

## Influence of Partially Hydrolyzed Guar Gum on Constipation in Women

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**Summary** A partially hydrolyzed guar gum preparation (PHGG, average molecular weight: 20,000), obtained as a water-soluble dietary fiber by digestion of guar gum with  $\beta$ -D-endomannanase, was administered as a beverage (11 g a day, bid) to 15 constipated women for 3 weeks. Defecating frequency, pH, weight, moisture, and bacterial flora of the feces were investigated and compared with the control periods. Average total dietary fiber taken from food was  $9.7 \pm 0.1$  g/day during the experiment. PHGG caused an increase in the defecating frequency from  $0.46 \pm 0.05$  (frequency/day,  $M \pm SE$ ) to  $0.63 \pm 0.05$ . Fecal moisture significantly increased from 69.1% in the control period to 73.8% by ingestion of PHGG. Fecal moisture content also increased consistent with lowering the pH of feces ( $r = -0.478$ ). The frequency of *Lactobacillus* spp. occurrence in feces significantly increased ( $p < 0.05$ ) compared with the control period. These results clearly indicate that PHGG softens and improves the output of feces.

**Key Words** partially hydrolyzed guar gum (PHGG), water-soluble dietary fiber, constipation, defecating frequency, women, fecal pH, fecal moisture, *Lactobacillus* spp.

Constipation was one of the first symptoms to be classified as a fiber deficiency disorder. Dietary fiber has been shown to improve fecal bulk and consistency and to increase intestinal motility. The average fecal weights of people taking high protein diets has been reported in the order of 100 g/day while that of people ingesting a high carbohydrate and high fiber diet is 300 g/day (1). For relief of constipation, it has been suggested that feces output should be 150 g/day as a

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therapeutic goal (2). Bacterial cells normally contain 80% water (3), the effect of fiber on fecal bulk is considered to be related not only with water-holding capacity, but also with stimulation of bacterial growth (4). The fecal bulk and laxation of defecation varies, however, with the kind of fiber.

Guar gum (GG), a galactomannan derived from the cluster bean of *Cyamopsis tetragonolobus* which is cultivated in India, Pakistan, and the United States, has been shown to be effective in the treatment of hyperlipidemia (5) and post-prandial glycemia of diabetes (6). It has been reported that intake of 20 g guar gum a day increases the fecal weight of healthy volunteers by 20% (7). In another study, however, intake of 11.4 g guar gum a day resulted in no increase in the fecal weight (8).

The molecular weight and viscosity of partially hydrolyzed guar gum (PHGG) used in our study were much less than those of intact guar gum, and administration of 36 g of PHGG per day to healthy volunteers resulted in an increase of fecal volume up to 42% (9). Few papers so far have dealt with the effects of water-soluble dietary fiber on fecal volume, pH, moisture, and bacteria of constipated subjects.

It has been reported that the defecating frequency of constipated individuals increases by the daily ingestion of 7.2 g psyllium (10). In the present study, the effect of PHGG on constipated women was examined using 11 g PHGG per day.

#### MATERIALS AND METHODS

**Fiber material.** Sunfiber 55 (Taiyo Kagaku Co. Ltd., Japan) was used in the present investigation. One pack of Sunfiber 55 consisted of 5.5 g partially hydrolyzed guar gum (PHGG), 1.5 g sucrose, 0.45 g strawberry broth, and 0.05 g citric acid. Its water-soluble dietary fiber content was 4.2 g which was analyzed by using the gravimetric method after hydrolysis with Termamyl (120L, Novo, Denmark), proteinase (No. P-5380, Sigma, USA), and amyloglucosidase (No. A-3042, Sigma, USA) (11). Partially hydrolyzed guar gum was manufactured by a partial hydrolysis of guar gum with  $\beta$ -D-endomannanase isolated from *Aspergillus niger* (12). Its average molecular weight was 20,000, as determined by gel filtration HPLC using a G3000PW column (7.8 $\times$ 300 mm, Tosoh Co., Tokyo, Japan). Pullulan, having molecular weights of 5,800, 12,200, 23,700, and 48,000, was used as a size marker (Shodex standard P-82, Showa Denko Co., Tokyo, Japan). A 28-day oral toxicity study of PHGG (500 and 2,500 g/kg) in rats was performed. No abnormal change was observed in their general condition, body weight, food consumption, organ weight, urinalysis, ophthalmologic examination, hematological test, blood biochemistry tests, necropsis, or pathological examination (data not shown). Administration of PHGG for 4 weeks to adult men at the dose of 36 g/day resulted in no side effects except for slight flatulence detected in the beginning of intake of PHGG (9).

