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The postprandial glucose response to some varieties of commercially available gluten-free pasta: a comparison between healthy and celiac subjects

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The objective of the present paper is to evaluate the post-prandial response to some varieties of gluten free (GF) pasta that are commonly consumed in Italy. The glycaemic responses were compared with a glucose standard in healthy subjects and gluten-free diet celiac subjects. Subjects were served portions of the test foods and a standard food (glucose), on separate occasions, each containing 50 g available carbohydrates. Capillary blood glucose was measured from finger-prick samples in fasted subjects and at 15, 30, 45, 60, 90 and 120 minutes after the consumption of each test food. For each type of pasta, the glycaemic index (GI) was calculated by expressing the incremental area under the blood glucose curve as a percentage of each subject's average incremental area under the blood glucose curve (AUC) for the standard food. Gluten free pasta exhibited a range of GI values from 46 to 66. The glycaemic load (GL) and glycaemic profile (GP) were also calculated. A higher GI value was observed in pasta containing rice flour as the main ingredient. Lower values were observed in pasta obtained using corn or a mixture of corn and rice flour as the main ingredients. The results were confirmed in celiac subjects. The information presented in this paper may be useful in helping celiac people to select low-GI pasta.

Introduction

Glycaemic index (GI) is an indicator of glucose absorption into the systemic circulation and of the disappearance of glucose after ingestion of foods. Since 1981, when Jenkins showed that complex carbohydrates are digested more slowly and raise blood glucose less than simple sugars,[1] many studies have been performed to investigate the physio-pathological relevance of postprandial hyperglycaemia.[2] Recent studies have shown that postprandial hyperglycaemia increases oxidative stress and protein glycation in susceptible individuals.[3] Western dietary patterns are associated with an increased risk of type 2 diabetes and other metabolic diseases. There is much scientific and popular interest in the role of low glycaemic index foods[4] and several public health organizations have recently integrated consideration of the glycaemic index in their nutritional recommendations for patients with metabolic diseases and for the general population.[5] In 2002, the American Society for Clinical Nutrition compared many foods regarding their GI and discovered that gluten-free (GF) foods have a higher GI than gluten-containing equivalents.[6] Higher GI of gluten free breads than gluten-containing equivalents has been demonstrated also by Segura *et al.*[7] Other authors have not demonstrated significant differences in the GI of a range of gluten-free foods with respect to conventional products.[8,9] GI of different kinds of gluten free pasta has not been previously investigated. This study examines the effect of gluten-free pasta on postprandial blood glucose concentrations in controls and in celiac patients. Berti *et al.* demonstrated for the first time differences in the post prandial glucose response in celiac subjects about ten years ago.[9] The interest to further investigate these aspects is supported by an increasing number of people with both diabetes and celiac disease. Celiac disease occurs in patients with type 1 diabetes with the prevalence in the range of 4.4–11.1% *versus* 0.5% of the general population.[10,11] Type 1 diabetes and celiac disease are both auto-immune diseases sharing common susceptibility traits. The post prandial glucose response is determined not only by the food composition, but also by the rate of glucose absorption from the ingested food and endogenous glucose uptake into tissues. A possible alteration of glycaemic response in celiac subjects is suggested by lower plasma levels of incretins (glucose-dependent insulinotropic peptide, glucagon-like peptide 1 and amylin) related to gastric emptying and insulin secretion.[12,13]

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Results

Postprandial glucose response to gluten-free pasta in healthy subjects

Glycaemic index (GI) and glyceamic load (GL). Fasting blood glucose concentrations in healthy subjects were similar before each test meal (4.47 ± 0.07 mmol L^{-1}). Fig. 1 shows the mean blood-post-prandial glucose response following consumption of three different GF pasta samples in healthy subjects. A comparison of the post-prandial glucose response demonstrated a peak value at 30 min and a return to baseline within two hours (Fig. 1). AUCs of the blood glucose response over 120 minutes for healthy subjects are shown in Table 1. A higher value was observed for GF pasta containing rice flour as the main ingredient (sample C). The GI and GL values were similar in pasta obtained using corn or a mixture of corn and rice flour as the main ingredients (samples A and B). Higher values were observed in rice pasta (sample C) (Table 2).

