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Commentary

Database values for food-based dietary control of glycaemia

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ABSTRACT

Data representing the glycaemic potency of foods and carbohydrates are being increasingly included in food composition databases for managing the worldwide problems of diabetes and obesity. This paper identifies a number of criteria for assessing the quality of food data intended to guide healthier food choices for postprandial glycaemic control. The criteria are then applied to various carbohydrate and glycaemic potency data that are now being added to food composition databases. Our analysis suggests that if communication is based on the glycaemic potency of whole foods, as consumed, it is more likely to be useful for consumers, nutritionists and food producers than if based on food carbohydrates alone. Basing glycaemic impact values on foods rather than on carbohydrates would allow them to be expressed per serving and per 100 g of food, consistent with other information presented in food labels, but would still allow carbohydrate-based food selections from food groupings of similar composition, as is required when using the glycaemic index. Furthermore, we recommend *in vitro* measurement of glycaemic potency, to overcome the expense, difficulty and imprecision of *in vivo* analysis, which makes it unsuitable in product development, quality assurance, and accumulation of food composition database values.

1. Introduction

Controlling postprandial glycaemic response is considered important for maintaining long-term health and preventing or ameliorating serious diseases common in affluent countries, and that are becoming increasingly common in developing ones, notably Type 2 diabetes and cardiovascular disease (Zimmet et al., 2001; Seidell, 2000). Blood glucose in elevated concentrations is known to react chemically with a range of cellular components, leading to diffuse systemic damage through formation of advanced glycation end products. Oxidative stress, resulting from mitochondrial responses to high glucose concentrations, also creates an unfavourable, oxidative cellular environment, which is thought to lead to vascular and other damage via several pathways (Brownlee, 2001; Guigliano et al., 2008). The combined and cumulative damage from the prolonged action of such processes over a period of time contributes to the spectrum of symptoms and complications associated with the metabolic syndrome and Type 2 diabetes. Steps to avert the long-term effects of chronic hyperglycaemia therefore require dietary habits that are established early in life and sustained, supported by valid and practical food information.

Unquestionably, eating appropriate foods over a lifespan is one of the most important behaviour patterns that individuals can choose in order to minimise the overall glycaemic impact of their diet. However, it is difficult for consumers to sense a physiological state of hyperglycaemia, and they depend on information that describes the relative glycaemic effects of different foods. But consumers, health professionals and food manufacturers still do not have ready access to simple quantitative data that accurately represent the glycaemic potency of foods in relevant quantities, such as are used to present other basic nutritional information, including nutrient composition and energy values (Monro, 2000). For instance, grams per serving, grams per 100 g to allow equal weight comparison, and reference amounts customarily consumed (RACC) per eating occasion favoured by the United States Food and Drug Administration (2005) allow comparability and relevance. Without such data it is difficult for nutritionists to construct diet plans, for consumers to make appropriate choices at point of sale, and for manufacturers and retailers to develop and promote healthier foods.

AACC International[1] recently recognized the need for food values to facilitate food choices for glycaemic control, by establishing a committee on glycaemic definitions charged with providing "... a

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[1] Formerly the American Association of Cereal Chemists.

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measurable definition that will enable manufacturers to communicate the glycaemic response in grams per serving of food" (Miller-Jones, 2007). Several groups have started to compile databases of glycaemic index and glycaemic load values for addition to food composition databases, using various strategies to overcome the lack of comprehensive data (Martin et al., 2008; Schakel et al., 2008). As demand increases for databases of glycaemic impact, it is important at this early stage to carefully consider the nature and uses of the data that are being selected.

In this paper we discuss the essential characteristics required of food data to enable consumers to select foods for postprandial glycaemic control, and recommend an approach that satisfies the criteria identified.

2. Variables used to indicate the glycaemic potency of foods

The glycaemic potency of foods has been expressed in several ways. For instance, it has been quantified as the amount of available carbohydrate consumed, the relative glycaemic potency of the carbohydrate constituents in a given food, and the product of the glycaemic potency of the food itself and the quantity consumed (Monro and Shaw, 2008).

2.1. Carbohydrate content

Carbohydrate alone is an inadequate indicator of the glycaemic properties of foods because it does not account for differences in glycaemic potency of the component carbohydrates in the food. For instance, the blood glucose response to fructose is about one-fifth that of an equal weight of glucose. Also, because carbohydrate analysis for food labelling is conducted after exhaustive extraction from finely ground samples, it does not take into account differences in rates and extent of availability during digestion due to food structure, or interaction of carbohydrates with other food constituents.