**Subjects and diets.** Fifteen women suffering from constipation, 18 to 48

( $28.7 \pm 3.1$ ) years of age, weighing  $50.3 \pm 1.8$  ( $M \pm SEM$ ) kg, who were members and families of our company (Taiyo Kagaku Co. Ltd., Japan), were selected as volunteers for a 9-week study. Subjects commonly felt considerable discomfort before movements as excretion was usually unexpected and they suffered abdominal pain and their fecal output were usually below 3 days a week. An examination was performed according to the ethical standards described in the Declaration of Helsinki in 1975. This project was approved by the Human Subject Ethical Committee of the Taiyo Kagaku Co. Ltd. Informed consent was obtained from each subject after the purpose and procedures of the project were explained. Volunteers maintained their regular diets ad libitum during the experimental period with the exception of laxatives, other fiber drinks, yogurts, or fermented soybeans. Quantity and content of all meals eaten by each subject were recorded in detail. The 9-week examination period was divided into three periods of 3 weeks each. The first (C1) and third (C2) examination periods of each experimental periods were designated as control periods. During the second examination period (PHGG), subjects took PHGG preparation dissolved in adequate amounts of water (70–100 ml) as a beverage twice a day after meals. Water-soluble and -insoluble dietary fiber content in the diets were calculated based on the Standard Tables of Food Composition in Japan, —Dietary Fiber— (Table 1).

*Analysis.* Feces of the subjects were collected twice during the third week of each period (C1, PHGG, and C2), in plastic air-free bags and kept at  $4^{\circ}\text{C}$ . After weighing, fecal pH values were directly measured by inserting a glass electrode (Horiba, Tokyo) into fecal specimens. Bacteriological analysis of the feces was carried out according to the method described by Mitsuoka et al. (13). After thoroughly mixing fecal specimens, a serial dilution ( $10^{-1}$  to  $10^{-8}$ ) was made using an anaerobic diluent. Aliquots of the diluted samples were taken and spread onto four lactobacilli-selective agar plates, and incubated at  $37^{\circ}\text{C}$  for 2 days. The water content of the feces was determined by lyophilizing 10 g of fresh feces.

*Colonic function.* Subjects recorded stool frequency, occurrence of abdominal pain, flatulence, and full emptying sensation daily.

*Statistical analysis.* Student's *t*-test was applied to analyze all parameters except the frequency of bacteria occurrence which was analyzed by Fisher's exact probability test.

## RESULTS

As shown in Table 1, the daily fiber intake of the subjects during the C1, PHGG, and C2 periods of this study were  $9.7 \pm 0.2$ ,  $17.4 \pm 0.1$ , and  $10.1 \pm 0.1$  g, respectively. The daily intake during the PHGG period of the present investigation was considered to provide  $10.4 \pm 0.1$  g per 1,000 kcal of given diet.

Figure 1 shows the effect of PHGG intake on the defecation of the constipated women for each week. The average defecating frequency of the constipated subjects was  $0.46 \pm 0.03$  times per day during the C1 period. There was an increase

Table 1. Daily intake of total dietary fiber (TDF) in each period.

	Periods		
	C1	PHGG	C2
DF intake from diets (g/day)	9.2±0.1	9.2±0.1	10.1±0.1
DF in PHGG <sup>1</sup> (g/day)		8.2 <sup>2</sup>	
TDF intake (g/day)	9.7±0.2	17.4±0.1	10.1±0.1
Energy intake <sup>3</sup> (kcal/day)	1,642±16	1,667±18	1,688±21
TDF intake (g/1,000 kcal/day)	5.9±0.1	10.4±0.1	6.0±0.1

The values indicated were calculated from the Standard Tables of Food Composition in Japan, 4th edition and —Dietary Fiber—, Resources Council, Science and Technology Agency, Japan. The values are daily  $M \pm SEM$ . <sup>1</sup>Partially hydrolyzed guar gum. <sup>2</sup>Water-soluble dietary fiber containing in PHGG determined by the method of Prosky et al. (11). <sup>3</sup>PHGG was calculated as to be 2.4 kcal/g (25).

