Use of xanthan gum in dietary management of diabetes mellitus

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ABSTRACT Xanthan gum (12 g/day) was fed in muffins during either the first or second half of a 12-wk period of muffin feeding, to free-living subjects. Nine subjects were diabetic, having moderately elevated serum glucose but managing without insulin or hypoglycemic drugs, and four were nondiabetic controls. Before the study and at the end of the xanthan and xanthan-free periods, bloods were taken before and 2 h after an oral glucose load. The feeding of xanthan gum lowered fasting and postload serum glucose and reduced fasting levels of total plasma cholesterol in diabetic subjects. Xanthan gum also tended to lower fasting and postload levels of gastrin and gastric inhibitory polypeptide (GIP) and fasting levels of total and VLDL triglyceride and cholesterol in VLDL and LDL fractions. Subjects reported a sense of fullness after consuming xanthan muffins but no severe digestive symptoms. Am J Clin Nutr 1985;42:597-603.

KEY WORDS Xanthan gum, fiber, diabetes mellitus, blood lipids, cholesterol, enteric hormones

Introduction

Considerable interest relates to the manner in which edible gums and other fibers may alter the chemical indications of diabetes (1-8). The chronic feeding of guar gum or of a high level of insoluble fiber lowers fasting levels of blood glucose (1-5), slows urinary excretion of glucose (2, 3, 5, 6, 7), and reduces requirements for exogenous insulin (3, 5, 8) in diabetics. These effects of edible gums have been attributed to the viscous nature of the gums (9, 10) and to a slowing of gastric emptying (11, 12) and of intestinal absorption (13, 14) of nutrients.

The consumption of edible gums also lowers serum cholesterol (2, 7, 15-17). These effects have been reported in both diabetic (1, 7) and nondiabetic (15-17) populations and are not direct measures of diabetic control. However, due to the high risk of cardiovascular disease in diabetics, gum effects on serum lipids in diabetic subjects are of special concern.

Xanthan gum, a biosynthetic edible gum of wide use, is produced under highly controlled conditions by a microorganism Xanthomonas campestris. It is an unusually pure and highly viscous gum, which is relatively resistant to bacterial breakdown and reproducible in its viscous properties from batch to batch (18). Like guar, xanthan gum has been reported to slow gastric emptying of glucose and nutrient energy in animals (19). It proved more effec-

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Received August 20, 1984.
Accepted for publication March 19, 1985.
tive than guar in inhibiting the preferential emptying of sugar vs fat from the stomach (20). Xanthan gum attenuated the hepatic lipogenic response in starved rats when they were again fed high-carbohydrate diets (21). Xanthan gum, like guar, appears to be a suitable candidate for metabolic studies in man.

The present study examined the acceptability of xanthan gum (contained in muffins) at a 12 g/day level in diets of diabetic and non-diabetic subjects. It examined further whether the feeding of xanthan gum in a free-living situation with little dietary control or counselling would affect various biochemical indices which were or might be related to diabetes mellitus.

Methods

Nine recently diagnosed borderline, type II diabetics (2 males and 7 females) were selected on the basis of a serum glucose of 105± mg/dl during fasting and/or of 140± mg/dl 2 h after an oral glucose load of 1 g/kg body weight. Four nondiabetic subjects (1 male and 3 females) were also included in the study. The mean and standard error of age were 53 ± 4.3 yr for the diabetic group and 36.5 ± 5.4 yr for the controls. Body weights were 83 ± 9.5 and 71 ± 3.9 kg, respectively, for the two groups. Five of the diabetic subjects and one control had been subjects on previous dietary studies. All were expected not to take any prescribed medicines during the 2 wk before and the 12 wk of the study.

The study protocol was approved by the Alcorn State University Committee on Protection of Human Rights. Informed consent of each subject was obtained.

The study consisted of two consecutive 6-wk periods in which subjects consumed either xanthan-containing muffins (XCM) or xanthan-free muffins (XFM). The daily dosage of the gum, when given, was 12 g, i.e., 2 g in each of six muffins. Five of the nine diabetic and two of the four control subjects received first the XCM and then the XFM, while the remaining six subjects received these two otherwise identical kinds of muffins in the reverse order. The muffins were to take the place of the bread group and were provided as a 3 or 4 day supply at a time. Subjects were instructed to consume at least two muffins at the main meal of the day and to eat the rest at other meals with other foods. Subjects were further instructed to eat the same variety of other foods and at the same meal frequency as was customary for them.

