Guar gum and reduction of post-prandial glycaemia: effect of incorporation into solid food, liquid food, and both

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1. The influence of the dose and the form in which guar gum was given on the degree of 'flattening' of blood glucose curves was studied in five subjects using meals of bread and soup containing 5 or 10 g guar gum.

2. When 5 g guar gum was added to bread the peak increase of blood glucose was reduced by 41 % ($P < 0.002$), with 5 g guar in soup, the reduction was 54 % ($P < 0.001$) while a reduction of 68 % ($P < 0.001$) was seen with 10 g guar gum (5 g in bread and 5 g in soup). The corresponding reduction in insulin peak increases were 37 % ($P < 0.002$), 50 % ($P < 0.001$) and 65 % ($P < 0.001$) respectively.

3. The difference between the two 5 g doses was not significant with respect to the reduction of the peak increases in blood glucose and serum insulin; however the difference between the 5 g dose in bread and the 10 g dose was significantly different ($P < 0.02$ for glucose, $P < 0.01$ for insulin).

4. The results indicate that as little as 5 g guar gum may reduce the glycaemia following a 45 g carbohydrate meal, but perhaps due to earlier and more complete mixing, guar gum is most effective when added to the liquid phase of the meal.

Guar gum, one of the gel-forming plant polysaccharides, has been shown to lower the post-prandial glucose and insulin responses in both normal (Jenkins, Leeds *et al.* 1977) and diabetic (Jenkins *et al.* 1976) subjects and to reduce the 24 h urinary glucose output in diabetics (Jenkins, Wolever *et al.* 1977). Comparison of guar gum with other unabsorbable polysaccharides has also shown it to be the most effective in 'flattening' the blood glucose increase which follows 50 g oral glucose loads (Wolever *et al.* 1978). This action was demonstrated to be related to the ability of guar gum to increase the viscosity of aqueous solutions (Jenkins *et al.* 1978).

In view of the potential therapeutic use of this and other such agents in the treatment of diabetes, an attempt was made to define both the dose and the form in which guar gum might be given to be most effective in lowering the blood glucose level or at least preventing an excessive increase after a meal. We have therefore given meals containing guar gum in a solid food, bread, or a liquid food, soup, with total doses of guar gum of either 5 or 10 g.

EXPERIMENTAL METHODS

The approval of the hospital ethical committee was obtained for this study in which five normal volunteers (one female, four male; 20–34 years; 103 ± 2 % desirable weight, Diem & Lentner, 1972) took four different meals in random order on separate days after an overnight fast. Although there was significant heterogeneity between the subjects with respect to fasting blood glucose concentrations ($P < 0.01$) this was not seen with respect to fasting insulin levels (Table 1). After accounting for the variation between subjects there were no differences in the mean fasting blood glucose or serum insulin levels on the 4 d (Table 1). Each meal, taken over 10 min, consisted of white bread and tomato soup. The test experiments contained 5 g guar gum added to bread (Apling *et al.* 1977), or 5 g guar gum added

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Table 1. *Mean fasting blood glucose (mmol/l) and serum insulin (pmol/l)*

(Values for each subject and each day with their standard errors and significances of heterogeneity)

Subject ...	DN		ME		BS		TW		DJ		Variance ratio	*P*
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Fasting blood glucose	4·0	0·13	4·3	0·08	3·9	0·12	4·7	0·03	4·8	0·05	16·82	< 0·01
Fasting serum insulin	59·0	9·5	51·0	4·6	39·0	5·6	49·0	9·4	51·0	8·9	0·79	NS

	Control		5 g guar gum in bread		5 g guar gum in soup		10 g guar gum		Variance ratio	*P*
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Fasting blood glucose	4·3	0·23	4·4	0·19	4·3	0·25	4·4	0·14	0·16	NS
Fasting serum insulin	56·0	6·4	42·0	2·4	50·0	7·8	52·0	9·8	0·60	NS

NS, not significant.

