



## REVIEW PAPER

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# The impact of the glycemic index and glycemic load of food products on human health

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### ABSTRACT

The supply of carbohydrates, contained in food products and meals, to the organism causes an increase of glucose in blood, which is referred as "glycemic effect". The concentration of glucose in blood increases after eating each meal and usually reaches its maximum after 20–30 min after food consumption, and then is gradually reduced. It returns to the level of fasting within 1–2 hours. However this pattern shows some individual variation.

The increase of interest of the glycemic index and glycemic load of food products came through the interconnection of these indicators of noncommunicable chronic diseases like diabetes, cardiovascular disease, cancer, overweight and obesity.

**Key words:** glycemic index, glycemic load, carbohydrates, nutritionally dependent illnesses.

Providing the organism with carbohydrates products and meals causes an increase of blood glucose, which is referred as "glycemic effect". After 20–30 minutes of food consumption the glucose concentration reaches its maximum, then decreases gradually and is returning to the level of fasting after 2 hours. Human insulin hormone protects against excessive glucose concentration in blood, it is stimulating the conversion of excess glucose into glycogen and its storage in the liver. The indicator that is used for classification of the carbohydrate food products in terms of increase in the concentration of blood glucose after the ingestion is the glycemic index (GI). GI is an average increase of blood glucose concentration after ingestion, by a statistically representative group of people (10–12 persons) a portion of product which contains 50 grams of digestible carbohydrates compared to the increase in blood sugar level after the ingestion of the reference glucose solution. The increase of blood sugar concentration after ingestion of 50 g glucose is the base of scale (IG = 100) [1].

Easily digestible carbohydrate from products with a high GI are rapidly digested and absorbed from the gastrointestinal tract. They cause a rapid increase of blood glucose and then a rapid decrease of glycemia

after a meal. Products with a low GI cause a low and slow increase of glucose concentration in blood. The lowering of the blood glucose is also slower after 60 minutes [2]. The value of glycemic index depends on the physico-chemical factors of food and the individual ability to digest carbohydrates, so GI should not be the only criterion for assessing the suitability of products in patients nutrition [3]. The glycemic index defines only the type of carbohydrates which can increase blood glucose, and does not indicate the quantity of carbohydrates consumed. It is an important complement of the glycemic load (GL). It is the product of the glycemic index and the content of the digestible carbohydrates in the given product or meal. The value of the glycemic load has a practical use, because it is expressed per portion. This facilitates to compare products taking the usual consumption into account and calculate the total load of dishes by summing the values of the glycemic load of its particular components [1]. The usefulness of the glycemic load of products in the diet planning is based on the assumption that high GI foods, consumed in small quantities, have the same impact on the secretion of insulin into the blood as low-GI products consumed in large quantities [4].

The first studies on the GI values for different products and their role in human nutrition have been taken 31 years ago and are continued to the present. The glycemic index is used throughout the world as a physiological indicator differentiating carbohydrate-containing food products, depending on the degree of increase in postprandial blood glucose [5, 6]. This indicator was then popularized as a way to select foods to decrease risk of obesity, diabetes and cardiovascular disease. Knowing the GI values of foods also allows to select food products which are stimulating the secretion of insulin and resignation from products which can contribute to the resistance of cells to this hormone [7, 8].

It was assumed that the glycemic index of food products less than 55 is low, the average is in the range of 56 to 69, and the high GI above 70.