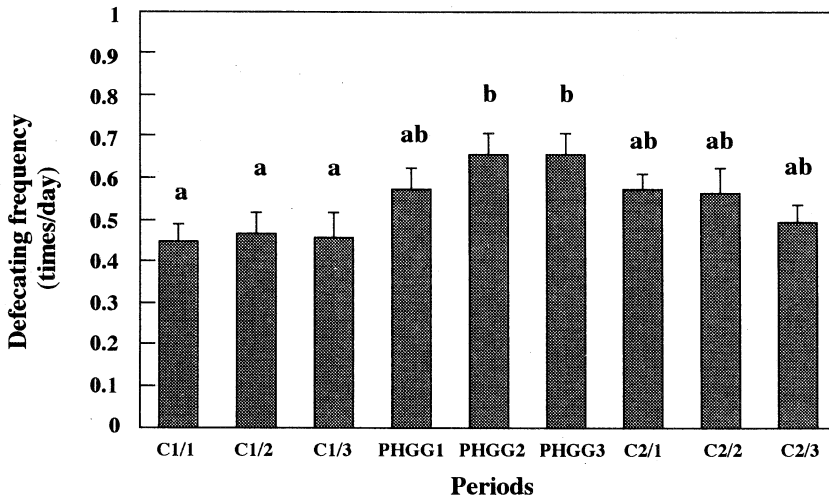


Fig. 1. Effect of intake of partially hydrolyzed guar gum on defecation of each week in constipated women. Each point in the  $M \pm SEM$ . Different superscript letters indicate significant differences between each week ( $p < 0.05$ ). C1/1, C1 period, 1st week; PHGG1, PHGG period, 1st week.

in defecating frequency during the 2nd and 3rd weeks of the PHGG period and the average frequency was  $0.66 \pm 0.05$  times per day. Shifting the test stage to the C2 period returned the frequency to  $0.52 \pm 0.04$  times per day.

Table 2 shows the changes in fecal pH, weight, and moisture during each period. The fecal pH value of the C1 period was  $6.9 \pm 0.1$ , but lowered to  $6.4 \pm 0.1$  in the 3rd week of the PHGG period. At the end of the C2 period, the value returned to  $6.7 \pm 0.1$ . No significant difference in the fecal wet and dry weight was observed over the three periods. Fecal moisture increased ( $p < 0.05$ ) from  $69.1 \pm$

Table 2. Effects of intake of partially hydrolyzed guar gum on fecal pH, weight, and moisture.

	Periods					
	C1/3/1 <sup>1</sup>	C1/3/2	PHGG3/1 <sup>2</sup>	PHGG3/2	C2/3/1	C2/3/2
Sample number	15	12	15	12	15	11
pH	6.87±0.09 <sup>a*</sup>	6.91±0.13 <sup>a</sup>	6.42±0.13 <sup>bc</sup>	6.36±0.15 <sup>b</sup>	6.66±0.09 <sup>ab</sup>	6.79±0.13 <sup>ac</sup>
Wet weight (g/sample)	90.4±10.6	87.3±5.9	103.7±10.1	104.4±10.5	92.9±6.1	85.0±11.8
Dry weight (g/sample)	27.7±3.0	27.2±1.8	27.0±2.4	26.4±2.1	26.4±2.5	26.5±2.7
Moisture (%)	70.0±1.4 <sup>ab</sup>	68.1±1.5 <sup>a</sup>	73.5±1.0 <sup>bc</sup>	74.1±1.0 <sup>c</sup>	71.5±1.3 <sup>ac</sup>	71.0±1.5 <sup>ac</sup>

The values are daily  $M \pm SEM$ . <sup>1</sup>C1 period, 3rd week, first collection. <sup>2</sup>PHGG period, 3rd week, first collection. \*Means not sharing a common superscript letter within the same row are significantly different at  $p < 0.05$ .