Glycaemic profile (GP). The GP values are shown in Table 2. GP, defined as the duration for the incremental post-prandial blood glucose response divided by the blood glucose incremental peak, is a useful tool for the evaluation of post-prandial glycaemia.[14] The GP values were in the order: pasta containing corn flour > pasta containing both corn and rice flours > pasta containing rice flour (Table 2). Products characterized by high GP are indicative of a lower glucose peak and a less pronounced hypoglycaemia and thus are considered to have a favourable post-prandial glycaemic response.[14]

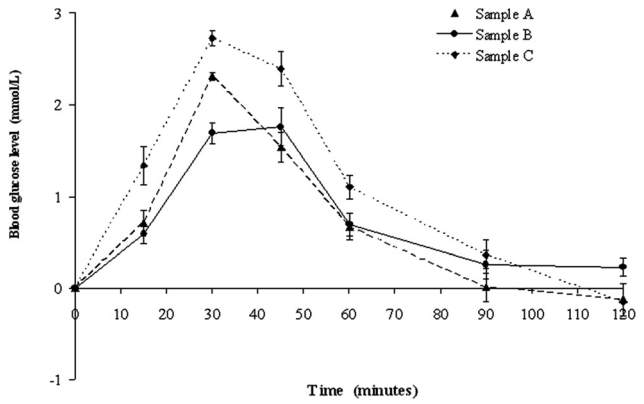

Fig. 1 Mean blood glucose concentration increments in healthy volunteers (n = 8) following ingestion of different types of pasta (values are mean ± SEM).

Table 1 Areas under the blood glucose curve (AUC) over 120 minutes after test foods in healthy and celiac subjects (values are mean ± SEM)

Gluten-free pasta	AUC of glucose response (mmol min L^{-1})	
	Healthy subjects	Celiac subjects
Sample A	90.5 ± 6.0[a]	102.4 ± 14.3[a]
Sample B	89.6 ± 5.7[a]	90.5 ± 13.5[a]
Sample C	127.5 ± 9.1[b]	140.6 ± 12.6[c]

Values with different superscript letters are significantly different (p < 0.05).

Table 2 Glycaemic index (GI), glycaemic load (GL) and glycaemic profile (GP) of different types of pasta in control and celiac subjects (values are mean ± SEM)

		Glycaemic index (GI)	Glycaemic load (GL)	Glycaemic profile (GP)
Control subjects	Sample A	46.1 ± 2.5[a]	23.8 ± 1.3[c]	50.8 ± 2.2[e]
	Sample B	46.3 ± 3.5[a]	25.2 ± 1.9[c]	64.6 ± 4.8[f]
	Sample C	66.2 ± 2.8[b]	37.4 ± 1.6[d]	42.2 ± 1.8[g]
Celiac subjects	Sample A	49.7 ± 2.1[a]	29.3 ± 1.2[c]	51.2 ± 3.2[e]
	Sample B	48.2 ± 4.6[a]	29.9 ± 2.9[c]	61.7 ± 3.6[f]
	Sample C	75.0 ± 4.3[h]	48.3 ± 1.6[i]	42.0 ± 3.1[g]

Values with different superscript letters are significantly different within the same experimental time (p < 0.05).

Table 3 Clinical characteristic of healthy and celiac subjects (values are mean ± SEM)

	Healthy subjects (n = 8)	Celiac subjects (n = 10)
Male/female	3/5	3/7
Age (years)	40.2 ± 4.6	39.9 ± 2.6
BMI (kg m^{-2})	22.13 ± 0.9	21.9 ± 1.1
Fasting glucose (mmol L^{-1})	4.47 ± 0.07	4.96 ± 0.14

Postprandial glucose response to gluten-free pasta in celiac subjects

The blood-glucose response following consumption of the three GF pasta types has also been studied in celiac subjects. Basal values of glycaemia in celiac subjects were slightly higher but the difference was not significant (p = 0.067) (Table 3). The higher AUCs of glucose response to gluten-free pasta in celiac subjects reflect higher glycaemic index and glycaemic load (Table 2); however, the differences were not statistically significant. As previously observed in control subjects, the blood-glucose response to GF pasta containing rice flour (sample C) was significantly higher when compared with samples A and B (p < 0.05).

