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Differential glycaemic effects of potato, rice and spaghetti in Type 1 (insulin-dependent) diabetic patients at constant insulinaemia

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Summary. The blood glucose responses to cooked potato, rice and spaghetti were studied in six Type 1 (insulin-dependent) diabetic patients who had attained euglycaemia by the artificial pancreas prior to the meal intake. The amount of potato (raw weight 200 g), parboiled rice (raw weight 50 g), and spaghetti (raw weight 50 g) had approximately identical caloric content (range 203-225 kcal) and amount of available carbohydrate (range 39.4-43.4 g). The postprandial blood glucose response areas after cooked potato and cooked parboiled rice were similar (180 min values: cooked potato: 1190 ± 110 mmol/l × min, cooked rice: 1160 ± 140 mmol/l × min and 240 min values: cooked potato: 1690 ± 140 mmol/l × min, cooked rice: 1740 ± 210 mmol/l × min). In contrast, the response after cooked spaghetti was slower and less pronounced (180 min value: 830 ± 80 mmol/l × min and 240 min value: 1320 ± 120 mmol/l × min), and was significantly smaller than those of cooked potato (180 min: $2p < 0.01$ and 240 min: $2p < 0.01$) as well as cooked rice (180 min: $2p < 0.01$ and 240 min: $2p < 0.02$). Our study emphasizes the importance of determining the glycaemic response of foodstuffs under conditions of isoinsulinaemia.

Key words: Type 1 diabetes, blood glucose, artificial pancreas, diet.

In view of the increasingly accepted goal of euglycaemia for diabetic patients [1], it is surprising that until recently there has been sparse systematic investigation on the effects of different carbohydrate sources on blood glucose excursions [2-7]. The influence of different types of complex carbohydrates has mostly been studied in normal subjects and Type 2 (non-insulin-dependent) diabetic patients [2, 3, 5, 7, 8]. The reason for the relatively few studies in Type 1 (insulin-dependent) diabetic patients may be due to difficulties in obtaining reproducible, near-normal blood glucose levels before meal intake in these patients [9, 10]. This latter problem can, however, be circumvented by means of the artificial pancreas [11]. Further, in normal subjects and diabetic patients with preserved endogenous insulin production, some of the observed effects on blood glucose may be due to varying responses of insulin stimulatory gut factors, making the results inapplicable to most Type 1 diabetic patients.

The present investigation was performed to study the short-term metabolic effect of exchangeable amounts of potato, rice and spaghetti on blood glucose levels in lean Type 1 diabetic patients who, by means of the artificial pancreas, had obtained near-normal blood glucose levels prior to the meal intake. The amount of food was designed to fit Danish exchange lists and foods were similar in caloric content.

Subjects and methods

Subjects

Six Type 1 diabetic patients fully informed of the experimental nature of the investigation were studied. Clinical data are given in Table 1. All patients were free of clinical signs of peripheral neuropathy and had normal serum creatinine levels. Two patients (AL and TK) had background retinopathy. The six patients were randomly assigned to the three meal challenges.

Experimental protocol

Intermediate insulin was withdrawn 48 h prior to the experiments and the patients were treated with soluble insulin only. The last soluble in-

Table 1. Clinical data for the six Type 1 (insulin-dependent) diabetic patients

Patient	Sex	Age (years)	BMI	Duration of diabetes (years)	Insulin requirement (U/d)
AL	M	64	22.2	25	36
JW	M	21	21.3	11	40
TK	M	22	22.8	11	40
CJN	M	30	21.8	6	28
BR	M	37	22.3	8	54
BJ	M	42	21.4	6	50
Mean		36	22.0	11	41
SD		16	0.6	7	9

Table 2. Meal composition[a]

Food	Weight	Energy		Starch	Sugars	Dietary fibers	Fat	Protein
	(g)	(Kcal)	(Kj)	(g)	(g)	(g)	(g)	(g)
Rice parboiled, raw	50	181	768	43.4	Tr	1.2	0.5	3.3
Spaghetti, white raw	50	189	806	40.7	1.4	–	0.5	6.8
Potatoes, old raw	200	174	744	40.6	1.0	4.2	0.2	4.2