Table 2. *Composition (g/meal) of test and control meals*

	Total	Fat	Protein	Carbohydrate	Guar gum
Tomato soup:					
Control	300·0	11·4	2·1	28·8	0·0
Test	280·0	11·5	3·4	24·9	5·1
White bread:					
Control	41·3	0·5	3·2	20·6	0·0
Test	62·5	0·5	4·9	20·6	5·0
Total for meals:					
Control soup, bread	—	11·9	5·3	49·4	0·0
Test soup, control bread	—	12·0	6·6	45·5	5·1
Control soup, test bread	—	11·9	7·0	49·4	5·0
Test soup, test bread	—	12·0	7·3	45·5	10·1

to soup, or 10 g guar gum, added as 5 g to both the bread and the soup. The compositions of the four meals are shown in Table 2.

Blood samples were taken in the fasting state and at 15, 30, 45, 60, 90, 120 and 180 min after the start of each meal for the analysis of glucose (Werner *et al.* 1970) and insulin (Soeldner & Slone, 1965).

The results are expressed as mean values with their standard errors, and the significance tests performed utilizing an estimated true standard error calculated by analysis of variance for a randomized block design (Bailey, 1964) by reference to Student's *t* distribution.

Areas under the curve for glucose and insulin were derived from the 0–120 min values.

RESULTS

Allowing for the variability between subjects, there was significant heterogeneity between the mean blood glucose values at 30 min ($P < 0·01$) and 45 min ($P < 0·05$), between the mean serum insulin values at 30 min ($P < 0·01$), 45 min ($P < 0·05$) and 60 min ($P < 0·05$) (Fig. 1), between the mean areas under the glucose ($P < 0·05$) and insulin ($P < 0·05$) curves from 0–120 min, and between the mean peak increases of glucose ($P < 0·01$) and insulin ($P < 0·01$) (Table 3).

Guar gum in bread (5 *g*). Allowing for the variability between subjects, after the meal containing 5 g guar gum in bread, with respect to the control meal, the mean blood glucose levels were significantly reduced at 30 min by 10% ($P < 0·01$) and at 45 min by 15% ($P < 0·01$) (Fig. 1); the mean area under the curve and peak increase of blood glucose were

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Table 3. *Areas under the curve from 0–120 min and mean peak increases of blood glucose and serum insulin*

(Mean values with their standard errors, variance ratios and significance of heterogeneity)

	Control		5 g guar gum in bread		5 g guar gum in soup		10 g guar gum			
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Variance ratio	*P*
Blood glucose										
Areas under curve (mmol h/l)	1·58	0·34	0·91	0·10	0·73	0·17	0·75	0·33	3·77	< 0·05
Peak rises (mmol/l)	2·17	0·38	1·29	0·23	1·00	0·25	0·70	0·21	9·19	< 0·01
Serum insulin										
Areas under curve (pmol/l)	289	55	228	39	147	44	118	23	5·69	< 0·05
Peak rises (pmol/l)	379	50	240	20	190	74	131	24	10·01	< 0·01

significantly reduced by 44 % ($P < 0·01$) and 41 % ($P < 0·002$) respectively (Table 3); the mean serum insulin levels were significantly reduced at 30 min by 30 % ($P < 0·001$), at 45 min by 34 % ($P < 0·001$) and at 60 min by 40 % ($P < 0·001$) (Fig. 1); and the mean peak increase in serum insulin was significantly reduced by 37 % ($P < 0·002$) (Table 3).

Guar gum in soup (5 *g*). Allowing for the variability between subjects, after the meal containing 5 g guar gum in soup, with respect to the control meal, the mean blood glucose levels were significantly reduced at 30 min by 23 % ($P < 0·001$) and 45 min by 15 % ($P < 0·01$) (Fig. 1); the mean area under the curve and peak increase of blood glucose were both significantly reduced by 54 % ($P < 0·002$, and $P < 0·001$ respectively) (Table 3); the mean serum insulin levels were significantly reduced at 30 min by 62 % ($P < 0·001$), at 45 min by 36 % ($P < 0·01$) and at 60 min by 35 % ($P < 0·01$) (Fig. 1); and the mean area under the curve and peak increase of serum insulin were significantly reduced by 49 % ($P < 0·001$) and 50 % ($P < 0·001$) respectively (Table 3).