Experimental

Test meals

Gluten-free pasta from three major brands of these specialties was acquired from the Italian market and was representative of the most consumed products in Italy. Food structure (*i.e.*, shape) is considered, by some authors, as one of the factors that modulate postprandial glycaemic responses, therefore we analysed the pasta type "fusilli". Three commercially available gluten-free pasta were studied: Sample A ("Fusilli" by Dr Schär AG, Italy), Sample B ("Le eliche" by Le Veneziane, Molino di Ferro, Italy), Sample C ("Pasta Riso, Fusilli" by Scotti, Italy). Nutritional properties and ingredients of the different kinds of

Table 4 Nutritional composition of gluten free pasta

	Sample A ingredients: corn flour, rice flour, pea isolated protein, E471	Sample B ingredients: corn flour, E471	Sample C ingredients: rice flour, rice germ (2%), E471
Energy (kcal/100 g)	353	345	360
Carbohydrate (%)	73.7	77.75	80.6
Fat (%)	2.5	0.71	1.5
Protein (%)	9.0	7.75	6.2
Fiber (%)	2.2	1.7	1.2

pasta are shown in Table 4. The three samples of gluten-free pasta differed only slightly in macronutrient composition.

Subjects

Healthy subjects (n = 8) and sex and age matched celiac subjects (n = 10) treated with gluten-free diet were recruited. Informed consent was obtained from each patient before beginning the study and formal approval of the study protocol was given by the Local Ethical Committee. In healthy subjects and in celiac subjects no co-morbidities such as type 1 or 2 diabetes or other diseases of glucose metabolism were observed, as demonstrated by the serum levels of glycated hemoglobin (HbA1c < 5%). Clinical characteristics of controls and celiac subjects are summarized in Table 3.

Evaluation of glycaemic index (GI), glycaemic load (GL) and glycaemic profile (GP)

The products were provided as breakfast to fasted subjects. The amount of carbohydrates on the food package was used to calculate the weight of the servings with 50 g of available carbohydrates. The portions were professionally prepared in the expected quantity. All pasta samples were boiled in unsalted water following the cooking instructions on the packages. GF pasta was served hot and all subjects completed the meal within 10 minutes. Each subject was asked to consume 50 g of available carbohydrate portions of the test food. Finger capillary blood samples were collected at the start of eating and 15, 30, 45, 60, 90 and 120 min after consumption. To determine differences in glucose kinetics, the 0–120 minutes incremental area under the blood glucose curve (AUC) was calculated using the trapezoidal rule.[15] The averages of fasting measurements were used as baseline values and areas below baseline were not included.

Glycaemic index (GI) and glycaemic load (GL). The glycaemic index (GI) was calculated as the ratio between the AUC of the glycaemic response obtained from the different samples of pasta compared to the AUC reference food (glucose).[15] From the value of GI we calculated the value of the glycaemic load (GL), expressed by the product of the amount of available carbohydrate, present in a portion of the product, for its GI value;[15] GL = (GI/100 × portion carbohydrate content). GL was calculated considering a portion of 70 g pasta, as indicated by Italian LARN (1996).

Glycaemic profile (GP). The course of post-prandial glycaemia was analyzed by calculating glycaemic profile (GP).[14] GP was introduced by Rosen *et al.*[14] as a tool to discriminate between differences in blood glucose profiles. The GP is defined as the duration of the incremental postprandial glycaemic response divided by the glucose iPeak, thus rendering a high value for a long and low glycaemic profile. iPeak is the incremental glucose peak calculated as maximum postprandial increase from baseline. Therefore, GP was calculated by the ratio between the time (min) during which the blood glucose was above the fasting concentration and the iPeak (mM) of the blood glucose for each subject and test meal.

