Dietary Carbohydrates: Positive and Negative effects on Health

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University of Nottingham
### Disclosures

<table>
<thead>
<tr>
<th>AFFILIATION/FINANCIAL INTERESTS (prior 12 months)</th>
<th>CORPORATE ORGANIZATION</th>
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<tr>
<td>Grants/Research Support:</td>
<td>Unilever – Academic lead of UoN strategic partnership</td>
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<td>UK Government/Mars – Project support</td>
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<td>Scientific Advisory Board/Consultant:</td>
<td>Mars Scientific Advisory Council</td>
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<td>Waltham Centre for Pet Nutrition</td>
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<td>Speakers Bureau:</td>
<td>UK Nutrition Society</td>
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<td>UK Association for the Study of Obesity</td>
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<td>American Society for Nutrition</td>
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<td>Stock Shareholder:</td>
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<td>Other</td>
<td>UK Government: Dept of Health – Obesity Review Group, Food Network</td>
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<td>UK Government: PHE – SACN</td>
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Outline

Impact of different carbohydrates on health

• Metabolism of Carbohydrate

• Types of Carbohydrate:
  – Starch/refined/wholegrains
  – Glycaemic characteristics
  – Mono and disaccharides – fructose and sucrose
  – Fibre - what it is and what it does
    • UK approach to fibre

• Implications of 'good vs bad' carbohydrates for food manufacturing

• Benefits and risks of low carbohydrate diets
Carbohydrate metabolism

an overnight fast

(a high CHO breakfast

(values approx. mg/min glucose equivalents for 65kg person)

Thus brain requires approx 6 g. glucose per hour

(Frayn 1996)
Types of carbohydrate

• Mono and disaccharides
• Oligosaccharides (3-9 ‘sugars’ in a single molecule)
• Polysaccharides – starch
• Fibre

• Main dietary components are mono- and disaccharides and starch
What are ‘Good’ and ‘Bad’ carbohydrates?

• At one level there is no such thing as good and bad
• But high intakes of some carbohydrate sources are associated with a risk to health, whilst other are associated with health benefits

• So should consider
  – ‘Good’ carbohydrates as those that can be eaten in large amounts (but not exceeding energy requirements) and offer health benefits, whilst
  – ‘Bad’ carbohydrates are those which increase the risk of ill-health when consumed in relatively high amounts
Dietary carbohydrate

• Starch: polymer of glucose
  – Different degrees of cross-linking leads to variation in the speed with which it can be digested
  – Raw starch indigestible
  – Cooking ‘cracks’ the polymer and increases digestibility
  – Cooling of cooked starch can lead to reconstitution of the polymer giving a refractory molecule resistant to digestion – resistant starch (eg in salad potatoes)
  – Wholegrains include the starch, fibre, protein and vitamins in the original plant material
  – Refined starch has the fibre and some/all vitamins removed
  – Wholegrain sources of starch are associated with health benefits due to the increased fibre intake (and possibly other components)
Dietary carbohydrate

• Is there a difference between different types of carbohydrates in terms of energy intake, body weight/composition/metabolism?
  Focus on:
  – Glycaemic index
  – Sugars

• Is fructose a particular concern?
Glycaemic index/load

• The Glycaemic index (GI) of a carbohydrate food (containing starch or sugars) refers to the increase in blood glucose after eating the food relative to the response seen after an equivalent amount of a standard carbohydrate source (usually glucose).

• Glycaemic load (GL) of a diet is a product of the glycaemic index of the individual carbohydrates and the amounts of them in the diet.

• There is epidemiological evidence that high GI/GL diets are associated with increased risk of cardiovascular and metabolic disease.
An association is indicated between a higher GI/GL and a higher incidence of type 2 diabetes mellitus incidence
  (RR 1.03, 95% CI 1.01, 1.06, for each two GI unit increase; p=0.01).

  (RR 1.03, 95% CI 1.00, 1.05, for each 20 GL unit increase; p=0.02)

  Association
  Adequate evidence
The direction of the association indicates consumption of a higher GI diet is detrimental to health, but it is not possible to exclude confounding by other variables
  The association is biologically relevant

(Similar conclusion for higher GI and cholesterol, LDL cholesterol – BUT these were weight loss studies and higher GI was associated with a smaller reduction in cholesterol. )
(Same for GL and lipids, GL and DBP)
Study of the effects of dietary GI/GL on liver and muscle fat and glycogen contents

• Recent study in Nottingham by Bawden and colleagues looked at muscle and liver glycogen and fat contents in healthy young men (using MR spectroscopy) after a single meal and 7 days dietary intake of a high or a low GI diet.

