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Symposium 3: Dietary sugars, resistant starch and fibres

Free sugars

Ian A. Macdonald

Metabolic and Molecular Physiology, MRC/ARUK Centre for Musculoskeletal Ageing Research, National Institute for Health Research Nottingham Biomedical Research Centre, School of Life Sciences, University of Nottingham, Queen's Medical Centre, Nottingham NG7 2UH, UK

It is clear that the sugars component of the diet has potentially deleterious effects on health. In the past, the dietary sugars were collectively referred to as non-milk extrinsic sugars (UK) or added sugars. The WHO first proposed a new term, free sugars, which is rather broader than added sugars, and also includes the sugars in fruit juices and purees, as well as honey and syrups. This review considers the potential problems that free sugars represent in relation to health risks, and the recent proposals that free sugars are a more appropriate focus than added or total as far as public health initiatives are concerned. This will require major activities in relation to measurement, labelling and communication to the consumer if attempts to reduce dietary free sugars content are to be successful.

Free sugars: Dietary carbohydrate: Health risks

Carbohydrates are one of the three macronutrients in the diet and in most situations, they would provide the largest proportion of the total dietary energy content[1]. A common mistake which occurs when people talk about carbohydrates, especially in the lay press but also in some scientific or clinical scenarios, is the implication that carbohydrates represent a single chemical entity. The reality is that there are several different types of carbohydrate and that the foods which contain dietary carbohydrates can be very varied and have a number of other constituents. This latter situation has led to the use of the term 'carbohydrate quality' which refers not only to the speed with which the particular food might deliver glucose to the body but also what other components might be in the food, e.g. vitamins, minerals and dietary fibre[2].

At the simplest level, carbohydrates can be separated into sugars, oligosaccharides, polysaccharides and fibre (Table 1). Until 2015, UK definitions included the term 'non-milk extrinsic sugars' to cover all of the sugars except for lactose when it was included in milk and milk products, whilst fibre was limited to plant cell wall material and lignin. In 2015, the Scientific Advisory Committee on Nutrition (SACN) published a Report on Carbohydrates and Health[3] which reviewed the literature on the links between dietary carbohydrates and oral, cardiometabolic and gastrointestinal health and proposed changes to some of these definitions which brought the UK into a similar position to most other countries. These definitions, along with the rest of the Carbohydrates Report, were accepted by the UK Government and should now be applied to the UK diet. Thus, the carbohydrate definitions now distinguish between free sugars and those which are an integral part of the fresh, unprocessed food, whilst the fibre definition has been extended to cover all carbohydrates which are not digested in the mouth and small intestine so that the oligosaccharides and resistant starch are recognised as dietary fibre.

A separate aspect of dietary carbohydrates is the extent to which they produce an increase in blood glucose and comparative information between different carbohydrate foods is provided by the measurement of the glycaemic index of a food, and linked to the glycaemic

Abbreviations: SACN, Scientific Advisory Committee on Nutrition; SSB, sugar sweetened beverages.

Corresponding author: Ian A. Macdonald, email ian.macdonald@nottingham.ac.uk

Table 1. Classification of carbohydrates

Starch (polysaccharides)
Sugars* (mono- and di-saccharides: glucose, fructose, galactose, sucrose, lactose, maltose)
Oligosaccharides (3–9 'sugar' molecules – e.g. Fructo-oligosaccharides, Galacto-oligosaccharides)
Fibre (includes resistant starch, oligosaccharides)

*Since 2015 in the UK the 'Sugars' category has been sub-divided to distinguish between free sugars (e.g. in drinks, syrups, fruit juices, purees, confectionery, processed food, or added to food by the consumer or cook) and the sugars which are an integral part of unprocessed carbohydrate food (e.g. fresh fruit, milk).

load that might arise from the overall diet[4]. Foods which have a high free sugars content (especially if it is predominantly glucose) or which have a high refined starch content, will be likely to generate a large increase in blood glucose and have a high glycaemic index. By contrast higher fibre foods, as well as foods with a high fructose content, will normally have a lower glycaemic index [5,6].

