Glycaemic index of conventional carbohydrate meals*

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The glycaemic index (GI) and the triacylglycerol response were measured in thirty non-insulin-dependent diabetes mellitus patients given 50 g portions of five different conventional Indian meals containing semolina (*Triticum aestivum*) cooked by two different methods, or combinations of semolina and pulse (black gram dhal (*Phaseolus mungo*), green gram dhal (*Phaseolus aureus*) or Bengal gram dhal (*Cicer arietum*)). There were no significant differences among meals in mean GI except for meals based on roasted semolina or semolina–black gram dhal. Compared with the blood glucose response for a 50 g glucose load, only meals based on steam-cooked semolina and semolina–Bengal gram dhal elicited a significantly lower response at 1 h postprandially, and only meals based on semolina–black gram dhal at 2 h postprandially. No significant differences were found among the meals in the triacylglycerol response.

Glycaemic response: Diabetes mellitus: Conventional Indian meals

In spite of drug therapy, dietetic management is still the backbone of the control and management of diabetes mellitus, particularly of non-insulin-dependent diabetes mellitus (NIDDM), where the primary derangement is of carbohydrate metabolism, with secondary abnormalities involving lipids and proteins. Reduction of postprandial glycaemia is now considered a desirable goal for the treatment and management of diabetes. One of the simplest approaches is to emphasize foods with a low glycaemic index (GI). Jenkins *et al.* (1981) introduced the concept of GI of foods as a physiological basis for ranking carbohydrate foods based on the glycaemic response they produce on ingestion, but few traditional Indian foods have been tested for their glycaemic response. In an earlier study (Mani *et al.* 1990), a higher GI was found for rice alone than for rice in combination with legumes or pulses (in India pulses are referred to as dhals). The present study involved measuring the GI of some more conventional cereal–pulse (dhal) combinations widely consumed in this region of India. Alteration in lipid metabolism is usually a prominent feature of the NIDDM syndrome, so dietary advice should also take into consideration foods with low lipaemic responses in addition to reducing the postprandial glycaemic response. Hence, the triacylglycerol response of the meals was also determined.

MATERIALS AND METHODS

Thirty confirmed NIDDM patients over 40 years of age who had been routinely visiting the diabetic clinic for follow-up and who had been on oral hypoglycaemic drugs were randomly selected from the out-patient department of the diabetes clinic of the local general hospital.

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Table 1. *Clinical details of diabetic patients*

(Mean values with their standard deviations)

	Men (*n* 17)		Women (*n* 13)	
	Mean	SD	Mean	SD
Age (years)	60	9	56	10
Weight (percentage of ideal body-weight)	106	18	112	20
Duration of the disease (years)	3	1	3	1

Table 2. *Composition of meals containing conventional Indian carbohydrate sources*

Meal	Ingredients	Uncooked wt (g)	Energy (kJ)	Carbohydrate (g)	Protein (g)	Fat (g)	Crude fibre (g)
R1	Semolina* (*Triticum aestivum*)	67·0	933	50·0	7·0	0·54	0·13
R2	Semolina	45·0	653	34·0	4·7	0·36	0·09
	Black gram dhal (*Phaseolus mungo*)	26·0	377	16·0	6·2	0·36	0·23
R3	Semolina	45·0	653	34·0	4·7	0·36	0·09
	Green gram dhal (*Phaseolus aureus*)	26·0	377	16·0	6·3	0·31	0·20
R4	Semolina	45·0	653	34·0	4·7	0·36	0·09
	Bengal gram dhal (*Cicer arietinum*)	26·0	377	16·0	5·4	1·41	0·31
R5	Semolina*	67·0	933	50·0	7·0	0·54	0·13
R1–R5	Oil	5·0	188	—	—	5·0	—

* For meals R1 and R5, the semolina was cooked differently: see Materials and Methods.

Clinical information relating to the subjects is given in Table 1. On the first visit, an oral glucose tolerance test (GTT) was carried out for all the patients using 50 g glucose. Blood glucose was estimated in fasting and postprandial (1 and 2 h) samples by the *o*-toluidine method of Hultman (1959), using a diagnostic kit (Council for Scientific and Industrial Research, New Delhi, India). Plasma triacylglycerols were determined in fasting and 2 h postprandial blood samples by the method of Foster & Dunn (1973). The subjects were then randomly divided into five groups of six. Within 7 d, the subjects were given the test meal containing 50 g carbohydrate which was eaten over 8–10 min. The composition of the meals was calculated using the food tables compiled by Gopalan *et al.* (1979) (Table 2). Blood glucose and plasma triacylglycerols were estimated as described previously for GTT.

Blood glucose response curves were plotted for both the GTT and the test carbohydrate food, and the GI of the food was calculated using the method described by Jenkins *et al.* (1981) by determining the ratio area under the glucose response curve for the food : area for the GTT. Triacylglycerol response was calculated from the percentage increase in the mean triacylglycerol level compared with the mean fasting value for six subjects.

