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RAPID COMMUNICATION

Glycemic index of cereals and tubers produced in China

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Abstract

AIM: To determine the GI of some cereals and tubers produced in China in an effort to establish the database of glycemic index (GI) of Chinese food.

METHODS: Food containing 50 g carbohydrate was consumed by 8-12 healthy adults after they have been fasted for 10 h and blood glucose was monitored for 2 h. Glucose was used as reference food. GI of food was calculated according to a standard method.

RESULTS: GI of 9 types of sugar and 60 kinds of food were determined.

CONCLUSION: Food GI is mainly determined by nature of carbohydrate and procession. Most of cereals and tubers produced in China have similar GI with their counterparts produced in other countries.

Key words: Glycemic Index; Cereals; Tubers; Carbohydrate

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INTRODUCTION

GI is a useful index initially coined by Jenkins[1] *et al* to describe the extent to which certain food can increase the blood glucose in human. It is an accurate determination of change of blood glucose after consumption, digestion and absorption of certain food. GIs of 60 kinds of food were determined and reported by Jenkins in 1981. Since then, GI of local foods have been reported by Miller and other scientists[2,3]. Up to date, GI of about 2000 foods have been determined and reported around the world.

The study of GI was limited to clinic research and dietary treatment of diabetes in the early stage of GI study. Since the late 1990s, more and more attention has been paid to the application of GI in body weight maintenance and chronic disease controlling and positive links have been established between diet GI and some pathological conditions such as obesity[4], heart disease[5], diabetes[6].

China is an Asian country with more than thirteen billion people of 56 nationalities and various eating habits and foods. With the rapid development of economy, lifestyle of Chinese people is changing also and a cluster of chronic diseases are emerging, some of which have become health threat of the people as seen in the western countries. Therefore, links between dietary habits and chronic diseases should be investigated and strategies should be developed for the prevention, as well as treatment of such diseases. It is urgent and necessary for us to determine the GI values of Chinese foods. The current study was designed to determine the GI of about 150 types of cereals and tubers by a standard method.

MATERIALS AND METHODS

Subjects

Healthy volunteers (aged 20-45 years, BMI in kg/m^2 range 18.5-25) from Beijing (north China), Chengdu (southwest China), Liaoyang (northeast China) and Yinchuan (northwest China) were involved in the study. All subjects were free from obesity, diabetes and other metabolic diseases and postmenopausal women were excluded. All subjects gave their written informed consent and ethical approval for the study was obtained from the Ethical Committee of Chinese Centers for Disease Control and Prevention.

Test foods: All the foods used in this study were purchased from local supermarket and raw foods were cooked by traditional method used in daily-life of

Chinese. The carbohydrate (CHO) content of the test food was calculated based on food composition data of China according to the following formula: weight of test food = 50/CHO proportion of test food. In cases when CHO content of test food was less than 10%, food weight used to determine its GI was reduced to 25 g. Each food was tested in 10-12 volunteers.

Methods

Oral glucose tolerance test (OGTT): About 10-12 volunteers received OGTT each time. After fasting for 10 h, volunteers were required to arrive at the laboratory at 8 o'clock in the morning. Venous blood samples were obtained before and 15, 30, 45, 60, 90, 120 min after consumption of 50 g glucose dissolved in 200 mL drinking water. Blood was collected into a syringe with sodium fluoride.

Test of glucose response of food: Volunteers with normal glucose tolerance were allowed to receive the glucose response test two days later. When volunteers fasted for 10 h arrived at the laboratory, venous blood samples were collected before and 15, 30, 45, 60, 90, 120 min after consumption of food containing 50 g carbohydrate. For each sample, blood glucose was determined. Each test was repeated and each group of volunteers received no more than tests of three foods. Between tests, at least two days was required for wash-out.

Determination of blood glucose: Calculation of GI: Glucose (GI = 100) was used as reference. The calculation was based on the method developed by Wolever[7]: GI = [(area under the 2-h blood glucose curve for food)/(area under the 2-h blood glucose curve for the same amount of glucose)]× 100

Statistical analysis

The values of GI were expressed as mean ± SD. Dixon test was used to evaluate differences between values of the same group. $P = 0.05$ was selected as level of significance.

RESULTS

Nine sugars were selected as test foods. When glucose was used as the reference (GI of glucose: 100), the GI rank of these sugars from high to low was maltose > white sugar > honey > sucrose > lactose > fructose (Table 1). The GI values of maltose of different source were not equal, which maybe was resulted from procession and the difference of purity.