The value of glycemic index depends on many factors such as:

- ratio between amylose and amylopectin fractions in starch. Amylopectin is characterized by the branched molecules, as a result of which it is more susceptible to digestion and the release of glucose. Food containing more amylopectin has a higher GI than products containing more amylose, such as: white rice compared to basmati rice. Amylose is composed of strongly interconnected glucose molecules in the straight chain and thus access for digestive enzymes is restricted;
- physical structure of the product – the GI value of a product increases with increasing fragmentation (e.g., mashed potatoes have a higher GI than conventionally cooked potatoes);
- content of protein and fat in product – if the product contains more of these nutrients, then it contains less of carbohydrates. In addition, fat slows down the digestion rate of starch (such as potato chips have a lower GI than boiled potatoes). The higher content of fat and protein in the product reduces the GI due to increased glucose utilization, by increase of insulin secretion;
- fructose content – fructose belongs to the group of products with a low GI, thus the value of GI decreases with the increase of fructose participation in the product / dish;
- degree of ripeness of fruits and vegetables – along with an increase in the degree of ripeness the amount of starch decreases which increases the content of free carbohydrates, which promotes the growth of products GI;
- content of organic acids in food – these acids slow down the digestion of ingested food. An exam-

ple would be a bread made from flour subjected to a fermentation process with yeast. This kind of bread contains higher amounts of the organic acids and thus has a lower GI value than white bread;

- dietary fiber content – whole grain cereal products containing more fibers have lower GI, and thereby delay the absorption of glucose into the bloodstream;
- thermal processing – it increases the GI of products, through intensification of swelling of the starch molecules, their rupture and consequently easier access of digestive enzymes to the glucose molecules of the starch (such as: pasta al dente has lower IG value than soft-boiled pasta);
- processing of food – starch from refined and highly processed food is more easily digested and has a higher GI (eg, white rice has a higher GI than brown rice);
- diversifying of the meal composition lowers the glycemic index (eg pasta has a GI of about 50, while serving the pasta with meat sauce reduces the IG to 20) [8–12].

The increased interest in the glycemic index and load followed as a result of connecting these indicators with the noninfectious chronic diseases, including diabetes, cardiovascular disease, cancer, overweight and obesity [13].

There were suggestions indicating that food with a high glycemic index is harmful to health and that consumers should be informed about the values of GI products that have a negative effect on the metabolism of glucose [14].

The disease closely associated with disorder of carbohydrate metabolism is diabetes (Diabetes mellitus), characterized by a reduction or inhibition of insulin secretion from  $\beta$  cells of Langerhans islets of the pancreas. This leads to metabolic disorder and abnormal use of carbohydrates in the body [15].

The concentration of glucose in blood and increased synthesis and secretion of insulin are dependent, inter alia, from the GI and origin of food products. Glycemic response to carbohydrates contained in the nutritional ration allows to predict the changes in concentration of insulin in the blood. The synthesis and secretion of the insulin, in addition to glucose, can also induce amino acids. Hyperinsulinemia promotes the development of insulin resistance and overstimulation of the  $\beta$ -cell to produce insulin, which is the reason for development of type 2 diabetes and increases the risk of coronary heart disease [2, 16, 17].

The Pavlicek's research [18] showed that a diet taking into account the GI of food products by the

patients with type 2 (insulin-dependent) diabetes has an impact improving the glycemic. The experiment was held for 24 weeks, involving 210 people aged approximately 60 years. The author proved that a diet based on low GI exerts a positive impact on the cardiovascular health among patients with type 2 diabetes. Moreover, there was a reduction in glycated hemoglobin in the blood and an increased concentration of HDL cholesterol in the blood. Barakatun (2009) conducted a study involving patients with type 2 diabetes. The aim of the study was to compare the severity of postprandial glycemia and insulin response among subjects who received meals with the same energy and macronutrient supply, and differed only in the value of the glycemic index. In subjects who ate meals with low GI values lower glycemic response and a decrease in insulin levels in the blood was observed. It was found that the meals having a low GI glucose decreased glycemia after their ingestion, as well as insulin response among patients with type 2 diabetes. It was recommended to replace food with high GI by products with a low GI [19].

