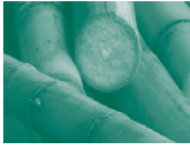




The Glycemic Index: Clinical and Public Health Significance

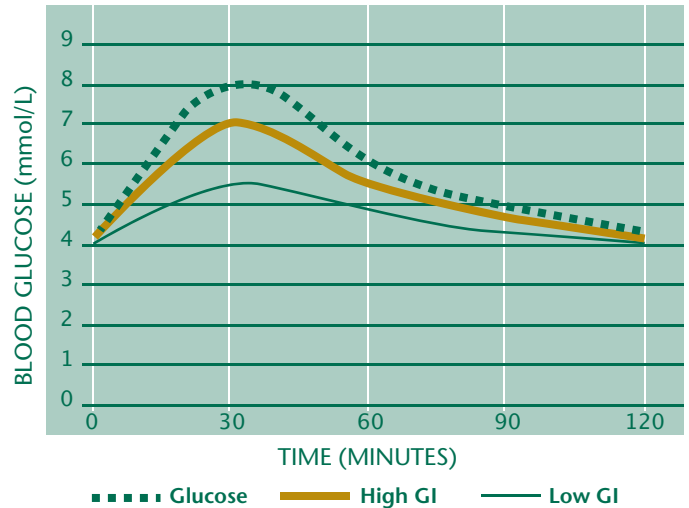


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Carbohydrate is the most important source of energy in the majority of human diets and has a wide range of physical, chemical, and physiological characteristics. Historically, carbohydrate has been defined based on its chemical properties, but more recently a physiological classification of carbohydrate has been developed.

The Glycemic Index (GI) is intended to quantitatively rank carbohydrate based on its impact on blood glucose levels (1). It is a measurement of blood glucose response (over two hours) after ingesting a test food that typically contains 50 grams of glycemic carbohydrate. This value is then expressed as a percentage of the response to 50 grams of glycemic carbohydrate from either white bread or glucose when consumed by the same subject. Generally, rapidly digested carbohydrate has the highest response while carbohydrate that is more slowly digested produces a much smaller area under the 2 hour blood glucose curve (AUC) (Figure 1). The goal is to characterize carbohydrates in foods by quantifying this response.

Figure 1.



Glycemic Load (GL) describes the effect of both the amount of carbohydrate consumed and the GI value of a carbohydrate on blood glucose response. The glycemic load is calculated by multiplying the amount of carbohydrate in a serving of the food by the GI. For instance, watermelon has a high GI, but because it contains very little carbohydrate, the effect of a serving on blood glucose is low (2). Table 1 defines GI and GL and provides an example of how the numbers are derived.

Since 1981, the GI of many carbohydrate-containing foods has been calculated and these values are listed to rank foods based on this clinical test (3). In general, foods made from grain flour such as snack foods, breads and ready to eat cereals have a high GI. Whole grains, pasta and fruits tend to have a moderate GI, whereas legumes and dairy products have the smallest glycemic response.

Although GI values are widely available and used in evaluating food choices, there are conflicting views on the reliability and application of this measure in clinical and public health settings. Proponents of the GI system consider it to be an important strategy to reduce fluctuations in blood glucose and insulin, improve glucose and lipid metabolism in diabetes, lower blood triglycerides in those who have elevated levels, and aid in body weight

Table 1: Definitions of glycemic index and glycemic load

| | | |
|----------------------------|---|---|
| Glycemic Index (GI) | Index that reflects the change in blood glucose after ingestion of a test food compared to the reference food, such as white bread or glucose. | GI of an apple = 34 (i.e. the carbohydrate in the apple provides 34% of the glycemic response of glucose) |
| Glycemic Load (GL) | Measure of the glycemic index of the food, taking into account the amount of available carbohydrate in a standard serving; this reflects the true effect on glycemia. | GL of an apple = 5 (i.e. amount of glycemic carbohydrate in the apple (14g) x GI/100 = 14 g x 34/100) |

management and athletic performance. The GI has also been popularized in a variety of diet books and GI symbols have emerged to promote "healthy eating" in countries such as Australia, Sweden, and South Africa.