GI of cereals

Cereals refer to a variety of foods rich in carbohydrate, including traditional starchy food such as steamed bread and noodle, and food processed by modern technology such as breakfast cereals and some instant foods. The significant difference of GI of different cereal foods suggested that food procession and food type were factors influencing the value of GI (Table 2).

GI of some tubers

Tubers also include various types of foods, of which potato, yam, taro and lotus are commonly eaten by Chinese people. Their GI values are shown in Table 3.

Table 1 Glycemic index of some sugars (mean ± SD)

Name	*n*	GI
Glucose	10	65.0 ± 6.3
Fructose	10	23.0 ± 4.6
Lactose	10	46.0 ± 3.2
Chocolate	10	49.0 ± 8.0
Maltose	10	105.0 ± 5.7
Maltose 2	10	75.0 ± 20.3
White sugar	10	83.8 ± 12.1
Honey	10	73.5 ± 13.3

DISCUSSION

Carbohydrate is a major source of energy of human being. Nutrition surveillance in China shows that carbohydrate intake is 360 g/d, which provides 60%-70% of total energy of a person. Cereals and food produced from cereals account for 90% of total dietary carbohydrate. It is obvious that cereals are critical for the health of Chinese.

Because people have realized that overtake of fat is associated with a cluster of chronic diseases, increasing the intake of carbohydrate has been the major concern of nutritionists in dietary recommendation. But controversies still remain as to how and what kind of carbohydrate should be increased in diet.

Food GI is a quantitative physiological parameter used to describe the relative glycemic effect of carbohydrate-containing food compared with reference food (glucose or white bread)[8]. After ingestion, all the digestible carbohydrates are conversed to monosaccharide and absorbed in the intestine, then blood glucose is increased and satiety is ensured. Insulin and other hormones secretion is induced by the increased blood glucose and blood glucose level is then reduced toward the basic level, thus homeostasis is maintained. Avoiding dramatic fluctuation of blood glucose is critical to both the healthy and the diabetic persons. A lower postprandial blood glucose peak and slower decreasing rate are seen after intake of low GI food compared with high GI food. It is evident that carbohydrate content of one food does not always reflect its availability. GI provides a new method for the nutritional evaluation of food.

Food is categorized into three groups according to their GI[8], food with GI < 55 is called low GI food, and high GI food means food with GI >75, food with GI ranging between 55-75 is called medium GI food. Consumption of low GI food will ensure a longer lasting satiety and keep more stable blood glucose, at the same time overtake can be avoided easily compared with consumption of high GI food. High GI food is not good for diabetes and people with impaired glucose tolerance.

GI is a concept comprehensively reflecting the digestibility and utility of food. Factors affecting the GI of food such as composition, content, and type of carbohydrate, physical character and procession are all taken into account in this concept[9,10]. Our results showed that different types of carbohydrate have different

Table 2 Glycemic index of cereal products (mean ± SD)

Food name	*n*	GI	Food name	*n*	GI
Cooked rice	12	83.2 ± 3.1	Steamed bread (refined)	9	88.1 ± 20.2
Brown rice (cooked)	10	87.0 ± 5.0	Wheat pancake	10	79.6 ± 11.5
Sticky rice (cooked)	10	87.0 ± 7.0	Wheat dough, deep-fried	8	74.9 ± 21.0
Sticky rice2 (cooked)	9	88.0 ± 5.6	Bread (refined wheat)	10	87.9 ± 10.2
Sticky rice (higher amylose)	10	50.0 ± 6.0	Bread (whole wheat)	10	69.0 ± 10.4
Rice porridge	10	69.4 ± 18.5	Bread (whole wheat with dried fruit)	10	47.0 ± 7.0
Sticky rice porridge	9	65.3 ± 20.6	Wheat Noodle(dried)	10	46.0 ± 5.8
Black rice porridge	9	42.3 ± 9.0	Wheat Noodle(fresh)	8	81.6 ± 19.1
Rice bran porridge	9	19.0 ± 3.0	Dumpling (shallot + meat)	10	28.0 ± 9.9
			Steamed stuffed bun (shallot + meat)	10	39.1 ± 13.0
Rice cake	8	82.0 ± 7.2	Biscuit (thin)	9	81.0 ± 7.5
Instant rice (in hot water 3 min)	10	46.0 ± 8.5	Biscuit	9	72.0 ± 15.5
Instant rice (cooked 6 min)	10	87.0 ± 5.5	Danone biscuit 1	9	47.1 ± 12.4
Corn powder porridge	10	68.0 ± 10.6	Danone biscuit 2	9	39.3 ± 11.8
Corn granule	10	51.8 ± 9.2	Cake crisp	10	59.0 ± 6.0
Corn flake	9	78.5 ± 12.2	Powder (buckwheat)	8	54.0 ± 3.0
Corn flake 2	9	74.0 ± 10.0	Noodle (buckwheat)	9	59.3 ± 3.0
Oatmeal (unpackaged)	9	55.0 ± 6.1	Bread (buckwheat)	8	66.7 ± 6.0
Oatmeal	8	83.0 ± 18.7	Instant noodle (buckwheat)	8	53.2 ± 5.0
Porridge (instant)	8	69.4 ± 7.2	Millet porridge	8	61.5 ± 9.0
Popcorn	6	55.0 ± 2.0	Powder (various cereals)	9	57.9 ± 3.5
Sweet corn (cooked)	10	55.0 ± 5.0	Whole wheat powder	10	42.0 ± 7.5
Oat biscuit	10	55.0 ± 2.5	Nutritional pancake	8	65.7 ± 5.3
Barley flake	7	69.0 ± 7.3	Biscuit	7	70.0 ± 8.3
Rice (S+R) porridge	9	65.5 ± 16.0	WoTao (Corn+wheat)	10	64.9 ± 16.5

