

Glycaemic Index

Relevance for health, dietary recommendations and food labelling^a

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Abstract

The glycaemic index (GI) concept is based on the difference in blood glucose response after ingestion of the same amount of carbohydrates from different foods, and possible implications of these differences for health, performance and well-being. GI is defined as the incremental blood glucose area (0–2 h) following ingestion of 50 g of available carbohydrates in the test product as a percentage of the corresponding area following an equivalent amount of carbohydrate from a reference product. A high GI is generally accompanied by a high insulin response. The glycaemic load (GL) is the GI × the amount (g) of carbohydrate in the food/100. Many factors affect the GI of foods, and GI values in published tables are indicative only, and cannot be applied directly to individual foods. Properly determined GI values for individual foods have been used successfully to predict the glycaemic response of a meal, while table values have not. An internationally recognised method for GI determination is available, and work is in progress to improve inter- and intra-laboratory performance. Some epidemiological studies and intervention studies indicate that low GI diets may favourably influence the risk of chronic diseases such as diabetes and coronary heart disease, although further well-controlled studies are needed for more definite conclusions. Low GI diets have been demonstrated to improve the blood glucose control, LDL-cholesterol and a risk factor for thrombosis in intervention studies with diabetes patients, but the effect in free-living conditions remains to be shown. The impact of GI in weight reduction and maintenance as well as exercise performance also needs further investigation. The GI concept should be applied only to foods providing at least 15 g and preferably 20 g of available carbohydrates per normal serving, and comparisons should be kept within the same food group. For healthy people, the significance of GI is still unclear and general labelling is therefore not recommended. If introduced, labelling should be product-specific and considered on a case-by-case basis.

Keywords: *body weight; carbohydrates; disease risk; starch; sugars*

Introduction

Dietary recommendations worldwide are concordant in recommending that carbohydrates should constitute 50–60 percent of the energy intake. This implies a more or less pronounced increase compared with current intakes in Western countries. The nutritional properties of the dietary carbohydrates then come into focus.

A primary nutritional classification of carbohydrates is to differentiate between those digested and absorbed in the small intestine, providing carbohydrate to body cells (available carbohydrates, “glycaemic carbohydrates”), and those passing to the large intestine, providing substrate for the colonic microflora, i.e. dietary fibre (1).

The glycaemic index (GI) concept was introduced by Jenkins et al. in 1981 (2). GI is defined as the incremental blood glucose area (0–2 h) following ingestion of 50 g of available carbohydrates as a

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percentage of the corresponding area following an equivalent amount of carbohydrate from a standard reference product. Different research groups have used somewhat different blood sampling techniques (venous or capillary), times for calculating the glucose response area (1.5–3 h) and reference product (glucose or white bread). These methodological differences impair the comparison of data from different groups. The definition and methodology described in a recent FAO/WHO expert report, however, is now referred to as an international standard (1, 3). Calculation of incremental area under the postprandial glucose response curve (IAUC) according to this method is illustrated in Fig. 1. GI is calculated as $(\text{IAUC}_{\text{sample}}/\text{IAUC}_{\text{standard}}) \times 100$.

The glycaemic response to a food, which in turn affects the insulin response, depends on the rate of gastric emptying, as well as on the rate of digestion and absorption of carbohydrates from the small intestine (4). People with diabetes have been advised to choose slowly absorbed carbohydrates. A low and prolonged glycaemic response helps these patients to improve their blood glucose control. “Slow carbohydrates” have often also been considered advantageous for healthy people to avoid an excessive insulin response and hypoglycaemia between meals. It was assumed that polysaccharides or “complex carbohydrates”, i.e. starch, were “slow carbohydrates”, whereas sugars (mono- and disaccharides) were considered “rapid”. Later it has been demonstrated that many food factors other than the molecular size of the carbohydrate component are

Table 1. Main food factors affecting the GI of foods and meals

Food factor	Examples of influencing factors	Effect on GI
<i>Structure</i>		
Gross structure	Grinding, heat treatment	Higher GI when homogenised
Cellular structure (cell wall integrity)	Ripeness	Higher GI with increased ripeness
<i>Starch</i>		
Granular structure (intact or gelatinised)	Heat treatment	Higher GI when gelatinised
Amylose (unbranched)	Genotype of raw material	Lower GI compared to amylopectin
Amylopectin (branched)	Genotype of raw material	Higher GI compared to amylose
<i>Other factors</i>		
Gel-forming types of dietary fibre	Genotype of raw material Added fibres	Lowers GI
Organic acids	Fermentation Added acids	Lowers GI
Amylase inhibitor	Heat treatment	Lowers GI
Fructose/glucose-ratio	Genotype of raw material Type of added sugars	Lower GI with increased ratio

important determinants of the glycaemic response, as reviewed by Björck et al. (5) and listed in Table 1. Therefore, different food products or meals with the same amount of carbohydrates show differences in glycaemic and insulinaemic responses.