Gestational diabetes mellitus (GDM), is a disorder characterised by impaired carbohydrate tolerance with a very high probability of progressing to diabetes diagnosed during pregnancy [20]. This kind of diabetes increases the risk of complications of pregnancy and childbirth, fetal development and newborn condition if it is not recognized, diagnosed too late or improperly treated [21]. In the Moses'es study [22], conducted among 63 pregnant women with GDM has shown that eating low GI meals from the first trimester has a positive effect on pregnancy. Women with GDM were divided into two groups. Among 31 women consuming meals with a low GI – 9 required insulin treatment during pregnancy, while a group of 32 women who were eating high GI foods, up to 19 met the criteria predisposing to start insulin therapy. Nine from nineteen women managed to avoid the use of insulin by replacing the food rations of products with a high GI by products with a low GI. Application of a low GI diet, taking into account the meals, by women with GDM significantly reduced the necessity of insulin treatment and had no adverse effects on pregnancy.

Improper diet increases the risk of cardiovascular disease by increasing levels of serum cholesterol, especially LDL cholesterol, lower HDL cholesterol, increasing serum triglycerides, increasing blood pressure and impact on the development of abdominal obesity, as well as disability of glucose tolerance [23].

Based on the Frost's research [24], performed between 1986 to 1987 in England with the participation of 2,200 people aged 16–64 years, with an average BMI of 25.0 kg/m<sup>2</sup>, an inverse correlation between GI diet and concentrations of serum HDL cholesterol was found. It was also found that body mass index (BMI), smoking cigarettes and GI diets are potential, modifiable factors that affect the concentration of HDL cholesterol serum. This suggests that a diet based on low GI may reduce the risk of developing atherosclerosis and coronary heart disease. In the studies of Liu [25], which were conducted with the participation of 75,521 women, aged 38–63 years, without any prior diagnosis of diabetes, myocardial infarction, stroke and other cardiovascular diseases, an inverse relationship was detected between glycemic index and prevalence of myocardial infarction. On the basis of information regarding the subjects – medical history, lifestyle, consumption of food products, containing mainly carbohydrates, it was found that the intake of foods with a high GI was strongly associated with risk of coronary heart disease. This applied especially to women with a BMI > 23.0 kg/m<sup>2</sup>.

Hyperglycemia and resistance to insulin are also risk factors for cardiovascular diseases. Large variations in postprandial glycemia by patients with overweight have negative impact on structure and function of blood vessels [26]. Studies have shown that eating food with a low index and low glycemic load helps to improve the health status of patients with cardiovascular disorders, regardless of the existing risk factors of these diseases, such as: older age, smoking, intake of high energy value of food rations. This leads to a reduction of triglyceride levels and increased HDL cholesterol concentrations in blood [9, 25].

There is also evidence that use of a diet based on low glycemic index food products for five weeks, among healthy men, contributed to the improvement of the lipid profile of blood plasma and consequently led to a reduction in total body fat mass and increase in fat free body mass [27]. In the years 2003–2004 a study was conducted, involving 290 patients with coronary heart disease and a control group consisting of 290 healthy individuals. Based on collected information regarding their dietary habits, glycemic loads of individual meals for each person were calculated. The total average of the glycemic load of patients meals was significantly higher compared to the control group. These studies have shown that high glycemic load diet is an independent risk factor for coronary heart diseases. Therefore, it is recommended to consume meals containing vegetables and fruit with low GI [28].

People with a high Body Mass Index (BMI) and impaired energy balance are more often diagnosed with metabolic diseases, mainly obesity. Obesity, according to the WHO assumed to be a global epidemic. It is a disease characterized by excessive accumulation of fat in the human body [23, 29].

In recent years, in the prevention and treatment of obesity the limitation of fat consumption was widely recommended. However, scientists started to wonder about the alternative recommendations. Hence the interest in the role of diet and products with a low GI in the treatment of this disease. Food with low values of this ratio satisfy the hunger for longer and reduce appetite more effectively. These products do not result in rapid weight gain. Upon delivery to the body of high GI meals blood sugar increases rapidly. It is a natural consequence of the rapid digestion and absorption of carbohydrates contained in these products. Products with low GI may be more useful for effective weight loss than moderate carbohydrate restriction in food ration [30].

