Effect of glucomannan (konjac fiber) on glucose and lipid metabolism in normal and diabetic subjects

KUNIHIRO DOI, MASAAKI MATSUURA, AKIRA KAWARA, RINZO UENOYAMA and SHIGEAKI BABA

Kobe University School of Medicine, Kobe, Japan

Epidemiological observations have suggested that diabetes, hyperlipidemia, coronary heart disease and colon cancer might be related to insufficient intake of dietary fiber (Burkitt, 1978; Trowell, 1976). As a result, much interest has been shown in the possibility of treating diabetics with fiber-rich diets (Doi et al., 1979).

Conflicting results have been reported concerning the effects of dietary fibers. Jenkins et al. (1977, 1978) showed that, when a gel-forming, unabsorbable carbohydrate – guar gum or pectin – was added to test meals, the postprandial blood glucose curve was flattened in both normal and diabetic subjects. However, Williams and coworkers (1980) reported that, when they compared the effects of guar gum and pectin taken in both gelled and non-gelled forms, these fibers had no effect on the postprandial blood glucose curves of diabetics. (Guar gum, or galactomannan, consists of galactose and mannose in the molar ratio of 1:2.)

The purpose of the present study was to clarify the effects of konjac mannan (glucomannan dietary fiber), taken in gelled or non-gelled form as a supplement to glucose or test meals, on glucose and lipid metabolism in normal and diabetic subjects. Glucomannan, an unabsorbable polysaccharide prepared from tubers of the Amorphophallus konjac plant, is composed of glucose and mannose (molar ratio 1:1.6) (Maeda et al., 1980). In Japan, crude konjac mannan in an alkalinized, gelled form, is a traditional foodstuff eaten as a normal part of the diet.

MATERIAL AND METHODS

A number of tests of the effects of dietary fibers were performed on 24 normal and 21 diabetic subjects. In all cases, unless otherwise mentioned, 3.9 g of dietary fiber was administered and the glucomannan used was of a type other than the most viscous, its viscosity being about 100,000-150,000 c.p.s. However, in an experiment examining differences of viscosity, other types such as 52,000 c.p.s. and 194,800 c.p.s. glucomannan were tested. The dietary fiber was given to the subject after 12 hours' fasting, either 15 min before a load of glucose or a test meal or together with it, either in powdered or in dissolved and gelled form. Venous blood samples were drawn from the antecubital vein in the fasted state and 30, 60, 90, 120, and 180 min after a load.

The following items were tested: (1) effects of glucomannan on glucose tolerance; (2)

effects of glucomannan on blood glucose and serum insulin levels after a 646-calorie test meal; (3) difference in viscosity between glucomannan and guar gum; (4) effects of glucomannan of different viscosities on blood glucose level after the test meal; (5) effects of glucomannan on xylose absorption; (6) effects of glucomannan on bile acids; and (7) effects of glucomannan on blood glucose and serum cholesterol in clinical tests on diabetics.

Blood glucose was determined using Hoffman's auto-analyzer method and serum insulin by a modification of the double-antibody technique. Plasma cholesterol and triglyceride determinations were performed with commercially available enzyme methods (Nihon Shòji, Japan). Serum bile acid was measured by high-performance liquid chromatography (Baba et al., 1980). The results are expressed as mean plus or minus standard error of mean and the significance calculated by Student's t test for paired data.

RESULTS

Effects of glucomannan on glucose tolerance

Although the usual amount of fiber given in the studies by Jenkins et al. (1978) and Williams et al. (1980) was between 8 and 15 g per test meal, in the present study, only a relatively small amount of glucomannan (generally 3.9 g) was used. The reason for the limitation of the amount of glucomannan was that our Japanese patients, physically smaller than westerners, complained of abdominal pain, diarrhea or other problems when they were given amounts over 5.2 g.

Guar gum had so far been found to be the most effective of the dietary fibers in reducing postprandial blood glucose levels and glycosuria. We therefore compared the effects of glucomannan and guar gum on glucose tolerance. The supplements in all cases were given in their powdered forms 15 min before the oral glucose load. The mean blood glucose levels of the subjects receiving glucomannan supplements were significantly reduced below those of the controls at 90 min (85.9 ± 4.9 mg/dl compared with 112.2 ± 11.7 mg/dl, mean ± SE, $p < 0.05$). On the other hand, there was no significant reduction of the blood glucose level in those subjects who took guar gum (or in others who were given only 2.6 g of glucomannan).