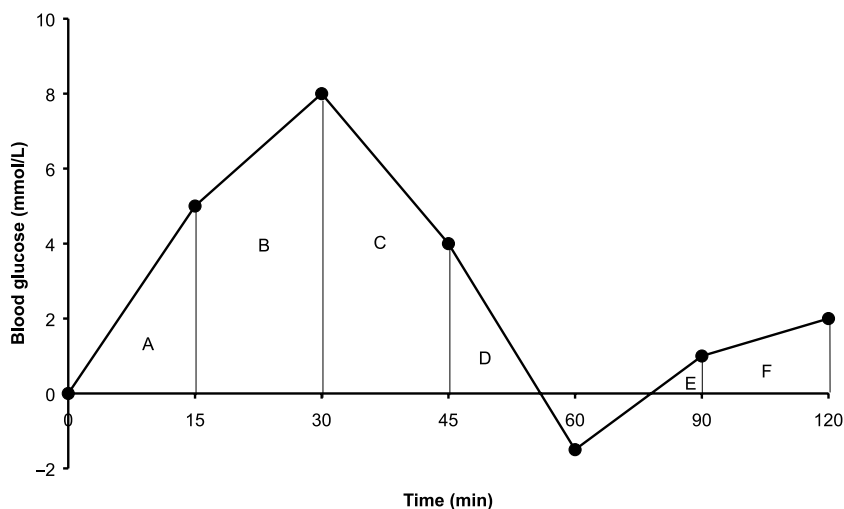


Fig. 1. The incremental area under the curve (IAUC) equals the sum of the areas A, B, C, D, E and F. Negative areas are not included. The figure is adapted from (1).

The glycaemic response to the same food or meal may be influenced by the time, composition and GI of a previous meal. A prolonged glucose response after a breakfast meal has been demonstrated to improve glucose tolerance at lunch, denoted as the “second meal effect” (6–9). Overnight second meal effects have also been demonstrated (8, 10, 11). Second-meal effects may reveal mechanisms for long-term effects of low GI foods, but the implications for health and clinical applications remain to be demonstrated. From a technical point of view regarding GI determinations, it is important to recognise that the second meal effect may influence the glycaemic response to a food. Probable mechanisms behind the second meal effect are briefly commented on in Box 1.

The present report focuses on the relevance and utility of the GI concept in relation to disease risk and weight management in healthy people. GI in relation to physical exercise is also briefly commented on (Box 2) and some important methodological considerations are summarised (Table 2). Finally, the application of GI in dietary recommendations and dietary counselling is considered, and in this context the relevance of and scientific support for introducing GI labelling on food products. Reference is made to the importance of GI for metabolic control in diabetes, although dietary counselling in diabetes is outside the scope of the report.

GI tables and methodology

GI values for more than 750 types of foods have been published in an international review of available GI values (12). The GI data in this table have been compiled over time in different laboratories.

Box 1. THE SECOND MEAL EFFECT – PROBABLE MECHANISMS

Breakfast to lunch

- Low-GI breakfast attenuates the glycaemic response at lunch in both healthy and diabetic subjects (7–9).
- Some low-GI foods give a prolonged insulinaemic response, providing sustained, slightly elevated insulin levels at the time of the next meal (lunch).
- This may improve peripheral glucose uptake, i.e. glucose tolerance, as well as removal of circulating lipoproteins.

Overnight effects

- A late evening meal with slowly digested starch improves glucose tolerance at breakfast in type 2 diabetic patients (10, 11).
- A prolonged insulin response with concomitant prolonged nocturnal suppression of free fatty acids is a probable mechanism.
- In healthy individuals a similar effect was seen after an evening meal with low GI and rich in dietary fibre (8).
- Colonic fermentation of dietary fibre, resulting in elevated serum levels of short-chain fatty acids, may reduce serum-free fatty acids and hepatic glucose output.