The five meals tested were based on: R1, semolina (*Triticum aestivum*) alone; R2, semolina–black gram dhal (*Phaseolus mungo*); R3, semolina–green gram dhal (*Phaseolus aureus*); R4, semolina–Bengal gram dhal (*Cicer arietinum*); R5, semolina alone. The semolina in meals R1 and R5 was prepared differently: for R1, the semolina was steamed

with gelatinization; for R5, the semolina was roasted at 105° with resultant gelatinization when water was added. The dhals were soaked for 4 h, ground to a paste and fermented for 8 h. All meals were cooked for 20 min; water (400 ml) was added during cooking. Groundnut oil (5 g) was added to each meal to enhance palatability. The meals were approximately isoenergetic.

The glucose response after each test meal was compared with the GTT value using the paired *t* test. Responses for the different test meals were compared using Student's *t* test for unpaired values.

RESULTS

The GI values for the test meals are given in Table 3. The GI of meal R5 was significantly lower than that for meal R2 ($P < 0{\cdot}05$). There were no other significant differences among the meals, even though the GI for the other meals appeared lower than that for meal R5.

Table 4 shows the glycaemic responses to a 50 g glucose load and to the test meals. The responses to meals R1, R3 and R4 at 1 h postprandially were significantly different ($P < 0{\cdot}05$) from the corresponding response to the glucose load for the same group of subjects. However, at 2 h only meal R2 had a significantly lower glycaemic response than that of the glucose load ($P < 0{\cdot}05$).

The fasting and 2 h postprandial triacylglycerol responses to the test meals are shown in Table 5. There were no significant differences among the meals.

DISCUSSION

Studies by O'Dea *et al.* (1981), Jenkins *et al.* (1983), Thorne *et al.* (1983) and several others have shown that foods providing equicarbohydrate portions can produce different postprandial glycaemic responses. A number of factors such as the nature of source of starch, the physical form of the food, methods of processing or cooking, starch–nutrient interactions, dietary fibre and antinutrients have been implicated. In view of all the factors affecting GI, it is essential that many more foods and meals should be screened for their glycaemic responses and their suitability for a diabetic diet. The GI are available for some foods consumed in India (Dilawari *et al.* 1981; Akhtar *et al.* 1987) and elsewhere (Jenkins *et al.* 1981, 1983, using English foods), and in the present study an attempt has been made to determine the GI for some conventional Indian foods by determining the glucose response at two time-intervals.

Krezowski *et al.* (1987) and Behall *et al.* (1988) studied the effect of starch structure on glucose and insulin response in normal and diabetic subjects. Starch granules in cereal grains are structurally different from those in leguminous seeds. Differences in particle size and surface area result in altered digestion by hydrolytic enzymes. The ratio amylose:amylopectin and the amylopectin branching pattern affect the physical characteristics of the starch both in regard to its response to cooking and its digestibility in the small intestine. Legumes and pulses (or dhals) as a class contain 5–10% more amylose, which is more resistant to cooking and digestion than amylopectin, than do cereals. However, the amylose content of the different legumes and pulses is not known and additional research is needed to determine the extent to which the amylose content of a food is responsible for its GI.

Studies have been carried out by, for example, Jenkins *et al.* (1978), Dilawari *et al.* (1981) and Wolever (1990) to investigate the effect of dietary fibre on glycaemic response and its relationship to GI. Dietary fibre inhibits starch digestibility either by increasing the viscosity of intestinal contents, and thereby slowing the absorption of carbohydrate from the food, or by packing the carbohydrate and 'insulating' it from digestive enzymes. The

Table 3. *Glycaemic indices of meals† containing conventional Indian carbohydrate sources*
(Mean values with their standard errors)

Meal	Ingredients	Glycaemic index (%) Mean	SE
R1	Semolina‡ (*Triticum aestivum*)	55	9
R2	Semolina–black gram dhal (*Phaseolus mungo*)	46*	12
R3	Semolina–green gram dhal (*Phaseolus aureus*)	62	20
R4	Semolina–Bengal gram dhal (*Cicer arietinum*)	54	7
R5	Semolina‡	76	6

Mean value was significantly different from that for meal R5: * $P < 0{\cdot}05$.
† For details of composition, see Table 2 and Materials and Methods.
‡ For meals R1 and R5, the semolina was cooked differently: see Materials and Methods.