The present overview is focused on the role of free sugars in the diet and the potential links with disease risk that this class of carbohydrates represents. As was clear in the SACN Carbohydrate Report, the bulk of the evidence linking carbohydrates and health or disease risk is based on longitudinal cohort studies, with very few randomised controlled trials having been performed for sufficiently long periods of time to yield information on disease outcomes rather than risk factors.

Carbohydrates and health

The three main areas of health linked to dietary carbohydrates are cardiometabolic health, which includes obesity and diabetes, oral health and gastrointestinal health. The main impacts of dietary sugars are on aspects of cardiometabolic health, particularly obesity and diabetes, and on oral health, especially the risk of dental caries. Other carbohydrate components of the diet, in particular fibre, also impact on cardiometabolic health as well as gastrointestinal health but are beyond the scope of this overview.

Free, added and total sugars

Mela and Woolner[7] produced a perspective relating to the literature about these three categories of dietary sugars, and asked the question of whether free sugars or added sugars were most appropriate when considering risks to health? This distinction is of some importance as different expert panels and policy makers have used either 'added sugars' or 'free sugars' as the focus of their work and the resulting Public Health Recommendations.

The total sugars represent all the mono- and disaccharides present in food, irrespective of the source. In most cases, this is predominantly made up of sucrose, fructose, glucose and lactose. One confusion often found in the lay press is that the term sugar is sometimes used to represent table sugar or sucrose, whilst on other occasions, it is used to represent all of the dietary sugars.

Added sugars are those that are added to food or drink during processing, cooking or at the table and include all sources of mono- and disaccharides (e.g. honey, maize syrup, high fructose maize syrup, molasses and any sugars extracted from a whole food and concentrated, such as fruit juice concentrates). The term added sugars does not include sugars present in intact fruit or vegetables or milk, or in juiced or pureed fruit or vegetables[7].

The category of free sugars is somewhat wider ranging than added sugars as it includes all dietary mono- and disaccharides except those that are naturally occurring and present in intact whole fruit and vegetables and milk.

In addition to the recommendation from SACN that free sugars should be the category that is used when considering health risks associated with dietary sugars, this is also the approach taken by WHO[8].

Recent international recommendations regarding dietary sugars intake

The detailed processes which are used by expert committees to evaluate links between diet and health and formulate recommendations for public health implementation are beyond the scope of the present paper. It is worth reflecting on the SACN and WHO reports from 2015, which reviewed the literature relating to sugars and health risks and came up with slightly different conclusions and recommendations. SACN recommended no more than 5 % of dietary energy should come from free sugars, whilst WHO recommended 10 % but encouraged people to aim lower towards 5 %. It should also be noted that the SACN report covered a much wider remit, including all carbohydrates, not just sugars. The criteria for including published papers in the systematic reviews undertaken by the two organisations were somewhat different, mainly related to the duration of studies when weight loss or appetite was the primary outcome variable, and it is worthwhile ensuring that the inclusion and exclusion criteria are scrutinised before drawing conclusions about apparently similar reviews.

A recent review by Buyken *et al.*[9] summarised recommendations from ten countries (or groups of countries; the Nordic region) plus the European Food Safety Authority and WHO. The criteria for including recommendations in this review were that the report should be in English, or have been translated, and so it is not too surprising that the reports were from European countries plus Australia and the USA. The majority of the recommendations had total carbohydrate intake as a % of total energy at about 50 %, although it was notable that WHO had a goal of 55–75 %, whilst the Australian report was not able to set a value except for infants. The higher value provided by WHO is likely to reflect the higher carbohydrate content of the diet in Asia, although it is surprising that the lower value was 55 % of energy as this is higher than most of the mean values in the European reports. The variability between the various recommendations in sugars intake was marked, as six of the twelve reports

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did not quantify their recommendations but simply encouraged limiting or reducing the intake of sugars in food and beverages. Of the other six reports, five of them recommended added sugars (or in the case of WHO, free sugars) should be less than 10 % of total energy whilst the UK recommendation was less than 5 % of total energy as free sugars.