Guar gum in both bread and soup (*total* 10 *g*). Allowing for the variability between subjects, after the meal containing 10 g guar, with respect to the control meal, the mean blood glucose levels were significantly reduced at 30 min by 21 % ($P < 0·001$) and 45 min by 19 % ($P < 0·002$) (Fig. 1); the mean area under the curve and peak increase of blood glucose were significantly reduced by 52 % ($P < 0·002$) and 68 % ($P < 0·001$) respectively (Table 3); the mean serum insulin levels were significantly reduced at 30 min by 59 % ($P < 0·001$), at 45 min by 61 % ($P < 0·001$) and at 60 min by 49 % ($P < 0·001$) (Fig. 1) and the mean area under the curve and peak increase of serum insulin were significantly reduced by 59 % ($P < 0·001$) and 65 % ($P < 0·001$) respectively (Table 3).

Differences between meals containing guar gum. After accounting for the variability between subjects, following the meals containing 5 g guar gum in soup only and that containing a total of 10 g guar gum, when compared with the meal containing 5 g guar gum in bread only, respectively, the mean blood glucose levels were reduced at 30 min by 15 % ($P < 0·002$) and 12 % ($P < 0·01$) (Fig. 1); the mean peak increases of blood glucose were reduced by 22 % (not significant) and 46 % ($P < 0·02$) (Table 3); the mean serum insulin levels were reduced at 30 min by 46 % ($P < 0·001$) and 42 % ($P < 0·001$), and at 45 min by 3 % (not significant) and 41 % ($P < 0·05$) (Fig. 1); and the mean areas under the curve and peak increases of serum insulin were reduced by 35 % ($P < 0·05$) and 48 % ($P < 0·01$), and 21 % (not significant) and 45 % ($P < 0·01$) (Table 3) respectively.

The only significant difference between the meal containing 5 g guar gum in soup only

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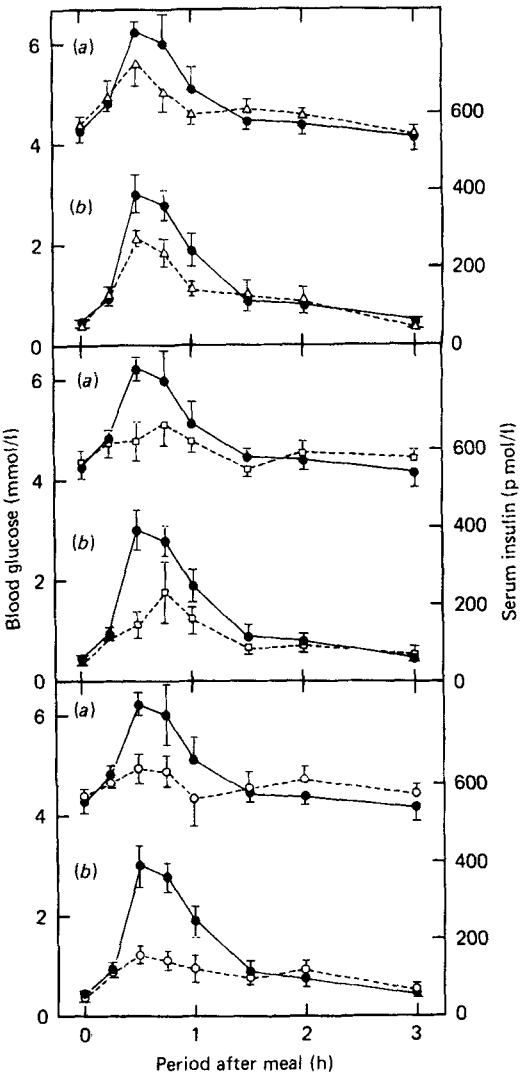

Fig. 1. Mean (*a*) blood glucose (mmol/l) and (*b*) serum insulin (pmol/l; five subjects) after taking a control meal (●—●) or test meals of bread and soup containing either 5 g guar gum in the bread (△---△), 5 g guar gum in the soup (□----□) or 10 g guar (5 g in both the bread and the soup) (○---○). For details of meals, see Table 1 and p. 505. The points represent mean values, with their standard errors represented by vertical bars.

and that containing 10 g guar gum in total was, after accounting for the variability between subjects, a significantly reduced insulin level at 45 min after 10 g guar gum when compared with the 5 g dose (39 %, $P < 0{\cdot}05$) (Fig. 1).