Effects of glucomannan on blood glucose and serum insulin levels after test meal ingestion

When 3.9 g of glucomannan was given in gelled form to 7 normal subjects 15 min before test meals, the mean blood glucose levels were significantly reduced below those of the controls at 30 min (104.4 ± 4.3 mg/dl compared with 131.1 ± 3.9 mg/dl, $p < 0.005$) and 180 min (100.9 ± 5.1 mg/dl compared with 119.4 ± 3.3 mg/dl, $p < 0.005$); but the mean insulin levels were not significantly reduced (Fig. 1A).

When glucomannan was mixed into the test meals, the mean blood glucose levels were significantly reduced below those of the controls. The blood glucose level in each test subject was lower than in the controls at 30, 60, 120 and 180 min. Serum insulin levels were also significantly below the control levels at 30, 60 and 90 min (Fig. 1B).

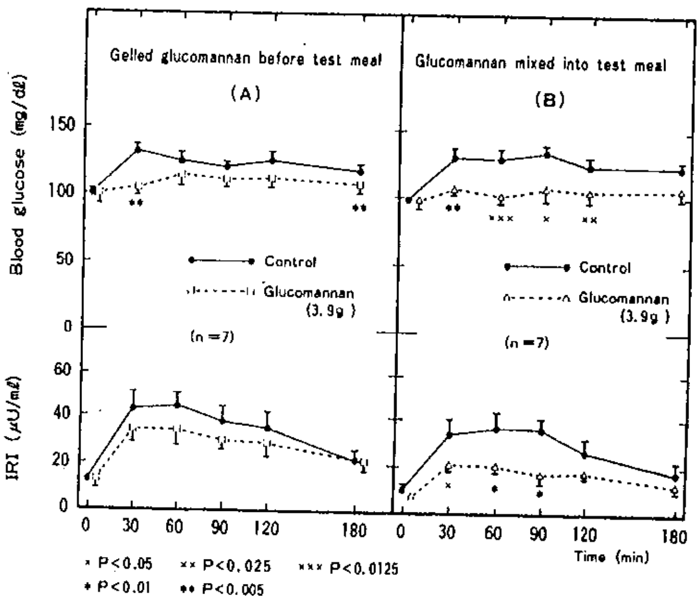


FIG. 1 *Effects of glucomannan on blood glucose and serum insulin levels of normal subjects after test meals.*

After glucomannan was mixed into test meals given to 6 non-insulin-dependent diabetics, the mean blood glucose levels were significantly below those of the normal control subjects at 30 and 60 min (Fig. 2C). However, when guar gum was given in the same way as glucomannan, no significant reduction was seen in the mean blood glucose levels during the period of observation (Fig. 2D).

Effects of glucomannan of different viscosities on blood glucose level after test meal ingestion

It has been suggested that the viscosity of the fiber within the gastrointestinal tract may be an important factor in flattening the curves of glucose tolerance or postprandial blood glucose levels.

Firstly, the viscosities of three kinds of fibers were examined. The viscosity of 1% highly purified glucomannan solution (Shimizu Chemical Industries Co. Ltd.) reached 194,800 c.p.s., whereas those of 1% guar gum solution (Kodama K.K.) and 3% pectin (apple) solution (Wako K.K.) were only 7,700 c.p.s. and 2,420 c.p.s., resp., measured with a B-type viscometer at 25°C, 5 hr after dissolution in water. The viscosity of glucomannan is not only by far the highest of the 3, but also by far the most persistent. An examination of the effects of differences in viscosity using 2 types of glucomannan,