Those who are skeptical of the GI and GL have questioned its usefulness for reasons including: 1) the failure of the index to

consider the insulin response (4); 2) the high intra- and inter-subject variation in the glucose response to a food (5;6); 3) the lack of discrimination between foods found as part of a mixed meal (7); and 4) the varied methodologies used by different laboratories (2).

Blood glucose versus insulin response.

Although a linear relationship is typically observed between insulin and blood glucose in foods that are primarily carbohydrate, some foods do not display this same association (4). Milk products are a good example, because even though lactose is a low glycemic sugar, milk proteins stimulate insulin release (8).

Intra- and inter-individual variability. The high variability in GI values has been attributed to differences in the chemical and physical properties of the food (7;8), the biological variation between individuals (5;8), day-to-day variability within individuals (6), and the methodology used when testing foods (9). The method by which food is prepared (cooking time, method of cooking, and temperature of food) may result in a different GI value for a similar food (10). The physical state of foods (e.g., raw or cooked, whole or ground) has a large influence on the GI rating, particularly in starchy foods. For instance, the GI of freshly cooked potatoes increases when they are mashed versus whole, but if allowed to cool prior to eating they have a low GI due to the formation of resistant starch (3). Similarly, the geographic region where the food is consumed can impact the glycemic response because of differences in regional varieties and cooking methods – rice is a good example (3). Individual variability in

the rate of eating and the extent to which food is chewed affects digestion and absorption and influences the GI (11;12). These factors vary both between individuals and within the same individual and may contribute to the lack of reproducibility in GI values as observed in the same individual on different days (6).

Single foods versus mixed meals. When a food is eaten as part of a mixed meal, the GI of the meal may not be accurately predicted (7). One technique that has been used to evaluate a mixed meal is to rank the meals by the GI of the food that provides the most carbohydrate. Alternatively, the GIs of individual

components of a meal have been summed to predict the overall GI of the meal. However, combining foods of varying composition has different effects on the overall glycemic response. For instance, adding protein and fat to a carbohydrate containing meal reduces the glycemic response (13;14).

Variability in estimates. The GI values from different laboratories can vary for the same food. Figure 2 illustrates the variability of GI reported for certain foods due to different analytical methods (2) and to other sources of variation as described above (15) (Figure 2).

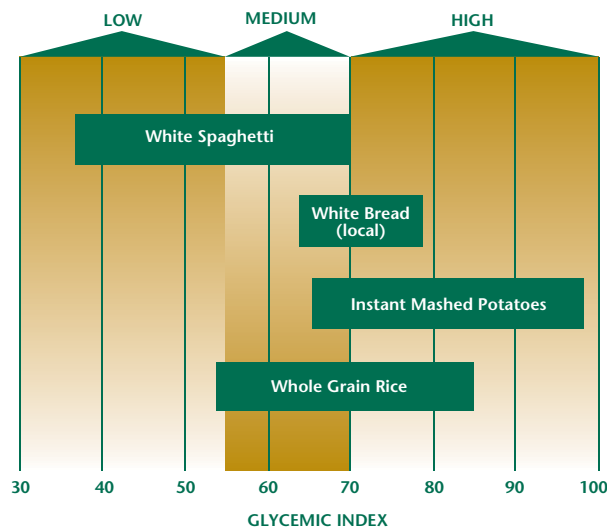


Figure 2. Ranges of GI values for a given food as part of an interlaboratory study by Wolever et al. (2003). With the exception of the bread, foods were purchased centrally and distributed to participating laboratories. 8–12 subjects were studied in 7 laboratories around the world using a method recommended by the FAO/WHO (15).