• Effects on liver glycogen and lipid content of the high GI diet. Lipid effects are potentially detrimental to health if sustained in the long term.
Impact of low v. high GI/GL diets on liver glycogen and lipid (MRS) in healthy young men
(Bawden et al, unpublished)

High GI has expected effect on liver glycogen but also increases liver lipid
Sugars

• Evidence is accumulating that diets high in free sugars are associated with increased risk of dental caries, increased risk of type 2 diabetes, increased energy intake, higher BMI in children

• How robust is this evidence?

• Particular concern that Sugars sweetened beverages may represent a particularly high risk of these undesirable outcomes
Dietary sugars and body weight/fatness

So no specific problems with free sugars if energy intake fixed
Sugars – why might free sugars pose an increased health risk?

• Sugars Sweetened Beverages (and other energy containing drinks) may be poorly recognised by ‘appetite / satiety’ systems.
  – Could lead to passive overconsumption of energy

• Metabolic effects of fructose (how does it differ from glucose?)
  – Does not stimulate insulin secretion
  – Stimulates hepatic de novo lipogenesis (? Increases liver fat, increases serum TG) – glucose may do the same
  – Depletes hepatic ATP – but at what ‘dose’?
SSB / Fructose

• Evidence of a link between SSB and energy intake, especially in children, as presented in the WHO Sugars report

• The metabolic effects of high fructose and glucose intakes were studied by Johnston et al in overweight but otherwise healthy men
<table>
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<th>Study</th>
<th>Log (odds ratio)</th>
<th>Standard error</th>
<th>Odds ratio (95% CI)</th>
<th>Weight (%)</th>
<th>Odds ratio (95% CI)</th>
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<td>Dubois 2007 (1)</td>
<td>0.77</td>
<td>0.32</td>
<td>2.16 (1.15 to 4.07)</td>
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<td>Lim 2009 (2)</td>
<td>0.31</td>
<td>0.12</td>
<td>1.37 (1.08 to 1.74)</td>
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<td>Ludwig 2001 (3)</td>
<td>0.39</td>
<td>0.44</td>
<td>1.48 (0.63 to 3.47)</td>
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<td>Weijs 2011 (4)</td>
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<td>0.24</td>
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<td>Welsh 2005 (5)</td>
<td>0.26</td>
<td>0.25</td>
<td>1.30 (0.80 to 2.11)</td>
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<td>Welsh 2005 (6)</td>
<td>0.59</td>
<td>0.24</td>
<td>1.80 (1.12 to 2.89)</td>
<td>11.2</td>
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<td>Welsh 2005 (7)</td>
<td>0.59</td>
<td>0.23</td>
<td>1.80 (1.14 to 2.84)</td>
<td>12.1</td>
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<tr>
<td>Total (95% CI)</td>
<td></td>
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<td>1.55 (1.32 to 1.82)</td>
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Test for heterogeneity: $\chi^2=3.93$, df=6, $P=0.69$, $I^2=0\%$

Test for overall effect: $z=5.42$, $P<0.001$

(1) OR for incident obesity in frequent versus infrequent consumers of SSB between meals
(2) OR for incident overweight per daily serve SSB (8 oz)
(3) OR for incident obesity per daily serve SSB
(4) OR for incident overweight per approximate daily serve SSB (5% energy from beverage sugar)
(5) OR for incident overweight in normal weight children who consumed >1 serve/d SSB versus <1 serve SSB/d
(6) OR for remaining overweight in overweight children who consumed >1 serve/d SSB versus <1 serve SSB/d
(7) OR for incident overweight in children at risk of overweight who consumed >1 serve/d SSB versus <1 serve SSB/d

**Fig 7** Association between free sugars intakes and measures of body fatness in children.
Fructose v Glucose

• In overweight men with elevated liver fat content, ‘calories’ from fructose and glucose are not substantially different

• The state of energy balance is more important than the type of monosaccharide – when either of them is eaten to excess there is an increase in liver fat content but when they provide 25% of energy as part of an energy balanced diet there is no effect on liver fat
Results

At energy balance, Fructose and Glucose had no effect on liver fat content.