[a] In addition, each meal contained 250 ml water

Table 3. Blood glucose response (area above basal) after meals of cooked potato (200 g), white rice (50 g) and white spaghetti (50 g) given to type 1 diabetic patients

	Blood glucose response (180 min postprandial period) (mmol/l × min)			Blood glucose response (240 min postprandial period) (mmol/l × min)		
	Potato	White rice	White spaghetti	Potato	White rice	White spaghetti
Patient	A	B	C	A	B	C
AL	780	870	570	1200	1360	910
SW	1480	1500	960	2080	2330	1670
TK	1130	820	630	1630	1230	1160
CN	1240	1010	760	1600	1440	1190
BR	1450	1620	1060	2110	2410	1600
BJ	1050	1160	970	1490	1670	1360
Mean	1190	1160	830	1690	1740	1320
± SEM	110	140	80	140	210	120

A vs. B, NS; A vs. C, $p < 0.01$; B vs. C, $p < 0.01$; A vs. B, NS; A vs. C, $p < 0.01$; B vs. C, $p < 0.02$

sulin was given at 17.00 h the day before the study. At 22.00 h the patients were connected to the artificial endocrine pancreas (Biostator, Miles Laboratories, Elkhart, IN, USA) to achieve a normoglycaemic equilibrium. The set constants were KR = 150, KF = 50, BI = 100, QI = 40, RI = 0.15/kg body weight, FI = 320, BD = 70, QD = 20, RD = 90 and FD = 360. Operating mode 3 : 0, indicating static plus dynamic control of insulin infusion, was used. At 08.00 h after an overnight fast, the operating mode was changed to 7 : 0 and the RD to zero in order to maintain a constant insulin infusion rate of 0.15 mU per kg body weight without glucose infusion.

Meals

The meal protocol consisted of administering on separate days in random order one of three complex carbohydrate meals containing 50 g parboiled rice (raw weight), 50 g white spaghetti made from durum wheat semolina (raw weight) or 200 g potato (raw weight). The concomitant water intake constituted 250 ml. Table 2 gives the approximate carbohydrate, protein, starch, sugar, fibers and energy content in these fixed meals according to Paul and Southgate [15]. As seen in Table 2, the content of available carbohydrate was approximately 40 g. Potatoes, rice and spaghetti were cooked for 19, 12 and 10 min. The meal was eaten between 08.30 and 09.00 h during a 10-min period. Blood glucose levels ranging between 4.8 and 7.7 mmol/l were maintained at this level for at least 1 h before starting the experiment. The subjects were asked to micturate just before meal intake. The glucose loss was then measured in the urine collected during the test period (0–240 min). Patients sat in their beds throughout the experiment.

Analytical techniques

Plasma and urinary glucose were measured by the glucose oxidase method. HbA_{1c} values were determined by a commercial kit (Bio-Rad, Richmond, CA, USA) (normal HbA_{1c} values 3.5–5.5%). Serum free insulin levels were determined as described by Nakagawa et al. [16] with modifications [17]. C-peptide was measured by a commercial kit (Immunonuclear Corporation, Stillwater, MN, USA).

Statistical analysis

Areas under blood glucose curves were calculated geometrically by subtracting the mean basal blood glucose concentration from each value. Results of all measurements are expressed as the mean ± SEM. The significance was calculated using Student's t-test for paired data.