Glycemic Index: The Application

Authoritative groups have conflicting views on the application of the GI. While the Canadian Diabetes Association is supportive (16), the American Diabetes Association (ADA) continues to provide guarded statements on the utility of the glycemic index in diabetes management, which was the original goal of the concept of 30 years ago. Their position is that “there is not sufficient, consistent information to conclude that low-glycemic load diets reduce the risk for diabetes”. From the perspective of glycemic control, the ADA suggests that the use of GI and GL may provide a modest additional benefit over the consideration of total carbohydrate

alone (17). This prudent conclusion is supported by the results of a large scale randomized control trial conducted in Canada (18). Subjects with type 2 diabetes showed little benefit after one year of manipulation of the GI or the amount of dietary carbohydrate. An editorial in the same journal arrives at the conclusion that “given the data from Wolever et al and previous equivocal data with respect to this issue it seems unwise at this point to burden type 2 diabetic patients with trying to pick and choose among different high and low-GI foods” (19).

While the original intent of GI was to help guide dietary choices for people with

diabetes, GI has more recently been advocated as a tool for weight management. A recent review conducted as part of the WHO/FAO scientific update on carbohydrate concluded that the current evidence on low-GI and low-GL diets provides little support for a significant role in weight management (20). The results of a recent long-term (one year) randomized control trial supports this conclusion (21). Furthermore, they could not make a specific recommendation with regard to GI for the prevention of obesity (20). It is doubtful that further large, long-term, well-powered, randomized control trials can be justified based on the current evidence.

Clearly the debate on the value of the GI concept in a clinical and public health setting will and must continue. The wide variation in individual responses to the same carbohydrate food as well as the poor reproducibility of the GI of a given food makes it extremely difficult to provide reliable advice to guide food choices in the clinical or public health context (6). Although several countries currently allow voluntary labelling of a food product with its GI, the unresolved issues surrounding the measurement, the lack of reproducibility, and the benefits of the GI in dietary guidance suggests that it is premature to support the labelling of foods with the GI. Unfortunately, while scientific consensus and a regulatory framework for allowing the labeling of GI on foods in Canada is not present, industry and lobbying pressures are being applied to achieve political action. Thus it is time to have an open and critical review of the state of the science and the application of the GI in Canada.

While the benefits of GI in general dietary guidance may be uncertain, dietitians can be confident that promoting foods and eating patterns that provide lower blood glucose response is not likely to cause adverse effects. Fortunately, most individuals appear to naturally consume a moderate glycemic diet by consuming foods that range from low to high GI (22;23). However, it is important to note that a food which elicits a low glucose response is not necessarily a healthier choice because it may be high in fat or low in essential nutrients. For the present time, directing consumers to the Nutrition Facts table on foods, providing education on interpreting the nutritional information, and recommending an eating pattern based on Canada's Food Guide should remain the focus of nutritional guidance.

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Carbohydrate Terminology

Written by the Nutrition Professionals of the Canadian Sugar Institute with support from Alison Stephen, PhD, Population Nutrition Research, MRC Human Nutrition Research, Elsie Widdowson Laboratory, Cambridge, UK

Dietary carbohydrate has a wide range of chemical, physical, and physiological properties. Carbohydrate is classified according to chemical composition, but these groupings are not always helpful when describing physiological and nutritional functions. As a result, a number of terms have emerged to group carbohydrate based on physiological properties and to help focus on specific health benefits. A recent review by Cummings and Stephen (2007) addresses the challenges in reconciling the various chemical and physiological terms and proposes some terms to be more useful than others.

The three major chemical classifications of carbohydrate comprise sugars (mono- and disaccharides), oligosaccharides

(composed of 3-9 monosaccharides), and polysaccharides (composed of >9 monosaccharides). This classification system is fundamental for the measurement of carbohydrate and for the assessment of dietary intake; however it is not always useful in describing nutritional benefits given the overlapping physiological effects of major chemical groupings. As a result, a number of terms or categories have evolved that attempt to group carbohydrate by physiological effect or health benefit, such as glycemic carbohydrate, dietary fibre, prebiotics and resistant starch (see definitions on page 4).