2.2. Glycaemic response

Clinically measured glycaemic responses to foods have been incorporated into values to guide food choices in two ways.

2.2.1. By attributing the responses to available carbohydrate content

When the postprandial glycaemic response is attributed specifically to the available carbohydrate content of a food, and indexed to the response to a quantity of glucose equal to the available carbohydrate in the food, the relative response is known as the glycaemic index, or GI (Jenkins et al., 1981). It may be defined as:

$$\mathrm{GI} = \frac{\text{blood glucose response to a quantity of food containing 50 g available carbohydrate}}{\text{blood glucose response to 50 g glucose}} \times 100$$

Although often referred to as the glycaemic index of a food, it is clear from the above that GI is, strictly speaking, a derived estimate of the glycaemic index of carbohydrate in a food, not of a food *per se*, although it is based on a response to whole food.

GI was designed to be used as an adjunct to food composition data in intensive diabetes management. It was intended to allow carbohydrate foods, after being placed into food exchange categories of the same composition, to be discriminated between in terms of glycaemic impact.

But because GI is applied to foods after they have been placed into categories of equal carbohydrate composition, there was no need for the original measured relative glycaemic potency of the food, on which GI was based, to have been converted to GI by being calculated to a carbohydrate basis and expressed as a percentage. A value of, for instance, relative glycaemic effect per 100 g of food (a true glycaemic index of a food), would have discriminated in exactly the same way as GI, between foods in equal carbohydrate food exchange categories. Because GI expresses the glycaemic potency of foods as unchanging carbohydrate-cased GI values, for comparing equal carbohydrate quantities, it cannot be applied with any accuracy in an environment in which foods are not presented in, or selected from, carbohydrate exchange categories, and amounts of food consumed are not governed by the prescriptions of intensive diabetes management.

Foods that have a low GI do not necessarily have a small glycaemic effect if the carbohydrate content per gram and the intake per serving are high. Two muesli bars will induce about twice the glycaemic response of one, but the GI value remains the same. In reality, blood glucose management needs to be able to deal with dietary loadings of glucose equivalents.

2.2.2. By attributing glycaemic responses to foods per se

When a glycaemic effect is attributed to a food *per se* the blood glucose response is regarded as an emergent property of the *whole food*. The glycaemic impact may then be expressed as the weight of glucose that would induce a glycaemic response equal to that induced by a given quantity of the food (Miller-Jones, 2007; Monro and Shaw, 2008), allowing the glycaemic impact of a food to be expressed in terms of the virtual food component, glycaemic glucose equivalents (GGE). GGE is based on an *equiglycaemic* comparison, so it is ideally measured off a glucose dose–glycaemic response standard curve, and may be defined as:

$$\mathrm{GGE} = \frac{\text{the weight of glucose inducing the same glycaemic response as a relevant reference food portion}}{\text{weight of the above food portion}} \times \text{weight of food consumed(g)}$$

The term GGE is an accurate scientific description of the food variable, as are niacin equivalents, or retinol equivalents, although some other term founded on GGE database values may be preferred for general use. The AACC, for instance, has recently suggested the term "glycaemic impact" (Miller-Jones, 2007), meaning relative glycaemic impact, with the same definition as GGE, so it would represent a given GGE intake.

Conceptually, GGE is straightforward, as it simply states the amount of glucose that would induce the same glycaemic effect as a given amount of food. In terms of glycaemic effect it says—"this amount of glucose equals that amount of food". Apart from direct clinical measurement, a database of GGE values may be compiled by a hierarchy of indirect methods to produce GGE values that approximate true GGE. For instance, an estimate of GGE may be obtained from the product of the carbohydrate content of a food quantity and the glycaemic index of the food. Importantly, the concept of GGE brings glycaemic impact into line with other nutrients that are expressed both as the quantity supplied per 100 g of food and per serving. The latter is gaining greater acceptance with the growing use of the RACC (as mentioned above, this is preferred by the US Food and Drug Administration (Food and Drug Administration (US), 2005), in food labelling).

One approach to a food-based measure of glycaemic potency, which is an approximation of GGE, has been glycaemic load (GL) (Salmeron et al., 1997), which for a single food intake is defined as:

$$\mathrm{GL} = \text{amount of carbohydrate(g) in food consumed} \times \frac{\text{GI of the food}}{100}$$

However, because GI is based on the blood glucose response to a glucose reference of 50 g, whereas most 50 g carbohydrate portions of foods induce a lower glycaemic response than glucose, the responses to food and glucose are often well separated on the