Results

In all diabetic patients, plasma C-peptide levels were lower than 1.1 ng/ml in the fasting state without a significant increase after the meals. The postprandial increase in blood glucose after cooked potato, rice and spaghetti is shown in Figure 1. Before the three meals no significant difference was seen in the mean fasting blood glucose values, which were close to normal. Furthermore, similar or identical HbA_{1c} values (7.3 ± 1.3(SD)% potato, 7.0 ± 0.9(SD)% rice, 7.6 ± 0.6(SD)% spaghetti) were also present before potato, rice and spaghetti meals respectively. Following potato and rice similar mean areas of blood glucose above basal values were found after 180 min and 240 min, being 1190 ± 110 mmol/l × min and 1160 ± 140 mmol/l × min and 1690 ± 140 mmol/l × min and 1740 ± 210 mmol/l × min respectively (Table 3). After ingestion of spaghetti, however, the blood glucose response was considerably slower (Fig. 1) and the mean blood glucose response area was significantly smaller, constituting 830 ± 80 mmol/l × min after 180 min and 1320 ± 120 mmol/l × min after 240 min (for p values see Table 3). Thus, compared to the potato response, the spaghetti blood glucose response area was reduced by 30±5% ($2p<0.01$) after 180 min and 22±3% ($2p<0.001$) after 240 min. When compared to the rice response, the spaghetti blood glucose response area was blunted by 28±3% ($2p<0.001$) after 180 min and 23±5% ($2p<0.01$) after 240 min. Although the amount of glucose being lost in the urine appeared slightly higher to potato (10.9±3.7 g) and rice (10.0±3.6 g) than to spaghetti (8.0±3.0 g), this difference did not attain statistical significance. As seen in Table 4, identical average plasma free insulin levels were measured during the test period (0-240 min) in response to potato (12.6±1.8 μU/ml), rice (12.3±1.7 μU/ml) and spaghetti (12.8±0.9 μU/ml).

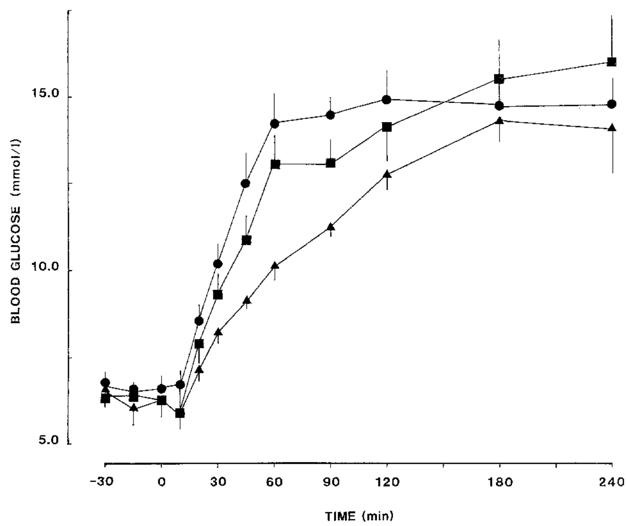

Fig. 1 Mean blood glucose variations observed after cooked potato (raw weight: 200 g) (●), white rice (parboiled) (raw weight: 50 g) (■), and spaghetti (raw weight: 50 g) (▲) in six Type 1 (insulin-dependent) diabetic patients receiving constant insulin infusion by an artificial pancreas. Meal intake took 10 min. Values are mean ± SEM

Table 4. Mean plasma free insulin (μU/ml) (mean±SEM) in 6 Type 1 diabetic patients ingesting cooked potato (200 g), white rice (50 g) and white spaghetti (50 g)

Time (min)	Potato	Rice	Spaghetti
-30	17.1±2.1	17.1±3.1	18.0±2.9
-15	12.1±0.9	16.0±0.8	18.9±1.4
0	14.8±2.2	14.5±1.7	13.0±0.6
10	14.0±3.1	11.7±2.3	12.1±1.0
20	11.8±2.4	12.0±1.6	13.1±1.6
30	14.0±1.7	13.0±2.5	16.5±0.9
45	13.3±2.4	12.5±1.9	13.5±1.8
60	12.5±2.2	13.3±1.6	14.1±1.3
90	14.0±1.9	12.5±1.5	13.0±0.8
120	11.0±1.8	13.1±2.3	12.2±0.6
180	12.5±1.5	11.5±0.9	12.0±1.8
240	13.6±1.4	10.7±1.0	12.3±0.8
Average level 0-240 min	12.6±1.8	12.3±1.7	12.8±0.9