Grouping carbohydrate by physiological properties or nutritional characteristics is more difficult than classifying by chemical composition because the physiological

effects of a particular carbohydrate can vary between individuals. For example, lactose is poorly digested and absorbed in the small intestine by many individuals, whereas others are able to break down lactose and utilize its constituent sugars, glucose and galactose. Furthermore, the physiological or nutritional classification of carbohydrate requires ongoing revision due to evolving scientific evidence in the area of food science and metabolism.

Cummings and Stephen (2007) reviewed the wide range of chemical and physiological terms used to describe carbohydrate. Terms were considered useful if they were: 1) measurable by a laboratory analyst; 2) understandable to the consumer; 3) indicative of the properties of the carbohydrates rather than the food itself.

Table 2: An evaluation of chemical and physiological terms used to categorize carbohydrate

| | Useful | Less Useful |
|----------------------|----------------------------|---|
| Chemical | Total sugars | Sugars |
| | Monosaccharides | Sugar |
| | Disaccharides | Free sugar |
| | Oligosaccharides | Refined sugars |
| | Polysaccharides | Added sugars |
| | Polyols | Intrinsic sugars |
| | Short-chain carbohydrates | Extrinsic sugars and non-milk extrinsic sugars (NMES) |
| | Starch | |
| | Non-starch polysaccharides | |
| | Total carbohydrate | |
| Physiological | Prebiotic* | Complex and simple carbohydrate |
| | Resistant starch* | Non-digestible oligosaccharides |
| | Dietary fibre* | Soluble and insoluble fibre |
| | Glycemic carbohydrate* | Available and unavailable carbohydrate |

* See definitions below.

Source: Adapted from Cummings and Stephen (2007)

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*DEFINITIONS

Prebiotic: 'A prebiotic is a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one of a limited number of bacteria in the colon and thus improves host health' (Gibson and Roberfroid, 1995; Gibson, 2004).

Resistant Starch: Starch and products of starch digestion (e.g., maltose) that are not absorbed in the small intestine.

Dietary Fibre: National and International bodies continue to struggle with the definition of dietary fibre. The common theme in all definitions is that dietary fibre includes 'non-digestible dietary carbohydrates'. However, the current proposed definition for Codex and the National Academy of Science in the United States is 'dietary fibre consists of intrinsic plant cell wall polysaccharides'.

Glycemic Carbohydrate: Carbohydrates that provide glucose for metabolism as evidenced by an increase in blood glucose levels after ingestion. See the Glycemic Index article above for further discussion.

Based on their review of the categories used to classify carbohydrate, Cummings and Stephen (2007) present a number of conclusions. A number of the conclusions relevant to the above discussion are summarized below.

1. Dietary carbohydrate should be classified according to chemical composition.
2. The physiological and health effects of carbohydrate are dependent not only on their chemical form but are also dependent on their physical properties.
3. Many terms exist to describe sugars in the diet. The most useful are total sugars and mono- and disaccharides. The use of other terms creates difficulties for the laboratory analyst, confusion for the consumer, and suggests properties of foods that may not be related to sugars themselves, but to the food matrix.
4. Because neither chemical nor physical descriptions of carbohydrate reflect its physiological properties and health benefits, a number of terms to describe carbohydrate based on their physiology have been created. Of these, prebiotic, glycemic carbohydrate, resistant starch, and dietary fibre are useful.
5. The term dietary fibre should not be used to describe physiological or health properties that vary considerably with type, but rather should reflect the health benefits of a diet rich in fruits, vegetables, and whole grains.
6. The distinction between soluble and insoluble forms of fibre is inappropriate considering that this separation is pH dependent and does not reflect the physiological properties of whole foods in the gut. Further investigation is required to examine the effect of foods containing different types of fibre on glycemic control and lipid levels and to determine the specific properties of the carbohydrate that induce improvements in these health biomarkers.

It is clear that dichotomy exists – the chemical classification of carbohydrate is insufficient to describe nutritional or physiological properties and physiological terms are not necessarily useful for measurement or labelling purposes. Furthermore, the use of a number of these chemical and physiological terms is not suggested by Cummings and Stephens (2007) because they may cause consumer confusion by describing the food matrix, rather than the carbohydrate.

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