Female completers

-4.9

-3.1

-4.8

-3.6

-6

-5

-4

-3

-2

-1

0

* Oneway ANOVA with baseline value as covariate p = 0.007

McMillan-Price et al. 2006

**LDL-cholesterol changes**

Men and women - completers only

- *p = 0.007
- "p = 0.002
- "p = 0.039

ANOVA with baseline value as covariate p = 0.015

McMillan-Price et al. 2006

**Fall in resting metabolic rate**

% change in RMR from baseline after 10% weight loss

- Low fat
- Low GL

-10.6

- 5.9

P < 0.05

Perriera et al. JAMA 2004

**GI and sporting performance**

Prolonged strenuous exercise

- Time to exhaustion (min)

<table>
<thead>
<tr>
<th></th>
<th>Potato</th>
<th>Lentils</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>117</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

p < 0.05


**High GI foods induce more CHO oxidation during exercise**

Effect of GI in 8 trained men at 70%VO₂max

- High GI
- Low GI

Muscle glycogen repletion - the place for high GI foods

After prolonged strenuous exercise and after 24 h recovery with high vs low GI meals

- Muscle glycogen (mmol/kg wet wt)

<table>
<thead>
<tr>
<th></th>
<th>High GI</th>
<th>Low GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>106</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

p < 0.05

Febbraio et al. J Appl Physiol 2000: 89;1845

Burke et al. J Appl Physiol 1993;75:1019
High GI diet during pregnancy increases birth weight

62 healthy women assigned to low or high GI before 16 wk

- Low GI
- High GI

SGA - small for gestational age
LGA - large for gestational age

Moses et al. 2006 Am J Clin Nutr, in press

Putting the GI into practice

- Which foods contribute most carbohydrate?
  - Bread - choose specific brands
  - Breakfast cereals - choose specific brands
  - Rice - choose specific types/brands
- Consume pasta, noodle, sushi dishes
- Eat more beans/legumes (eg as soups, dahls)
- Go easy on potatoes
- Need for reliable GI data

Duality of interest

- The GI is new tool in nutrition research and disease epidemiology
  - it replaces sugars vs starch distinction
  - Most modern starchy foods have high GI's
  - Sugary foods tend to have lower GI's
    - no longer need to be avoided in diabetic diets
  - High GI foods are associated with higher disease risk and risk factors
  - WHO/FAO (1998) recommends the use of the GI in food choice

Take home messages

Glycemic Index Symbol
International food labelling program

- Registered certified trademark
- Foods must be GI tested by accredited laboratory
- Must meet nutritional criteria (eg saturated fat, salt)

‘Wild About Fruit’ fruit juices

Published 2005

A/Prof. Jennie Brand-Miller, University of Sydney