Each muffin contained 17.6 g carbohydrate, 6.7 g fat and 2.6 g protein for a total of 140 kcal of metabolizable energy. Xanthan gum, when added to muffins, is believed to have added little nutrient energy from products of bacterial decomposition in the colon (18) and to have little altered the nutrient mixture that was absorbed. A cursory analysis of dietary recall records and muffin composition data indicated that the overall diet of the subjects provided about 40% of the total metabolic energy from fat. Although the addition of muffins to the diet appeared to reduce somewhat the intake of protein, protein intake exceeded the recommended dietary allowance (22) by at least 30% for all subjects.

Prior to the study and near the end of wk 3, 6, 9 and 12, fasting bloods were taken in the morning. At each time except during wk 3 and 9, subjects consumed an oral glucose load of 1 g/kg body weight, and a postload blood was taken 2 h later. Sera were obtained from both fasting and postload bloods and analyzed for glucose, insulin, gastrin and gastric inhibitory polypeptide (GIP). Triglyceride and total cholesterol were determined in total plasma from fasting blood and were also determined in high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) fractions.

Analytical methods

Serum glucose was measured spectrophotometrically by a hexokinase/glucose-6-phosphate dehydrogenase method (23). Insulin, gastrin and GIP were measured by radioimmunoassay techniques (24–27). The antibody to porcine GIP used in this study displayed no cross-reactivity to 10 ng of motilin, natural porcine secretin, synthetic glucagon, synthetic human gastrin, highly purified cholecystokinin, or vasoactive intestinal peptide.

Lipids were determined by the Lipid Research Clinic methods (28). Plasma was prepared from bloods collected with ethylene diamine tetracacetate (EDTA), and lipoprotein fractions were obtained by ultracentrifugation. Triglycerides and total cholesterol were measured in whole plasma and in lipoprotein fractions with an Auto-Analyzer II (Technicon Instruments Corporation, Tarrytown, NY).

Statistical analysis

Student’s t test was used in evaluating apparent differences between pretest values for the diabetic and nondiabetic groups. In testing for effects of xanthan feeding, we calculated, for each diabetic or nondiabetic subject, the concentration difference at the end of the XCM versus XFM periods and determined whether the means of these paired differences were significantly different from zero.

Results

Subjects indicated no difficulty in consuming 12 g xanthan gum per day, even though the xanthan-containing muffins were somewhat gummy and chewy. Subjects did report an occasional feeling of unusual fullness after eating them, but no one complained of diarrhea or severe gastrointestinal distress.

Tables 1 and 2 summarized pretest data on the diabetic and nondiabetic groups. Diabetics had higher HDL cholesterol and tended to be heavier and to have higher fasting levels of VLDL and total triglycerides than the nondiabetics. The latter were, strictly speaking, not normal controls, being somewhat overweight and having high fasting insulin levels. Except for one diabetic subject with unusually high
serum gastrin, fasting and postload concentrations of insulin, gastrin and GIP were similar in the two groups.

The most striking effects of including gum in the muffins relate to serum glucose, as indicated by Figure 1. The inclusion of gum lowered fasting glucose within 3 wk and appeared to further lower these concentrations in a second 3-wk period. On reversing the kind of muffin fed, the reduction of glucose concentration disappeared in 3 wk and reappeared at the end of the second period. Postload glucose, as measured at the end of each 6-wk period, was also lowered by the prior feeding of xanthan gum.

In subsequent evaluations of possible gum effects, only the differences for each subject between values at the end of the XCM and XFM periods were considered, and the means of these differences were evaluated. By this criterion, the feeding of the xanthan gum lowered fasting and postload levels of serum glucose (Table 3) and total cholesterol in fasting plasma (Table 4) in diabetic subjects. Xanthan feeding tended to reduce fasting and postload concentrations of gastrin and GIP in this group (Table 3). Xanthan tended also to lower total and VLDL triglyceride and cholesterol in VLDL and LDL fractions and to increase the fraction of total cholesterol and triglyceride in the HDL fraction.