In 2004, a study on rats was conducted to evaluate the effects of diets with different IG values. The experiment lasted 18 weeks. Animals were randomly assigned in two groups. The first group consisted of 11 animals receiving feed with a high GI, and the second group of 10 rats received a feed with a low GI. The feed of all rats contained 69% carbohydrate, 20% protein and 11% of fats and both, the first and second group, included starch in amount of 542 g/1 kg of feed. The group which consumed high GI food received 100% of amylopectin, and participation of the various starch fractions in the second group was: 60% amylose and 40% amylopectin. The other feed ingredients were: gelatin, casein, sucrose, soybean oil, wheat bran, methionine and a mixture of vitamins and minerals. It has been found that a diet with a high GI caused an increase of fat cover in rodents. Despite similar average body weight in rats fed a diet rich in carbohydrates compared to rats fed with a low GI feed, there was a 40% higher increase in body fat mass (higher susceptibility to obesity). These rats were characterized by furthermore 45% lower physical activity and resistance to insulin. Already in the 7<sup>th</sup> week of the experiment almost three times higher concentration of triglycerides in the blood of rats fed feed with a high GI was observed. In this group of laboratory animals, the glucose concentration was already significantly higher at the 5<sup>th</sup> week and remained such to the end of the experiment. A much higher percentage of pancreatic islet was clearly

abnormal, with the disorganized structure and extensive fibrosis [31].

Thomas et al. (2007) assessed the impact of low GI diets on body mass of people with overweight. The study involved 202 volunteers. In humans who applied the low GI diet, higher loss of body mass (1.1 kg), fat mass (1.1 kg) and BMI (1.3) were observed. Moreover a higher reduction of total cholesterol and its LDL fraction was found. (respectively 0.22 mmol/l and 0.24 mmol/l) [32].

Studies also indicate a high correlation between diet based on a high glycemic index and the risk of colorectal cancer (colon and rectum). To such conclusions have led, among others, researches conducted in the years 1992–1996, with participation of 1,125 men and 828 women with confirmed colorectal cancer. Age of the subjects ranged from 19 to 74 years. GI, GL and dietary fiber content in food portions were calculated using data obtained from the questionnaire concerning the amount and type of consumed food. It was observed that dietary GI and GL of patients was positively correlated with the consumption of breads, sweets, sugar and energy value of food ration, and negatively correlated with the consumption of fruit and vegetables. Thus, studies have proven negative meaning of refined carbohydrates in the etiology of the disease [33]. Similar conclusions have been reported in Augustin's research [34] conducted in 1991–1994, involving 2,569 women with confirmed breast cancer. The collection of information on the consumption took place in the same way as in the previous study. It was noted that the risk of breast cancer was associated with consumption of high GI products, particularly in the postmenopausal period. It is necessary to carry out further studies to understand the mechanisms of adverse effects of refined carbohydrates diet on the human organism.

Postprandial hyperglycemia significantly influences the growth and proliferation of neoplastic cells. It encourages several metabolic changes on cellular level as well as on tissue level. The results of the epidemiological research, connected with involvement of general risk of cancerous disease development or particular type of cancer, are inhomogeneous. Most of them indicate an increase of this risk together with rising GL of diet. Researches have also proven that reducing digestible carbohydrate in the diet has positive impact on the stability of the disease and an increased tolerance for radio- and chemotherapy [35].

Consumption of food products / meals with low GI and GL cannot only be beneficial for reduction of

postprandial glucose and insulin response, contributing to the preservation and improvement of health, but also for lipid metabolism and regulation of the energy changes in our organism. Application of a diet based on low GI and GL is an alternative to the current recommendations, often requiring restrictive limitations of food energy intake. This increases, among others, probability of long-term sustainable results of weight reduction.

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