Box 2. GI AND EXERCISE PERFORMANCE

Pre-exercise meal

- Low-GI foods ingested prior to exercise may contribute to enhanced performance (54–56).
- High-GI foods ingested 30–60 min prior to exercise may cause hyperinsulinaemia and hypoglycaemia and have therefore been suggested to contribute to impaired performance (57).
- The GI of a pre-exercise meal has been found to be of less importance if CHO are ingested during exercise (58).

Post-exercise meal

- High-GI foods ingested within 24 h after exercise may result in higher post-exercise glycogen synthesis than low-GI foods (59). This may be beneficial if the next workout takes place within 24 hours.
- The GI of post-exercise meals has been shown to be of less importance if the time between two workouts is > 24 h (60).

They are derived from products of different origin and brand, different types of test subjects, and somewhat different procedures for measuring and calculating GI have been used.

A considerable number of commercially available foods are included in the international review (12), but most foods represent the market in Australia, Canada, the US and the UK. From a Nordic perspective there is a lack of data for a variety of carbohydrate-rich foods (e.g. typical Scandinavian bread products, breakfast cereals, gruels, porridges, certain vegetables and legume products, such as pea soup and pickled brown beans). It should also be noted that an important number of the low-GI products included in the table are “experimental products” designed to answer specific academic questions regarding e.g. the impact of various food factors on GI, and many of the low-GI cereal products in the table are not available on the market. As shown in Table 3, there can be a considerable variation of reported GI values for one type of food, for example long-grain/parboiled rice (GI = 38–72) and boiled potatoes (GI = 24–101). Furthermore, the GI value of some items, e.g. jasmine rice, is based on one study only. Thus, a GI value obtained from a GI table should not be seen as an exact value but may be useful as an indication of the expected glycaemic response.

General principles for determination and calculation of GI have been described in the FAO/WHO report “Carbohydrates in Human Nutrition” (1). In a recent inter-laboratory study, the GI of 5 foods was measured in 7 different laboratories around the world using a local white bread as a standard (3). Mean GI values for the different foods did not differ considerably between laboratories, although individual determinations for the same food varied

Table 2. Important methodological considerations

Parameter	Comments
Subjects	> 10 test subjects Healthy subjects appropriate (lower within-subject variation than e.g. diabetic subjects using drugs)
Time of day	Mornings (more pronounced glycaemic response)
Background diet	Fasting subjects Standardised evening meal may reduce within-subject variation
Physical activity	Standardisation so far not successful in decreasing variation
Determination of glycaemic carbohydrates	“By difference” (total CHO minus dietary fibre): Acceptable estimation of digestible CHO in most normal foods, but may overestimate digestible CHO in products with undigestible CHO not determined as dietary fibre (e.g. oligosaccharides, resistant starch, and sugar alcohols). Specific assay of the CHO profile recommended for scientific purpose
Carbohydrate load	Typically 50 g glycaemic CHO (linear response for 25–50 g)
Reference product	White bread or glucose Other reference than glucose: GI characteristics of the reference maintained over time and recalculated/disseminated using glucose reference
Blood sampling/analyses	Capillary blood (preferable): higher postprandial glucose concentration, less variation Venous blood: lower glycaemic response, larger variation, higher GI than capillary blood Blood glucose analyses based on approved analytical methods, not enzymatic recognition in dry systems
Calculation	Typically 2 h incremental area (3 h area may be useful for products with extreme lente characteristics)

CHO = carbohydrates.

by 17 to 34 GI units. Thus, it is essential to accomplish further method standardisation on an international level. A major reason for variation in the GI determination was a random within-subject variation. It is outside the scope of the present paper to review the multitude of factors that may be important in relation to GI determination and calculation. An expert group within ILSI-Europe is currently working with this issue. Some methodological aspects are summarised in Table 2.

Several food factors (Table 1) and processing and cooking conditions (13) affect GI. This is the basis for designing foods with specific GI, but differences

in GI due to these factors are also perceived as a particular shortcoming of the concept *per se*. This problem is, however, shared with several other nutrients for which the content and bioavailability may be affected by processing and/or storage. To address this problem, and increase the utility of published data, relevant product characteristics need to be reported along with the GI in food tables. Furthermore, the content of energy, carbohydrate, fat and protein, as well as portion size, are important factors, which should be considered in dietary counselling and application of GI in practice.