Discussion

Traditionally, the dietary treatment of diabetes is based on the idea that foods with similar proportions of carbohydrate, protein and fat produce similar glycaemic responses. A growing body of data, however, shows that chemically similar foods can differ in their impact on blood glucose. Thus, different carbohydrate foods produce different glycaemic responses in normal subjects as well as diabetic patients [2-14, 18-21]. Most of this knowledge was obtained in non-diabetic or Type 2 diabetic individuals [2-10, 12, 14, 18-20]. The reason for the relatively scant number of studies testing carbohydrate foods in Type 1 diabetic patients [9-11, 13] may be ascribed to difficulties in obtaining similar basal blood glucose levels before the different test meals.

By use of the artificial pancreas, we avoided variation in subcutaneous insulin depot absorption and began the meal administration at reproducible, near-normal blood glucose concentrations. We used the Danish food exchange system to calculate the amounts of potato, rice and spaghetti [22]. The three test meals contained approximately 40 g available carbohydrate and were approximately isocaloric (Table 3).

We found that spaghetti produced a significantly smaller increase in blood glucose in Type 1 diabetic patients than either cooked potato or cooked rice in the period 0-180 and 0-240 min. Despite this observation, we were unable to pick up any significant difference in the amount of glucose being spilled in the urine in response to spaghetti versus potato and rice. This may in part be due to a rather large interindividual variability in the renal threshold in these insulin-dependent diabetic patients. In a heterogenous group of both Type 2 and Type 1 diabetic subjects, Jenkins et al. [18] also found that spaghetti caused a relatively slow and small blood glucose response when comparing with exchangeable amounts of white bread and wholemeal bread. In another mixed group of diabetic patients, Parillo et al. [23] looked at the glycaemic responses to a mixed meal to which either 50 g carbohydrate portion of either spaghetti or potato was added. They also found that the glycaemic response was significantly lower after a spaghetti meal than after a potato meal [23]. In none of these experiments were premeal blood glucose levels normalized, which makes strict comparison difficult. Most of their patients had retained insulin production, implying that differences in blood glucose profiles may partly be due to different ability to release insulin stimulatory gut factors. It is likely that different results are obtained in Type 1 diabetic patients without endogenous insulin. The amount of dietary fibers in the test meals seems to play a minor role, since removal of the fibres from rice [20] and spaghetti [18] has no effect on the glycaemic response to these foods. The disparity in results may be ascribed to differences in gastric emptying, differences between the forms of starches and differences in content of antinutrients [24]. The finding of relatively pronounced, and rapid blood glucose excursions after ingestion of cooked potato or cooked rice corroborate previous results obtained in Type 2 [2, 4, 13, 19] and Type 1 [4, 13] diabetic patients. In Type 1 diabetic patients Jenkins et al. [9] found large interindividual variation in the glycaemic responses to a specific test meal. This was, however, not the case in our study. The reason for this discrepancy may be that we have achieved the same, near-normal pretest blood glucose level as well as a constant insulinaemia throughout the experiment by the artificial pancreas. Thus, it is well known that the insulinaemia is extremely important for the postprandial glucose response to carbohydrate [25]. It is likely that great variations in insulin levels within as well as between experiments do exist in diabetic patients treated by conventional, subcutaneously administered insulin [9].

We conclude that the glycaemic response to spaghetti is significantly lower than so-called exchangeable amounts of potato or rice, and that spaghetti appears to be an acceptable alternative as a carbohydrate source. The approach in which the most important variable, i. e. the insulinaemia, was kept constant by the artificial pancreas seems to be a valuable tool for studying glycaemic responses to different carbohydrate meals in Type 1 diabetic patients. It is important to look not only at the glycaemic impact of the different carbohydrate foods since the amounts of fat and protein in the concomitantly ingested meal may profoundly modulate the glycaemic responses of these carbohydrate constituents.

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