The European Food Safety Authority was one of the organisations that felt unable to set an upper limit for sugars intake, but it should be noted that this report was published in 2010 and that a current European Food Safety Authority review process is looking again at dietary sugars recommendations.

Scientific Advisory Committee on Nutrition and free sugars

The SACN Carbohydrate Report concluded that on the basis of ten prospective cohort studies, a higher consumption of sugar and sugar-containing foods and drinks was associated with an increased risk of dental caries. Whilst the problems related to dental caries are not uniquely a UK-based problem, there does seem to be more concern over the links to dietary sugar intake than in some other countries. Despite the limitations of basing recommendations exclusively on observational studies, the SACN Working Group was convinced that evidence was sufficiently strong that the overall recommendation to limit free sugars intake to 5 % of total energy was based in part on the reduction in the risks of dental caries. Since the SACN report was published, a long-term assessment of dental health in the Pelotas birth cohort in Brazil was published[10]. The authors concluded that the higher the sugar intake over the life-course, the higher the increment in dental caries compared to the lower intakes. In addition, even the low intakes were accompanied by dental caries incidence despite the use of fluoride toothpaste.

The SACN report also concluded from five cohort studies that higher intake of sugar sweetened beverages (SSB) was associated with an increased risk of developing type 2 diabetes. This conclusion was also reported in other Systematic Literature Reviews, although the biological mechanisms underpinning this association have not been elucidated. The SACN report also presented evidence that in children and adolescents the consumption of SSB results in greater weight gain and increases in BMI than non-energetically sweetened drinks. This conclusion was based on only three studies and it is clear that there was some inconsistency between these studies. Nevertheless, the overall conclusion was that consumption of SSB, and thus associated free sugars, represented a risk to health in both children and adults.

The other main conclusion from the SACN report regarding sugars intake was in relation to total energy intake in adults. This related to a meta-analysis of eleven randomised controlled trials which showed higher *ad libitum* energy intakes when the diet had a high sugars content compared to the intake when sugars content was low. It must be emphasised that this meta-analysis did not focus on free sugars, but rather total dietary sugars.

On the basis of all of the evidence reviewed, SACN concluded that it was more appropriate to use the free sugars content of foods and drinks, rather than added sugars. This would ensure that the sugars present in fruit juices and purees, honey and syrups, were included in the category sugars (i.e. the free sugars) which should be limited in the diet.

Sugars and metabolic/inflammatory risk markers

O'Connor *et al.*[11] reported a cross-sectional study of over 9000 adults in the East of England, in which dietary sugars intake was related to metabolic and inflammatory markers. Mean total sugars intake was approximately 24 % of total energy, with a range of 4·2 to 56·7 %. Mean intake of sugars from liquids (which would be free sugars) was only 2·9 % of total energy intake, but the range was 0–6 %, whilst sugars in solids were 20 % of total energy. The free sugars represented approximately half of the total sugars intake. The overall conclusions from this study were that higher intakes of sugars from non-alcoholic beverages and sugar added to tea, coffee and cereal were associated with fasting insulin resistance (Homeostatic model assessment) and inflammatory markers. Similar associations were reported for free sugars intake but not for non-free sugars or for sugars in solid food. Overall, this study provides further evidence of an association of free sugars intake with an increased level of markers of health risk, but clearly, the conclusions are limited by the cross-sectional design and by the self-reported dietary intake data, which are known to be rather imprecise. Nevertheless, the observations are consistent with other studies and meta-analyses which did not show effects or increased risk associated with whole fruit and vegetables[12,13], with the overall conclusion being that SSB or other sources of free sugars are associated with major risks to health.