A main finding was that the feeding of xanthan gum for 3 or 6 wk induced a marked reduction in fasting serum glucose in diabetic subjects. After 6 wk, fasting glucose was nearly 40% lower than at the end of the period of eating xanthan-free muffins (XFM). A reduction in fasting glucose by guar has also been reported (1, 2, 7), but only among obese, insulin-resistant diabetics (1) was the degree of lowering as large as that reported here with xanthan gum.

**TABLE 1**
Pretest fasting and postload serum levels of glucose, insulin, gastrin and gastroinhibitory polypeptide (GIP) in diabetic and nondiabetic groups

<table>
<thead>
<tr>
<th>Components</th>
<th>Fasting sera</th>
<th>Postload sera</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diabetic group</td>
<td>Nondiabetic group</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>142 ± 7†</td>
<td>88 ± 3</td>
</tr>
<tr>
<td>Insulin (μU/ml)</td>
<td>60 ± 8</td>
<td>53 ± 10</td>
</tr>
<tr>
<td>Gastrin (pg/ml)</td>
<td>93 ± 39‡</td>
<td>53 ± 8</td>
</tr>
<tr>
<td>GIP (pg/ml)</td>
<td>593 ± 64</td>
<td>685 ± 88</td>
</tr>
</tbody>
</table>

* Mean ± SEM values are from nine diabetic and four nondiabetic subjects.
† Implies a difference from the nondiabetic group (p < 0.05).
‡ When the high values of one atypical subject are omitted, means become 55 (fasting) and 64 (postload) pg/ml.

**TABLE 2**
Pretest body weights and fasting levels of plasma lipids in diabetic and nondiabetic subjects

<table>
<thead>
<tr>
<th>Components</th>
<th>Diabetic group</th>
<th>Nondiabetic group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (kg)</td>
<td>83 ± 10</td>
<td>71 ± 4</td>
</tr>
<tr>
<td>VLDL Triglyceride (mg/dl)</td>
<td>62 ± 19</td>
<td>43 ± 14</td>
</tr>
<tr>
<td>LDL Triglyceride (mg/dl)</td>
<td>46 ± 7</td>
<td>37 ± 7</td>
</tr>
<tr>
<td>HDL Triglyceride (mg/dl)</td>
<td>16 ± 5</td>
<td>16 ± 3</td>
</tr>
<tr>
<td>Total Triglyceride (mg/dl)</td>
<td>124 ± 26</td>
<td>94 ± 9</td>
</tr>
<tr>
<td>% Total Triglyceride in HDL</td>
<td>15.0 ± 1.5</td>
<td>16.8 ± 3.1</td>
</tr>
<tr>
<td>VLDL Cholesterol (mg/dl)</td>
<td>16 ± 4</td>
<td>17 ± 4</td>
</tr>
<tr>
<td>LDL Cholesterol (mg/dl)</td>
<td>132 ± 11</td>
<td>133 ± 21</td>
</tr>
<tr>
<td>HDL Cholesterol (mg/dl)</td>
<td>54 ± 3*</td>
<td>42 ± 3</td>
</tr>
<tr>
<td>Total Cholesterol (mg/dl)</td>
<td>203 ± 11</td>
<td>193 ± 22</td>
</tr>
<tr>
<td>% Total Cholesterol in HDL</td>
<td>28.5 ± 2.5</td>
<td>22.6 ± 3.5</td>
</tr>
</tbody>
</table>

* Implies a difference from the nondiabetic (p < 0.05).
Prior feeding of xanthan gum reduced the 2-h postload concentration of serum glucose to a level (152 mg/dl) not far above normal limits. However, 2 h after the load meal, glucose levels were still elevated above fasting levels to a similar degree at the end of the xanthan-feeding and xanthan-free periods. This finding was not surprising. Stanik and Marcus (29) have reported that weight reduction of severely hyperglycemic obese patients lowered their fasting blood glucose dramatically but did not significantly modify the prolonged and exaggerated rise in blood glucose after an oral glucose meal. It appears likely that the 6-wk feeding of xanthan gum lowered the glucose tolerance curve but did not appreciably affect its shape.