Table 3. Glycaemic index, glycaemic load and energy per serving of selected foods

Food ¹	n	GI ² (glucose = 100)	Serving size ³ (g)	per serving		
				CHO (g)	GL	Energy (kcal)
Rice long-grain/parboiled (277, 230)	23	51(38–72)	175	50	26	200
Rice jasmine (300)	1	109	175	52	57	200
Spaghetti, white (532,535)	11	40 (32–47)	225	56	22	286
Spaghetti, white (532, 535)	11	40 (32–47)	180 ²	45	18	236
Potato, baked (602, 603)	5	80 (56–111)	160	29	23	136
Potato, boiled (604, 605)	12	65 (24–101)	150	29	19	130

¹ Numbers refer to the numbers used in (12).

² According to (12).

³ Typical Scandinavian serving sizes according to (61).

CHO = carbohydrates.

Given the definition of GI, the concept is useful only for foods that provide substantial amounts of available carbohydrates. GI values for low carbohydrate foods, e.g. vegetables or foods mainly containing fat and protein, are difficult to determine and may be misleading when used in practice. It is suggested, therefore, that the GI concept is applied only to foods providing at least 15 g and preferably 20 g glycaemic carbohydrates per portion, i.e. products such as bread, cereals, pasta, rice and potatoes.

Glycaemic load

In practice, the actual carbohydrate load from a normal portion size varies considerably between food products. In order to address this problem, the concept of glycaemic load (GL) was introduced (14, 15), representing both the quality and the quantity of the carbohydrates in a food or a meal. GL allows comparisons of the likely glycaemic effect of realistic portions of different foods, calculated as the amount of carbohydrate in one serving times the GI of the food (i.e. $GL = g \text{ carbohydrate} \times GI/100$). For example, spaghetti has a lower GI than boiled potatoes, but normal portion sizes of spaghetti are commonly larger than portions of potatoes. Therefore, GL may or may not differ between these two carbohydrate sources, depending on the applicable GI values and portion sizes, as illustrated in Table 3.

Mixed meals

One important point when using the GI concept is its applicability to mixed meals. Some studies using measured GI values of the key foods responsible for differences in GI have shown that the GI of a composite meal can be predicted from the GI values of the different carbohydrate-rich foods included (16–20), as exemplified in Table 4. However, other

studies have concluded that differences in GI between foods are diminished when incorporated in composite meals (21, 22). In one study, using GI values of the included food items from the international table (Foster-Powell 2002) and measuring the GI value of the final meal according to WHO (1), no correlation between the measured and calculated values of 14 European breakfast meals was found (23). In addition to the considerable range of values for the same food making it difficult to choose the relevant one, different countries might have different names for the same foods or the same name for foods with different compositions.

Fat and protein may influence gastric emptying and insulin secretion, but effects on GI are generally not seen unless relatively large amounts (about 30 g of protein and 50 g of fat per 50 g carbohydrates) are added (24). An exception is milk protein, which increases the insulin response. Although addition of fat and protein to a meal containing carbohydrates may result in a lower glucose response, the relative difference between starch-rich foods with different GI values remains (25).

Risk of diabetes and coronary heart disease

Hypotheses regarding protective effects of low-GI diets against chronic disease such as diabetes and coronary heart disease have been tested in epidemiological observational studies. Short- to medium-term intervention studies regarding risk factors have been performed mainly in type 2 diabetes patients.

Observational studies

A number of epidemiological studies have correlated the GL or GI to disease risk. A main shortcoming of some of these studies is the use of data from a dietary assessment method not geared to the study of GI and GL. Another shortcoming, shared with epidemiological studies in general, is a

Table 4. Principle for calculation of the glycaemic index of meals

Food	CHO per 100 g ¹ (g)	Portion size (g)	CHO per portion (g)	Proportion of total CHO (c = a/b)	Food GI ² (d)	Meal GI e = $\sum (c \times d)$
Yoghurt	4.9	250	(a) 12.3	(c) 0.24	(d) 51	
Cornflakes	78.6	25	(a) 19.7	(c) 0.38	(d) 116	
White bread	48.8	40	(a) 19.5	(c) 0.38	(d) 101	
Total			(b) 51.5			(e) 94

¹ According to (62).