There is a major concern over the possibility that dietary fructose is a major risk to health. The major dietary sources of fructose are whole fruit and fruit juices, as well as sucrose and high fructose maize syrup as components of sweetened drinks, bakery goods and confectionery. The potential problems associated with high fructose intakes are beyond the scope of this review. However, the German Nutrition Society[14], concluded that there was no association between a fructose intake of less than 100 g/d and fasting TAG concentrations. Higher fructose intakes did appear to be associated with elevated fasting plasma TAG levels. In addition, they concluded that a fructose intake below 50 g/d was not linked to postprandial TAG levels. Clearly, if free sugars intake was at 5 % of total energy intake, this would equate to 25 g sugars for an energy intake of 8368 kJ/d (2000 kcal/d), and if it was all sucrose this would only be approximately 12·5 g fructose. Total fructose intake would be higher than this due to the consumption of whole fruit, but it is highly unlikely that total fructose intake would be as high as 50 g/d if people were able to

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comply with the recommendation that only 5 % of total energy should come from free sugars.

One of the main concerns for health is the link between diet and liver fat content. It is now clear that obesity is a major risk factor for the presence of non-alcoholic fatty liver disease, and there is a concern that this may be enhanced by high dietary intakes of fructose. This possibility was tested by Johnston *et al.*[15], who studied men who were overweight or obese and had a large waist circumference but were otherwise healthy. The men were allocated to one of two groups and studied for two separate periods of 2 weeks each. One group received daily supplements of fructose and the other of glucose, with 25 % of energy intake being derived from the monosaccharide. The first 2-week period involved the participants being fed at energy balance, with measurements of body weight, liver and muscle fat and plasma lipids, glucose and insulin being measured at the start and end of the feeding period. After a recovery period of 6 weeks, the participants were then overfed for 2 weeks with one or other monosaccharide being provided at 25 % of energy requirements whilst the participants received food at 100 % of energy requirements. There were no differences between the effects of fructose or glucose on body weight, liver or muscle fat, plasma insulin or glucose and when fed at energy balance there was no effect on liver or muscle fat content (or body weight). By contrast, overfeeding with either fructose or glucose for 2 weeks led to an increase in liver fat content and in muscle fat, with no difference between fructose and glucose. Subsequent work in a similar group of men showed that overfeeding glucose for 2 weeks had a more marked effect to increase liver fat content than seen when fat was overfed to the same degree[16].

Policy aspects

The SACN Report on Carbohydrates was accepted in full by the UK Government, which meant that the recommendations for free sugars to be 5 % of total dietary energy, as well as for an increased fibre intake, were to be features of future government policy. One of the early initiatives then introduced by the UK Government was the taxation of SSB if the sugars content exceeded 5 g/100 ml. There is extensive debate as to the effectiveness of such taxation which is beyond the scope of this review[17]. However, there have been some recent suggestions in the lay press and media that this beverage tax should be extended to sugar-sweetened milks and even milk itself. There is some logic in considering milks which have sugar added to them being potentially similar to the SSB and limiting their consumption would seem justified. However, it is not appropriate to consider that all milk is in this category. The definition of free sugars does not include whole, semi-skimmed or skimmed milk provided that the milk has not been processed further than altering the fat content. The nutritional benefits provided by milk, especially to infants and young children, should not be underestimated and a full review of these benefits would need to be undertaken before considering whether the sugar content of milk (i.e. lactose) should be regarded as a free sugar.

There has been some suggestion that the metabolism of galactose (which when combined with glucose produces the disaccharide lactose) is potentially troublesome as far as health risks are concerned. Kritchevsky *et al.*[18] reported a study in baboons in which a small number of animals were fed diets with 40 % of the energy as carbohydrate, fed as either fructose, sucrose, glucose, starch or lactose for 17 months. The main outcomes were of an increase in faecal weight with lactose, suggesting a degree of intolerance, and an increase in staining of the endothelial surface of the aorta for lipid in the lactose group with clear atheromatous lesions in five of six animals. This observation does not appear to have been followed up or explained mechanistically so any suggestion that lactose or possibly galactose, represents a major risk to health is not supported by robust scientific evidence and further work is clearly needed.

Conclusions

The review by Mela and Woolner[7] provides a very thorough evaluation of the links between different categories of dietary sugars and weight gain, energy intake, type 2 diabetes risk and dental caries. They concluded that the relations between intake and risk were weakest for total sugars, and most consistent for free sugars (or in some cases the dietary sources which contain free sugars). They recommended that the focus should be on reducing the consumption of free sugars when considering monitoring of intake, public health guidance and communication to consumers.