The consumption of xanthan gum reduced total circulating cholesterol concentration, apparently in the LDL and VLDL fractions but not in the HDL. Guar has been reported also to lower cholesterol, especially in the LDL.

| TABLE 3 |
| Effect of xanthan feeding on fasting and postload serum levels of glucose and hormones in the diabetic group |
| Components | From fused subjects previously fed | From postload subjects previously fed |
| --------- | ------------------ | ------------------ |------------------ |------------------ |------------------ |
| Glucose (mg/dl) | XCM* 93 ± 10 | XFM* 149 ± 13 | Δ ± SEM # 56 ± 1 | XCM* 152 ± 29 | XFM* 221 ± 29 | Δ ± SEM # -69 ± 25 |
| Insulin (µU/ml) | 40 ± 11 | 42 ± 9 | -2 ± 11 | 81 ± 27 | 87 ± 28 | -5 ± 8 |
| Gastrin (pg/ml) | 85 ± 47 | 121 ± 68 | -35 ± 21 | 103 ± 56 | 128 ± 71 | -25 ± 17 |
| GIP (pg/ml) | 722 ± 114 | 791 ± 120 | -69 ± 99 | 1347 ± 167 | 1511 ± 238 | -164 ± 224 |

* XCM and XFM are xanthan-containing and xanthan-free muffins, respectively.
† Mean ± SEM of difference in serum level at end of XCM and XFM periods, for each of nine subjects.
‡ p < 0.05.
The effects of xanthan gum among diabetic subjects appear to be qualitatively similar to those of guar gum. However, guar and other gums do not reduce serum triglycerides (2, 7, 15-17), although some kinds of insoluble fiber have this effect (3, 4, 30). It will be of interest to note whether the trend toward a lowering of plasma triglyceride by xanthan gum is or is not supported by further studies.

When it became evident that guar gum slows the digestive processing of dietary carbohydrate and is useful in at least the short-term control of diabetes, the concept of lente or slow-release carbohydrate was put forth (5, 31). Other methods of slowing the digestive processing of carbohydrate besides the feeding of edible gums are now recognized (5, 31). Cell wall components of plant foods may resist the mechanical trituration necessary for the passage of chyle through the pyloric sphincter and may hinder contact between amylases and starch granules. Carbohydrate may also be fed in coarse particles (32, 33) and as starches that are relatively inaccessible or resistant to enzymatic hydrolysis when eaten in minimally processed foods, ie, rice (31, 34). Amylase or glucosidase inhibitors, eg, acarbose, may also be fed with starch or sucrose to slow their subsequent hydrolysis in the small intestine (35).

The feeding of gums or lente carbohydrate is known to alter gastrointestinal physiology in ways which may contribute to diabetic control. Edible gums may slow gastric emptying (11, 12, 19). They may impede mixing of intestinal contents, thus restricting the access of food to hydrolytic enzymes and particularly to intestinal glucosidases (36). A reduced lateral mixing of nutrients and a thickening of the unstirred layer slow absorption (13, 14). Nutrients may travel further in the small intestine before being absorbed; and the secretion of GIP (37) and of enteroglucagon (37, 38) are reduced. The inclusion of edible gums in a liquid meal reduces the rise in serum glucose and insulin (5, 9, 10, 39). The chronic feeding of gums may lower the average blood glucose level and reduce the urinary excretion of glucose, to the point that exogenous insulin injection may have to be reduced (5, 8). It is suspected that a period of good control of blood glucose may enhance the response of pancreatic beta-cells to elevated blood glucose (29). Clearly, the causal chain of events leading from the feeding of gum to improved diabetic control is complex and not well understood.
Xanthan gum proved to be well tolerated at a 12 g/day level for a 6-wk period. It remains to be determined whether xanthan gum will be well tolerated for longer periods of heavy use. The possibility exists that xanthan may interfere with the absorption of some critical micronutrients, although the chemical structure of the gum (40) does not appear to provide any special reason for this concern. Concern relates also to histological changes in the intestinal mucosa which may be mostly benign but have been reported for other gums in animal studies (41, 42).

A principal advantage of xanthan over guar gum is its greater purity. Its resistance to bacterial decomposition of the gum in the small or large intestine (18). The addition of xanthan gum to a control diet allows one to study effects of lente carbohydrate without appreciably altering the net uptake of other nutrients (18). We visualize xanthan gum as a promising tool for exploring the metabolic sequence of lente carbohydrate in both human and animal studies.

Our data suggest also that xanthan gum may prove useful in the initial treatment of newly diagnosed diabetes mellitus.

The authors thank Dr JB Collins and Dr Elisa Lee, respectively, for providing administrative and statistical assistance.

References