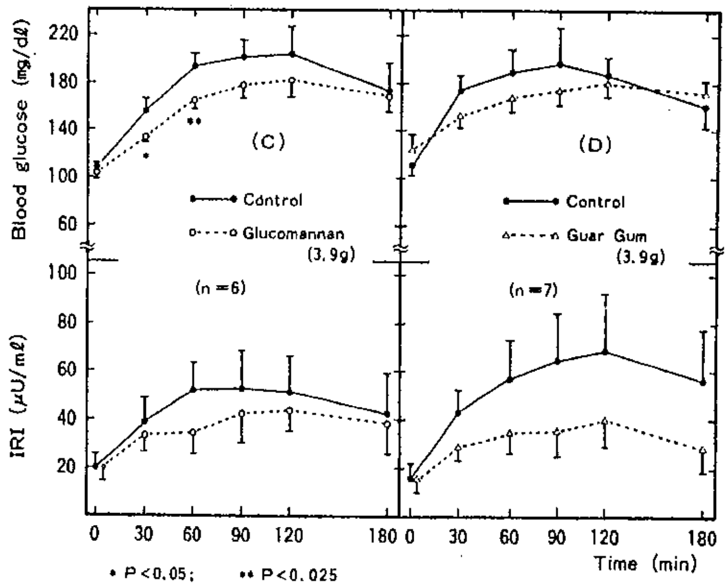
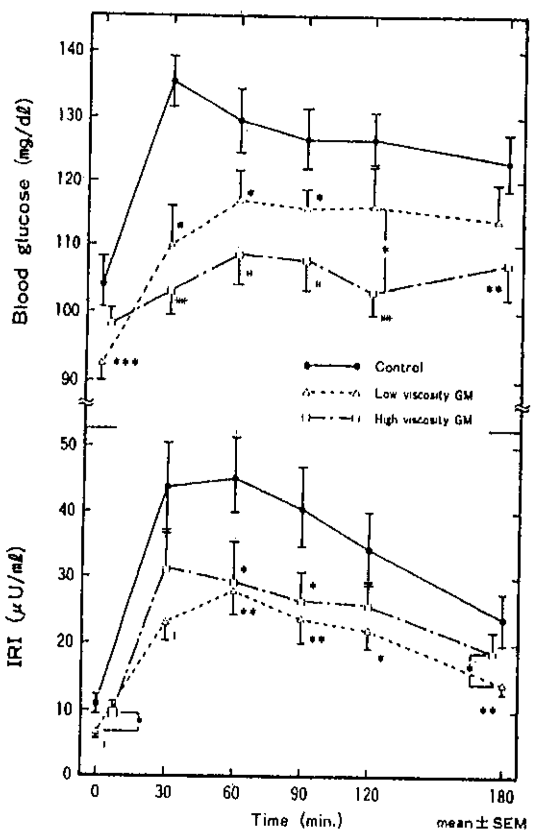


FIG. 2 *Effects of glucomannan and guar gum on blood glucose and serum insulin levels of diabetic subjects after test meals.*

was then made. When highly purified high-viscosity (194,800 c.p.s.) glucomannan was added to test meals and given to 9 normal subjects, no significant rise of the mean postprandial blood glucose levels was seen during the period of observation (Fig. 3). Moreover, these levels were significantly below the control at every point measured. On the other hand, when low-viscosity glucomannan (55,000 c.p.s.) was added to test meals and given to the same 9 subjects, the mean rise of the postprandial glucose level was 25.8% at 60 min, but this was almost the same as that of the control (23.5%) at 30 min. Thus, in this case, low-viscosity glucomannan merely delayed the rise, but high-viscosity glucomannan was far more effective in bringing about its suppression.

Effects of glucomannan on xylose absorption

It is believed that viscous forms of dietary fiber prolong the time required for absorption, and reduce the postprandial rise of glucose, rather than causing malabsorption. A xylose absorption test was performed on 5 normal subjects to check for malabsorption. The excretion of xylose in the urine was measured during a 2-hr glucose tolerance test in which 25 g of xylose was administered together with 50 g of glucose. A significant decrease in 2-hr urinary xylose excretion was observed with 3.9 g of glucomannan ($p < 0.025$). However, urine collection was continued for 6 hr, and the total excretion of xylose was the same in both control and glucomannan subjects. It thus appears that



*$p < 0.05$; **$p < 0.025$; ***$p < 0.0125$; †$p < 0.01$; ††$p < 0.005$; ‡$p < 0.0025$;
‡‡$p < 0.0005$.

FIG. 3 *Changes of postprandial blood glucose and serum insulin levels in normal subjects after test meals with or without glucomannan (GM) of low or high viscosity*

glucomannan reduces the postprandial rise of glucose levels by the same mechanism as guar gum (Jenkins et al., 1978).

Effects of glucomannan on bile acids

When the secretion of bile acids was endogenously stimulated with egg yolk, the levels in the serum were increased, but when glucomannan was taken 15 min before the egg yolk load, these rises were reduced, and in the case of glucochenodeoxycholic acid, the rise was especially suppressed.