With overfeeding, Fructose and Glucose both increased liver fat content.
Fibre

• Fibre
  – what it is
  – what it does

UK approach to fibre – needs to have a demonstrable beneficial physiological effect on the person (not just the GI bacteria)
Fibre

• What are the health benefits
  – Reduced risk of certain cancers and cardiovascular disease
  – Major benefit from cereal fibres, contributions from other food sources (F&V)

  – No studies have so far linked the novel fibres or fibre extracts with these health benefits
SACN’s draft recommendations: dietary fibre

- The definition of dietary fibre should be broadened
- The DRV for dietary fibre for an adult population should be 30g/day (using the new definition)
- The average intakes for children aged 2-5, 5-11, 11-16, 16-18 years should be 15g, 20g, 25g, 30g respectively
- Dietary fibre intake should be obtained from a variety of foods e.g. whole grains, pulses, potatoes, fruit and vegetables where it is a naturally integrated component.
Risk of CVD with increasing levels of total fibre intake (similar plots for other disease outcomes)

Threapleton et al. 2013c BMJ 347, f6879
Implications of 'good vs bad' carbohydrates for food manufacturing

• Healthy diets should contain high fibre foods with low free sugars content
• Lower GI carbohydrates, reduced use of refined starches

• Challenges relate to replacing
  – Sucrose with same functionality but no energy or substrate for oral fermentation
  – Starches with molecules that have the same thickening and other functions but a lower glycaemic response
Summary on ‘Good’ and ‘Bad’ Carbohydrates

• At one level there is no such thing as good and bad
  – But high intakes of some carbohydrate sources are associated with a risk to health, whilst other are associated with health benefits
  – ‘Good’ carbohydrates as those that can be eaten in large amounts (but not exceeding energy requirements) and offer health benefits, - eg high fibre, wholegrain, low GI
  – ‘Bad’ carbohydrates are those which increase the risk of ill-health when consumed in relatively high amounts – eg refined grains, sugars, high GI

At present there is a major concern among some Public Health experts that the Food Industry is not acting in the public interest as far as dietary carbohydrates are concerned.
Sugar Industry Influence on the Scientific Agenda of the National Institute of Dental Research’s 1971 National Caries Program: A Historical Analysis of Internal Documents

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Abstract

Background

In 1966, the National Institute of Dental Research (NIDR) began planning a targeted research program to identify interventions for widespread application to eradicate dental caries (tooth decay) within a decade. In 1971, the NIDR launched the National Caries Program (NCP). The objective of this paper is to explore the sugar industry’s interaction with the NIDR to alter the research priorities of the NIDR NCP.

Methods and Findings

We used internal cane and beet sugar industry documents from 1959 to 1971 to analyze industry actions related to setting research priorities for the NCP. The sugar industry could not deny the role of sucrose in dental caries given the scientific evidence. They therefore adopted a strategy to deflect attention to public health interventions that would reduce the harms of sugar consumption rather than restricting intake. Industry tactics included the following: funding research in collaboration with allied food industries on enzymes to break up dental plaque and a vaccine against tooth decay with questionable potential for widespread application, cultivation of relationships with the NIDR leadership, consulting of members on an NIDR expert panel, and submission of a report to the NIDR that became the foundation of the first request for proposals issued for the NCP. Seventy-eight percent of the sugar industry submission was incorporated into the NIDR’s call for research applications. Research that could have been harmful to sugar industry interests was omitted from priorities.
Benefits and Risks of low carbohydrate diets

• Minimum CHO requirement for brain function (approx 120g / day)
• CHO requirements for optimal insulin sensitivity (minimum of 250g/day)
• Low CHO – means either high fat /protein or low energy
• Weight reduction diets - CHO content does not matter, it is energy that is important
• Low CHO diet (or low fat) will work in weight loss
Diet Trials

- Weight loss: men & women % initial weight
- Weight loss (% initial) at 6 months, adjusted for initial fatness
- 95% confidence intervals

Graphs showing the weight loss and fat loss at 6 months for different diets, with 95% confidence intervals.