Table 4. *Fasting and postprandial glycaemic responses (mmol glucose/l) for a glucose tolerance test and meals† containing conventional Indian carbohydrate sources*
(Mean values with their standard errors for six subjects)

Meal	Ingredients	Fasting responses Mean	SE	Postprandial responses 1 h Mean	SE	2 h Mean	SE
Glucose		8	1·0	14	1·7	12	1·7
R1	Semolina‡ (*Triticum aestivum*)	8	0·8	12*	1·3	11	1·1
Glucose		11	2·0	17	2·7	15	2·7
R2	Semolina–black gram dhal (*Phaseolus mungo*)	9	1·7	12	1·8	14*	1·6
Glucose		10	1·7	15	1·8	14	1·5
R3	Semolina–green gram dhal (*Phaseolus aureus*)	10	1·5	12*	1·9	12	1·9
Glucose		7	0·9	13	1·0	11	1·6
R4	Semolina–Bengal gram dhal (*Cicer arietinum*)	7	0·7	10*	0·8	9	0·8
Glucose		11	1·4	17	1·2	14	1·2
R5	Semolina‡	9	0·8	14	1·3	13	1·2

Mean values were significantly different from those for glucose: * $P < 0{\cdot}05$.
† For details of composition, see Table 2 and Materials and Methods.
‡ For meals R1 and R5 the semolina was cooked differently: see Materials and Methods.

fibre in pulses (galactomannans) is more viscous than that in cereals and this may explain the hypoglycaemic effect of pulses compared with that of cereals. However, in the present study pulses (i.e. green gram and Bengal gram dhals) combined with cereal had no greater hypoglycaemic effect than cereal alone (see particularly meals R3 and R4, semolina–green gram dhal and semolina–Bengal gram dhal). The effect of fibre on GI needs further study. Moreover, studies on animals and on humans have revealed that cereal fibre *per se* had no direct effect on glycaemic response. Studies (e.g. Goswany *et al.* 1985; Ahren *et al.* 1987; Mani *et al.* 1985*a*,*b*, 1987; Mani & Mani, 1987) on the effect of supplementation with

Table 5. *Fasting and 2 h postprandial triacylglycerol responses (mmol triacylglycerol/l) for a glucose tolerance test and meals* containing conventional Indian carbohydrate sources*

(Mean values with their standard errors for six subjects)

Meal	Ingredients	Fasting response		Postprandial response		Mean percentage postprandial increase
		Mean	SE	Mean	SE	
Glucose		1·5	0·5	1·8	0·4	
R1	Semolina‡ (*Triticum aestivum*)	1·9	0·6	2·0	0·4	17
Glucose		2·2	0·6	2·3	0·6	
R2	Semolina–black gram dhal (*Phaseolus mungo*)	1·8	0·5	1·7	0·4	−2
Glucose		1·7	0·3	1·8	0·2	
R3	Semolina–green gram dhal (*Phaseolus aureus*)	1·4	0·1	1·7	0·2	21
Glucose		1·8	0·4	1·8	0·4	
R4	Semolina–Bengal gram dhal (*Cicer arietinum*)	1·8	0·6	2·0	0·4	17
Glucose		2·4	0·5	3·0	0·4	
R5	Semolina†	2·5	0·6	2·6	0·6	6

* For details of composition, see Table 2 and Materials and Methods.
† For meals R1 and R5, the semolina was cooked differently: see Materials and Methods.

wheat bran on the blood glucose response to different breads showed there was little effect in decreasing hyperglycaemia, and no significant effect in decreasing hyperlipidaemia in diabetic rats and in humans.

Many foods contain anti-nutrients such as enzyme inhibitors, phytates, tannins and lectins, which have been found to influence starch digestibility and hence the glycaemic response. Urooj & Puttaraj (1988) found that the α-amylase (*EC* 3.2.1.1) inhibitors present in wheat, which can withstand cooking, are effective in reducing blood glucose responses. The anti-nutrient contents of many foods are unknown, and more information is required before any conclusions can be reached about the effect of anti-nutrients on GI.

Wong & O'Dea (1983), Gannon & Nuttall (1987) and Behall *et al.* (1988) studied the role of the physical form of the food, method of cooking and the effect of processing of food on the starch digestion and thereby on postprandial glycaemic response. The meals tested in the present study were prepared from semolina, which is coarsely ground wheat endosperm, and pulses that were soaked, ground to a paste and fermented. Decreasing the particle size by grinding greatly increases the surface area and results in much more rapid digestion and absorption. Meals R1 and R5 both contained semolina but differed in the method of cooking (see Materials and Methods). Any differences in GI (the two meals were not significantly different) could be attributed to this.

Studies by Reaven (1987) and Cerami *et al.* (1987) reveal that primary disturbances in carbohydrate metabolism in diabetes mellitus bring about alterations in lipid metabolism, especially cholesterol and triacylglycerol, which in turn promote secondary complications. In view of this finding, the triacylglycerol responses of the meals were also monitored in the present study. Semolina–black gram dhal (meal R2) elicited the lowest triacylglycerol response, possibly owing to its higher fibre content. Further, triacylglycerol responses were not correlated with the fat content of the meals, indicating that this might be of

physiological importance in recommending low-GI foods. Moreover, the differences in triacylglycerol responses were not statistically significant.

It appears that further studies are necessary to examine the effect of each factor influencing GI using a larger sample size. At present GI can be considered an effective clinical tool for formulating the diabetic diet.

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