² According to (12).

CHO = carbohydrates.

lack of relevant analytical data for foods, in this case the shortage of standardised GI values relevant for foods consumed by the population under investigation.

Early studies indicated that there is no evident relation between intake of sugar and development of type 2 diabetes (26). In agreement with this, the Dutch Zutphen Study showed no relationship between intake of “simple” or “complex” carbohydrates and risk of diabetes in elderly (64–85-year-old) men and women during a four-year follow-up (27). On the other hand, a direct relation between increased intake of glucose and fructose (“simple carbohydrates”) and the risk of diabetes was showed in the Iowa Women’s Health Study (28). In the same study, an inverse relation between whole grain consumption and risk for diabetes was showed, but no relation between GI and diabetes risk. Thus, other factors in whole grains, or factors associated with whole grain consumption, may contribute to the preventive effect.

In the Nurses’ Health Study an increased risk of diabetes was positively related to increased GI or GL during a six-year follow-up (15). The combination of a low intake of cereal dietary fibre and high GL was associated with a doubled risk of women developing diabetes. In a recently published follow-up (16 years) of the same study the relation between high GL and risk of diabetes was confirmed (29). Furthermore, in the Health Professionals’ Follow-up Study from the same group, a similar relation between high GL and risk of developing diabetes was found in men (14). Also in this study the disease risk was further increased by a low intake of dietary fibre from cereals.

In a 10-year follow-up of the Nurses’ Health Study, a high dietary GL from rapidly digested and absorbed carbohydrates was related to an increased risk of coronary heart disease in overweight (BMI \geq 23) women (30). An increased risk of developing CHD due to a high GL diet was supported by the observation of a negative influence on the lipid risk profile (31). In fact, several observational studies show a negative correlation between GL and HDL-cholesterol, i.e. low GL was associated with increased HDL (31–33). In contrast, from the Zutphen Study with elderly men and women, no significant relation between GI and CHD was found after correction for other risk factors and dietary factors (34). Nor were any significant relations found between GI and blood

lipid values (total cholesterol, HDL and triglycerides) in that study.

A weakness in the observational studies regarding the relations between GI and GL and risk of diabetes and CHD is that most positive studies originate from one research group only (14, 15, 29, 31), using a certain type of food frequency questionnaires for GI and GL calculations. To provide convincing evidence, similar results should be published from other research groups, preferably from outside the US, using adequate dietary assessment methods. More studies on men are also needed.

Intervention studies

Mechanisms behind a possible protective effect of a low GI diet against diabetes and CHD might include effects on total and LDL cholesterol, insulin levels and insulin sensitivity, coagulation factors and protein glycation. Up to now intervention studies have been performed mainly in diabetic (4, 17, 35), hyperlipidaemic (36) and hyperinsulinaemic patients (37, 38). A recent meta-analysis demonstrates a small but clinically useful effect on medium-term glycaemic control, with an average reduction in HbA1c by 0.43% points, on a low-compared to high-GI diet in diabetic subjects (39). However, in a few studies on insulin sensitivity (a strong risk factor for development of type 2 diabetes) with validated methods, there were no significant differences between the treatment periods (17, 38). Controlled dietary intervention studies have suggested beneficial effects of low-GI food on total and LDL-cholesterol (4, 17, 35, 40). In one well-controlled study in type 2 diabetic subjects (17) there was a significant reduction of LDL cholesterol, and a reduction of PAI-1 on the low-GI diet, suggesting an improvement of the lipid profile and the fibrinolytic capacity. In non-diabetic subjects there is not yet any consistent data showing risk factor reductions on a low- compared with a high-GI diet. More well-controlled studies over longer periods are needed, in both diabetic and non-diabetic subjects.

Long-term effects

A most relevant question is whether low-GI foods incorporated in the diet have a sustained long-term effect in improving metabolic control. However, long-term effects of GI are not easily studied because of the limited availability of commercial low-GI

foods. Furthermore, most protocols used for collecting dietary data are poorly designed to identify the GI of the diet, and most long-term intervention studies with free-living persons comparing diets with different GI values lack a careful description of the details of the diet. The volunteers in the studies may only have been encouraged to change their major source of carbohydrates to either low- or high-GI food, without any further guidance (41). It is likely that also other macronutrients, e.g. dietary fibre and fat, will be changed if no specific dietary advice or menus are given to the volunteers, and this might influence the results. Such manipulations can only be expected to cause small differences between high-GI and low-GI diets (41, 42) and therefore do not fully explore differences between high- and low-GI diets. Furthermore, many studies lack or have questionable definitions of high- versus low-GI foods or diets. One important point is whether carbohydrates that are rapidly absorbed – such as fructose, sucrose and lactose – but have a low or moderate GI due to their chemical composition should be included in a low-GI diet or not.