Statistical analysis

The results were expressed as mean ± SEM of the values. Student's t-test was used to evaluate significant differences. All tests were 2-tailed and a $p < 0.05$ level of significance was used to assess the statistical significance (Microcal Origin 5.0, OriginLab, Northampton, MA).

Discussion

Corn and rice flours are widely used in the production of gluten-free products. We examined the effect of gluten-free pasta on postprandial blood glucose concentrations in controls and in celiac patients. Gluten free pasta exhibited a range of GI values ranging from 46 to 66 in healthy controls. A higher GI value was observed in pasta containing rice flour as the main ingredient either in controls or in celiac subjects. Moreover pasta obtained using corn or a mixture of corn and rice flour as main ingredients (samples A and B) had lower values of glycaemic load (GL) and glycaemic profile (GP) compared with rice pasta (sample C).

Some hypotheses can be formulated to explain the aforementioned differences. The post prandial modifications of blood glucose concentration represent a balance of both the entry and the removal of glucose into and from the blood.[16] The main determinants of the postprandial glucose response are the amount and type of the ingested carbohydrates, molecular arrangement, size of starch granules, co-components in the whole food like moisture, fat, protein, fiber, as well as external factors like processing technique.[17] The higher glycaemic index observed in pasta made with rice flour is in agreement with previous studies which have demonstrated that rice and rice-based products are digested and absorbed quickly in healthy humans, producing a high glycaemic response and low colonic fermentation.[18] Other factors such as the rate of gastric emptying also play a role in the post prandial modifications of blood glucose[19] and could explain the differences within the three types of GF pasta. In fact, incretin hormones such as glucagon like peptide-1 (GLP-1) and glucose-dependent insulinotropic polypeptide (GIP) which are secreted by endocrine cells located in the gastrointestinal mucosa, influence postprandial glucose excursions by potentiating glucose-induced insulin secretion.[20] The capacity of different

carbohydrates to induce the secretion of incretin hormones has been studied by Wachters-Hagedoorn *et al.*[21] The authors found differences in incretin response after the ingestion of rapidly and slowly available carbohydrates.[21]

It is well known that celiac disease is associated with a high incidence of type 1 diabetes[10,11] and is recognized as a risk factor for metabolic diseases.[2,3] Therefore an important task for these patients is to maintain good glycaemic control whilst adhering to a strict gluten-free diet. Previous studies have observed significant differences in glucose responses to GF pasta between healthy and celiac subjects in the absence of modifications in the AUCs of insulin responses.[9] We confirmed significant differences in post prandial glucose increase after the intake of rice pasta. Further studies in a larger number of CD subjects are necessary to investigate whether the impairment of the barrier functions due to oxidative stress and inflammatory processes[22–24] and/or differences in plasma levels of incretins related to gastric empty and insulin secretion[12,13] could elicit differences in post prandial glucose response in celiac subjects.

Conclusions

A gluten-free diet is currently the only available treatment for patients with celiac disease. The increasing demand for gluten-free products for diet for subjects affected by celiac disease and gluten-sensitivity has favored the design of numerous gluten-free products which intended to mimic the quality characteristics of wheat products. Starch digestibility of different gluten free food has been previously characterized and contrasting results have been reported.[6–9] From a technological point of view, pasta is not a homogeneous group. Previous studies have characterized the glycaemic index of various kinds of pasta obtained with different processes and ingredients reporting GI values ranging from 56 to 71.[25] Our results suggest that gluten-free pasta samples included in our study are located among medium GI foods.[2] The higher values of GI, GL and GP were observed in pasta containing rice flour as the main ingredient either in controls or celiac subjects. Further studies are necessary to investigate whether these values are due to differences in glucose absorption, gastric emptying, gut hormone profile related to different carbohydrates contained in rice compared with corn flour. An understanding of GI, GL and GP of GF foods can help in choosing suitable foods in the prevention and control of diabetes in celiac and control subjects.

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