influence on blood glucose. For example, rice rich in amylopectin has high absorption rate and consequently high blood glucose because digestive enzyme can easily reach the structure of starch chain. The opposite is true as to the amylose. Possible explanation for GI difference of different food is: first, food rich in dietary fiber, resistant starch or other indigestible carbohydrate has stronger resistance to digestive enzymes and its digestion and absorption in the intestine is slow and incomplete. Under this kind of conditions, low blood glucose is seen. Second, physical properties of food such as the size of granule and maturity are factors determining GI. Third, time and temperature in procession have significant effect on food GI as seen in the case of potato and vermicelli. It is also obvious that procession is a crucial factor in determining food GI as demonstrated by GI values of different corn, rice, potato and wheat products.

Table 3 Glycemic index of tubers (mean ± SD)

Food	*n*	GI
Potato (cooked)	10	66.4 ± 3.8
Potato (steam)	10	62.0 ± 5.7
Potato crisp (oil fry)	10	60.3 ± 7.0
Potato noodle (with meat)	9	16.7 ± 10.4
Cake (Cushawand potato)	8	108.0 ± 13.4
Yam (steam)	10	51.0 ± 12.0
Yam (cooked)	10	54.0 ± 5.5
Potato mashed	10	73.0 ± 9.2
Potato noodle	9	13.6 ± 2.1
Sweet potato (red, cooked)	8	76.7 ± 12.3
Taro (cooked)	7	47.7 ± 12.7
Pill potato+yam powder	9	34.5 ± 11.7
Lotus root powder	8	32.6 ± 17.0

In accordance with literatures, we found that GI of sucrose is not so high as and the GI of starch is not so low as predicted. The GI of sucrose is lower than expected because sucrose is disaccharide consisting of glucose and fructose which is absorbed and directly transferred to the liver where it is ultimately transformed into glucose and therefore has a lower GI (GI = 23). About half of all the sucrose we ingest is glucose, and fructose accounts for another half. Refined sugar is used in most of processed foods which has a GI of about 60, which is the mean of glucose GI and fructose GI. The GI of starchy foods depends on the rate at which the food can be absorbed and transferred into the blood, and the extent to which the food can raise the concentration of blood glucose. The GI of food with rapid digestibility is usually high. Compared with GI data of other countries, we found that GI of foods produced in China has similar GI to that of counterpart foods produced abroad with the exception of maltose, honey and white sugar. In the present study we found that maltose from different source shows different GI (105 *vs* 75); the GI of honey (67) and white sugar (83) are higher than that published by other authors (GI of honey and white sugar were 58 and 70, respectively). The explanation for this discrepancy is the difference of procession and origin of food. For example, maybe honey and white sugar were supplemented with glucose syrup.

Food of low GI often implies lower utilizable energy. In practice, control of quantity of total energy remains a primary concern in dietary prevention and treatment of obesitic diabetes. GI has been proved a useful and simple concept in food selection, diets arrangement and dietary regulation of blood glucose. GI is not only useful in the dietary treatment of diabetes, hypertension patients and obesity, but also can be applied to dietary

management of athletes, food procession and study of relationship between dietary intake and chronic disease[11]. Establishment of GI values of Chinese foods is the first step of GI study in China. More studies should be conducted in this field.

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