Weight management

There are several mechanisms by which low GI foods and diets could be advantageous in relation to weight management and obesity. A prolonged blood glucose response could e.g. be expected to favour satiety, possibly related to a more distal absorption. Furthermore, many carbohydrate-rich foods with a low GI also have a high fibre content (e.g. beans) and thereby a more pronounced satiating effect. However, in practice many factors have to be considered and related to possible effects of the GI on body weight. Some low-GI foods such as pasta and parboiled rice may in some instances be consumed in larger quantities and therefore provide more calories than high-GI alternatives such as boiled potatoes (Table 3).

Raben et al. recently made a systematic review of available studies on GI in relation to weight management and obesity (43). From 31 short-term (<1 d) intervention studies on satiety/hunger/appetite, low-GI foods were associated with greater satiety or reduced hunger in 15 of the studies only, and reduced *ad libitum* food intake in 7 studies. Both high- and low-GI carbohydrates have been shown to have an impact on satiety, but their effects have different time courses (44). High-GI carbohydrates are associated with a reduction in appetite

and food intake in the short term (e.g. one hour), whereas the satiating effects of lower-GI carbohydrates appear to be delayed (e.g. 2 to 3 hours).

The above-mentioned review also included 20 long-term (≥ 6 d) intervention studies on GI in relation to body weight. Since then, data from 4 more studies have become available (40, 45–47). However, of the 24 studies only 11 used test and control diets with comparable macronutrient composition, which is an appropriate design for specifically studying the effect of dietary GI on body weight. The mean weight change in the 11 studies was a reduction of 3.42 and 2.84 kg on the low-GI and high-GI diet, respectively. Only 4 studies allowed *ad libitum* intake (2–10 weeks duration), and in these the average weight change was a reduction of 0.55 and 0.50 kg on the low- and high-GI diet, respectively. Taken together, the available studies with appropriate design therefore do not indicate any major effect of GI on body weight. In contrast, another recent review concluded that obese patients should be counselled to follow a low-GI diet (48). This review did not, however, include all available studies in a systematic manner. Obviously, more long-term studies with an appropriate design, e.g. keeping all macronutrients, energy density and dietary fibre similar and only manipulating the GI, are needed to judge the usefulness of the GI concept for weight management.

Dietary recommendations and practical implications

International dietary guidelines

Current international dietary guidelines are concordant in stressing the importance of a diet rich in fruits and vegetables, pulses and whole-grain cereals, but vary regarding the importance of GI. In the latest recommendations on carbohydrate intake from FAO/WHO the choice of low-GI foods in persons with hyperlipidaemia and obesity as well as healthy persons is recommended (1). In the most recent WHO report, “Diet nutrition and the prevention of chronic diseases”, the strength of evidence that low-GI foods reduce the risk of obesity and diabetes is graded as “possible” (49). However, in the recent Food and Nutrition Board (FNB) macronutrient report it is concluded that: “Due to lack of sufficient evidence on the prevention of chronic diseases in generally healthy individuals, no recommendations based on glycaemic index are

made” (50). Regarding dietary guidelines for patients with diabetes, the “Recommendations for the Nutritional Management of Patients with Diabetes” by The Diabetes and Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD) (51) state that carbohydrate-containing foods that are rich in dietary fibre or have a low GI are especially recommended.

Main carbohydrate sources

The most important carbohydrate-rich foods in the Nordic countries, for which GI is relevant, are products based on cereals and potatoes. Many bread, breakfast cereals and potato products are found in the upper GI range, whereas e.g. pasta, parboiled rice and sourdough bread are found in the lower range (12). Most main carbohydrate sources in the Nordic diets, as well as minor sources such as beans and lentils, contribute to the intake of valuable nutrients, which have to be considered in addition to their GI. Different kinds of beans and lentils, belonging to the foods with the lowest GI values, contribute dietary fibre and other valuable nutrients, so increased consumption of these should be encouraged.