A focus of public health actions on free sugars will be challenging as there is no consensus on their definition and measurement, on labelling of foods or how accurate information can be provided for consumers to aid their understanding. The development of such a focus on free sugars will require the involvement of nutrition and food science expertise, public health agencies and the food industry. It remains to be seen how effectively these stakeholders engage in the process, but it is clear from the evidence currently available that dietary free sugars intake should be reduced.

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Conflicts of Interest

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Authorship

The author had sole responsibility for all aspects of preparation of this paper.

References

1. Institute of Medicine (2005) *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: Food and Nutrition Board, Institute of Medicine, National Academies Press.
2. Ludwig DS, Hu FB, Tappy L *et al*. (2018) Dietary carbohydrates: role of quality and quantity in chronic disease. *Br Med J* **361**, k2340.
3. Scientific Advisory Committee on Nutrition (2015) Carbohydrates and Health. London: The Stationery Office.
4. Atkinson FS, Foster-Powell K & Brand-Miller JC (2008) International tables of glycemic index and glycemic load values: 2008. *Diabetes Care* **31**, 2281–2283.
5. Livesey G & Tagami H (2009) Interventions to lower the glycemic response to carbohydrate foods with a low-viscosity fiber (resistant maltodextrin): meta-analysis of randomized controlled trials. *Am J Clin Nutr* **89**, 114–125.
6. Norona JC, Braunstein CR, Mejia SB *et al*. (2018) The effect of small doses of fructose and its epimers on glycemic control: a systematic review and meta-analysis of controlled feeding trials. *Nutrients* **10**, E1805.
7. Mela DJ & Woolner EM (2018) Perspective: total, added or free? What kind of sugars should we be talking about? *Adv Nutr* **9**, 63–69.
8. World Health Organization (2015) *Guideline: Sugars Intake for Adults and Children*. Geneva: World Health Organization.
9. Buyken AE, Mela DJ, Dussort P *et al*. (2018) dietary carbohydrates: a review of international recommendations and the methods used to derive them. *Eur J Clin Nutr* **72**, 1625–1643.
10. Peres MA, Sheiham A, Liu P *et al*. (2016) Sugar consumption and changes in dental caries from childhood to adolescence. *J Dent Res* **95**, 388–389.
11. O'Connor L, Imamura F, Brage S *et al*. (2018) Intakes and sources of dietary sugars and their association with metabolic and inflammatory markers. *Clin Nutr* **37**, 1313–1322.
12. Carter P, Gray LJ, Troughton J *et al*. (2010) Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *Br Med J* **341**, c4229.
13. Louie JCY & Tapsell LC (2015) Association between intake of total vs added sugar on diet quality: a systematic review. *Nutr Rev* **73**, 837–857.
14. Hauner H, Bechtold A, Boeing H *et al*. (2012) Evidence-based guidelines of the German Nutrition Society: carbohydrate intake and prevention of nutrition-related diseases. *Ann Nutr Metab* **60** Suppl 1, 1–58.
15. Johnston RD, Stephenson MC, Crossland H *et al*. (2013) No difference between high fructose and high glucose diets on liver triacylglycerol or biochemistry in healthy, overweight men. *Gastroenterology* **145**, 1016–1025.
16. Chee C (2016) The influence of age and nutrients on insulin sensitivity. PhD Thesis, University of Nottingham. http://eprints.nottingham.ac.uk/32935/8/Thesis%20C%20CHEE%20Dec2015.pdf.
17. Sarlio-Lahteenkorva S & Winkler JT (2015) Could a sugar tax help combat obesity? *Br Med J* **351**, h4047.
18. Kritchevsky D, Davidson LM, Kim HK *et al*. (1980) Influence of type of carbohydrate on atherosclerosis in baboons fed semipurified diets plus 0·1% cholesterol. *Am J Clin Nutr* **33**, 1869–1887.

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