Clinical use of glucomannan

When 21 diabetic patients had their metabolic ward diets supplement with 7.2 g of glucomannan daily for 17 days, their mean fasting blood glucose level was significantly lowered for the entire period ($p < 0.025$) (Fig. 4). The mean serum cholesterol level was observed for 90 days, and was seen to fall significantly for the first 38 days ($p < 0.05$), and then rose gradually. HDL-cholesterol and triglyceride levels, however, were not affected.

In some patients, the dosages of insulin or hypoglycemic agents were reduced.

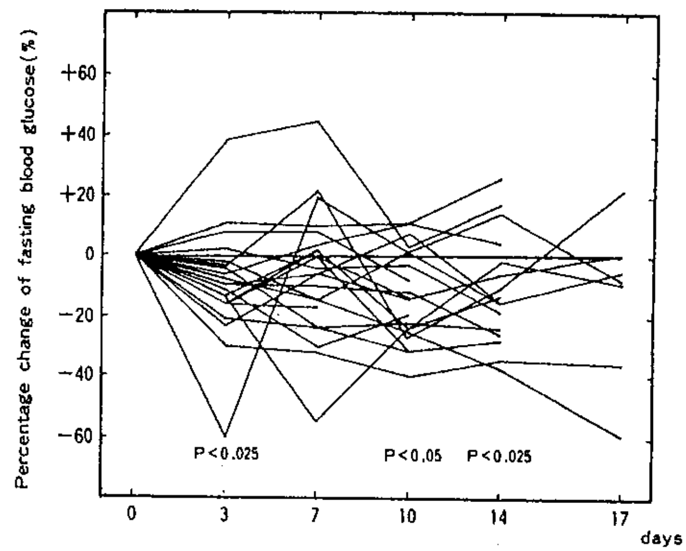


FIG. 4 *Percentage changes in fasting blood glucose levels with glucomannan supplements.*

CONCLUSION

Recently, dietary fibers have been used successfully to allow the use of lower dosages of insulin or hypoglycemic agents in the treatment of diabetics. These fibers are considered to increase the viscosity of the gastrointestinal contents, thus slowing gastric emptying and forming around the food a barrier that delays its absorption by the intestinal wall (Jenkins et al., 1978). Their viscosity appears to be a major factor in eventually suppressing, through this mechanism, the postprandial rise of the blood glucose level.

Guar gum (galactomannan), since it was thought to be the most viscous of the dietary fibers, was regarded as the most effective in reducing hyperglycemia. However, our data show that the viscosity of glucomannan is far higher than that of any other fibers. The suppression by glucomannan of the postprandial rise of glucose and insulin levels was more pronounced than that by guar gum when added to the glucose solution or test meal, and most pronounced when glucomannan was mixed into the test meal. Although the amount of glucomannan used in this experiment was rather small, the results were good. Some of the reasons for this have yet to be clarified, but one factor is its very high viscosity. Moreover, its ability to absorb carbohydrates, lipids and other high-calorie substances in the stomach and the small intestine is the greatest among all the dietary fibers.

The serum levels of cholesterol and bile acids decreased when glucomannan was used, but after 1 or 2 months, the serum cholesterol levels increased for a short time. One possible explanation of this phenomenon is that the enterohepatic circulation of the bile acids and cholesterol was interrupted by the absorption of these substances in the intestine by glucomannan, which was followed by a decrease in their serum levels. As a homeostatic response, then, the production of cholesterol in the liver may have increased for a short period.

We did not observe the serum bile acid levels over a long period, but it is presumed that, as with cholesterol, they also increased for a while 2 or 3 months after glucomannan was taken, and then fell again.

Serum Cu^{++}, Fe^{++}, Na^{+}, K^{+} and Cl^{-} levels of 6 diabetics were followed, but no significant increase or decrease was observed.

The postprandial blood glucose concentrations were lower when the subjects were fed fiber-supplemented diets, and in some of them, also the body weight decreased. There were some complaints of short-lived side effects such as nausea and discomfort when larger doses of glucomannan were given.

The effects of dietary fibers on glucose metabolism may be useful in the control of the diet and of the drug dosage of diabetics, especially for non-insulin-dependent diabetics or obese subjects. Further study is necessary in order to discover the metabolic and physiological effects of these viscous forms of dietary fiber.

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