Fruits and vegetables

According to GI tables, most fruits and vegetables have medium or high GI values but their carbohydrate density is rather low. Consequently, the GI concept should not be applied to this category of food. Fruits and vegetables provide dietary fibre, vitamins and minerals, and less energy than many other foods and should, thus, be promoted as a part of a healthy diet.

Sugars

The GI values of common sugars increase in the following order: fructose < lactose (glucose + galactose) < sucrose (glucose + fructose) < glucose. The application of GI to products mainly consisting of sugars, e.g. confectionary or carbonated drinks, however, is highly questionable in view of the high energy content/density and lack of micronutrients, which are reasons for limiting the consumption of these products.

Milk products

The GI of milk and other dairy products is low or medium-high. However, like fruits and vegetables, milk products are generally rather low in carbohy-

drates, with the exception of sweetened yoghurts, milk-shakes etc. The GI concept is therefore generally not applicable to milk products. Furthermore, an inconsistency between the glycaemic and insulinaemic responses has been shown for both regular and fermented milk products, both resulting in high postprandial insulinaemic responses (52). Also when included in a low-GI pasta meal, milk evokes a high insulin response (53). The importance of this insulintropic effect of milk remains to be elucidated.

Labelling

A possibility to label foods with GI would serve interested consumers and may be an incentive for producers to develop products suitable for low-GI labelling. GI values of certain products, e.g. bread and breakfast cereals, may vary widely. Low-GI alternatives and tools to identify them may be helpful for diabetic patients. However, for healthy people, the significance of GI is still unclear, and it cannot be judged at present to what extent labelling may contribute to overall public health.

Special consideration is needed if foods are labelled with GI values as an aspect of nutrition information. There are three main prerequisites for justification of such labelling: 1. GI has to be assessed for the specific food product to be labelled, by an experienced laboratory/clinic. 2. GI is only appropriate to use for carbohydrate-rich foods (e.g. bread, breakfast cereals, pasta, rice and potatoes, providing at least 15 g and preferably 20 g carbohydrate per normal serving). 3. Comparison of GI should be limited to foods within the same food group. In Sweden, GI might so far be regarded as a “product-specific physiological claim” and handled on a case-by-case basis within the code of conduct on health claims.

Summary and conclusions

Some epidemiological studies suggest that low-GI foods, or low-GI diets, might contribute to a reduced risk of cardiovascular disease and type 2 diabetes, but consensus is not reached. Regarding body weight control, more controlled studies are needed to provide conclusive evidence for the benefits of low-GI foods.

To draw conclusions regarding the overall role of GI for healthy people, well-designed long-term studies (preferably >6 months) are needed. However, the present shortage of low-GI carbohydrate foods on the market and the intrinsic connection

between low GI and high fibre content hampers the optimal design of such studies. The studies should be conducted with an *ad libitum* design and ideally only glycaemic index (i.e. not protein, fat, carbohydrate, dietary fibre or energy density) should be manipulated. Appropriate methods should be used to document dietary habits and compliance.

The GI concept is relevant for carbohydrate-rich foods only, i.e. foods providing at least 15 g and preferably 20 g of glycaemic carbohydrates per portion (i.e. products such as bread, cereals, rice, pasta and potatoes) and comparison should be limited to foods within the same product group.

GI values for food tables should be determined using an internationally standardised GI methodology. The accuracy of the proposed methodology should be verified in inter-laboratory tests as for other analytical methods in food analysis. It is essential that GI determinations are based on appropriate food analyses.

The GI concept should not be used in isolation. GI values in tables should therefore be accompanied by other relevant product characteristics, e.g. content of available carbohydrates, enabling the calculation of GL and the content of macronutrients and dietary fibre. If such data are present the GI tables may be a useful tool for dietary counselling to diabetic patients. Furthermore, the effects of the different components in the food on e.g. blood lipids and blood pressure, should be considered. Dietary recommendations, including the possible use of GI, have to be presented in a balanced way.

Labelling of foods with GI would be helpful for persons with diabetes, but the usefulness for healthy people is still unclear. Awaiting further intervention studies, international method standardisation and authorisation of laboratories, as well as forthcoming EU regulation of nutrition and health claims on foods, it is regarded as premature to introduce GI labelling generally.

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