DISCUSSION

This study showed that as little as 5 g guar gum in bread significantly reduced the post-prandial glycaemia and insulinaemia which followed a 45 g carbohydrate meal. When 5 g

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guar gum was taken in the form of soup, however, the effects on blood glucose and serum insulin were substantially improved. The differences between the two meals containing 5 g guar gum reached significance with respect to the mean blood glucose and serum insulin levels at 30 min and the mean area under the insulin curve.

Guar gum is not fully hydrated in bread or other semi-dry foods, but due to the convenience of such foods, it was potentially important to see whether they were therapeutically effective 'vehicles' for guar gum. Partly-hydrated guar gum forms lumps when added to other liquids and needs much mixing to form a homogeneous gel. If viscosity was of importance in the action of guar gum (Jenkins *et al.* 1978), then soup or foods which were already hydrated would be expected to be most effective in 'flattening' the post-meal blood glucose increase. The latter was indeed found to be the situation in this study.

Although the meal containing 10 g guar gum reduced both the peak increases in glucose and insulin and the area under the curve for insulin to a significantly greater extent than did 5 g guar in bread, the improvement over the meal containing 5 g guar in soup was smaller and not significant. However, when comparing the meals containing either 5 g guar gum in soup or 10 g guar gum with that containing 5 g guar gum in bread, the differences were more significant after the 10 g dose, suggesting that it may have had a more consistent effect.

It is of interest in the comparison of results with guar-gum-containing bread and soup that when guar gum was added to the soup there was an alteration in the pattern of the glucose and insulin responses with a delay in the peak increases. This might well have been due to more complete gastric mixing of the guar gum when given in the soup, resulting in guar gum entering the duodenum with the first part of the meal and so being present to delay the early absorption of carbohydrate. Another marker of slower absorption may well be the increase and its correlation with viscosity in the blood glucose concentration 2 h after glucose tolerance tests containing gel-forming dietary fibre (Jenkins *et al.* 1978). Progressive improvement in the ability to delay absorption after the meals containing 5 g guar gum in bread, soup, and both might therefore be reflected in the progressive increases in blood glucose levels which occurred 2 and 3 h after the respective meals, and may explain the apparent secondary peaks of blood glucose which are seen in Fig. 1.

Guar gum, although it is a gel-forming polysaccharide, is included under the broad heading of dietary fibre, being of plant origin and not digested in the human small intestine (Trowell *et al.* 1976). Other forms of dietary fibre have recently been used in the treatment of diabetes. High-carbohydrate, high-fibre diets consisting largely of unrefined cereals, legumes, and vegetables have been shown to allow withdrawal of insulin therapy in patients who previously had been maintained on low doses (Kiehm *et al.* 1976; Douglass & Rasgon, 1976). Addition of a fibre-enriched bread (largely as cellulose) resulted in a reduction in mean post-prandial blood sugar levels during the day (Miranda & Horwitz, 1977). Bread has, in both these instances, been the major 'vehicle' for addition of fibre to the diet and there is no doubt that if fibre is effective in this form, then bread provides a very versatile food in terms of transportation and meal formulation. The present results suggest that higher levels of fibre addition may be necessary for the gel-forming types of dietary fibre to be effective in bread than if given in a more hydrated form.

We conclude that addition of as little as 5 g guar gum may reduce the insulin and glucose response to a 45 g carbohydrate meal and that this effect is most marked when guar gum is given in hydrated form.

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