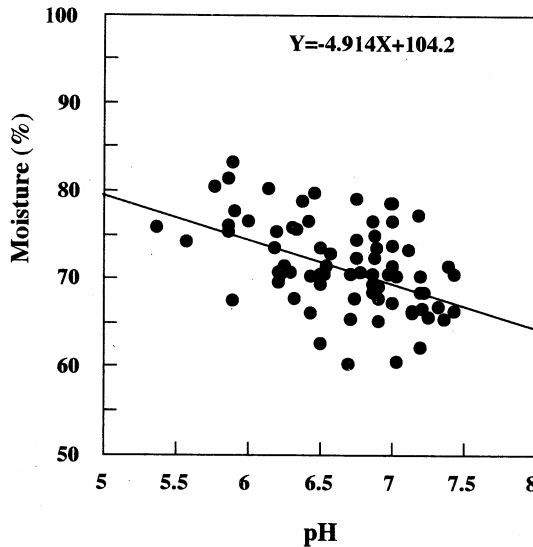


Fig. 2. Relationship between fecal pH and moisture. The data represent the results obtained during the entire experiment periods.

1.0 (C1) to  $73.8 \pm 0.7\%$  (PHGG), and subsequently decreased to  $71.3 \pm 1.0\%$  at the end of the C2 period.

The relationship between the pH and moisture content of feces during each period is shown in Fig. 2. A significant inverse correlation between fecal pH and moisture during the experimental period was observed ( $r = -0.478$ ,  $p < 0.05$ ).

The frequency of *Lactobacillus* spp. occurrence in feces was also investigated

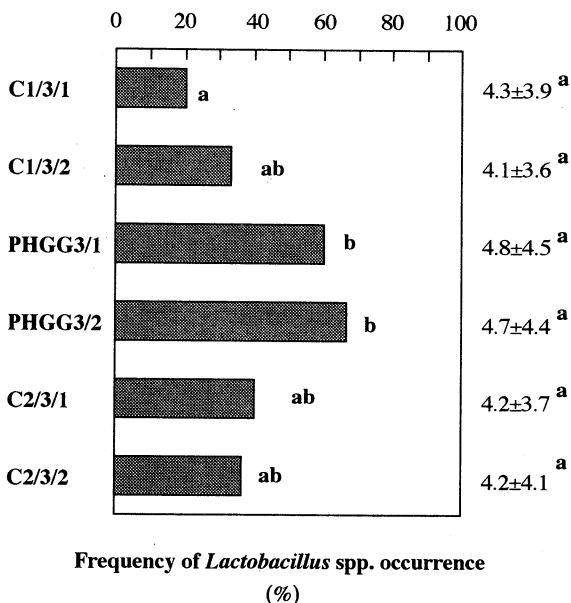


Fig. 3. Effect of intake of partially hydrolyzed guar gum on the frequency of *Lactobacillus* spp. occurrence and cell count in feces. Numbers on the right indicate the cell number of *Lactobacillus* spp. (log/g wet feces). The values are  $M \pm SEM$ . Different letters on the right of the columns indicate significant differences ( $p < 0.05$ ). C1/3/1, C1 period, 3rd week, first collection.

as shown in Fig. 3. It was observed that the frequency of *Lactobacillus* spp. occurrence in feces was 20 (1st collection) or 33% (2nd collection) in the C1 period, but increased to 60 or 67% at the 3rd week of the PHGG period. At the 3rd week of the C2 period, this frequency was found to decrease to 40 or 36%. The average cell number of *Lactobacillus* spp., however, in the feces was essentially unchanged.

#### DISCUSSION

Constipation is defined as a symptom of hard feces, which causes difficulty of output due to delayed fecal transit time (14). Constipation occurs when there is no fecal output for 3–4 days and followed by a sensation of pain. In this experiment, subjects commonly felt considerable discomfort before movements, suffered abdominal pain and their fecal output occurred on an average of 2.8 days per week.

A diet rich in plant fiber is considered to be an effective prevention from diseases such as constipation. It has been reported that intake of dietary fiber of 20–35 g/day in the United States (15) and 30 g/day in the United Kingdom (16) is recommended. The daily allowance of total dietary fiber for the average Japanese

has been indicated to be 10–12 g per 1,000 kcal of the diet (17). Therefore, the intake of dietary fiber by the subjects who participated in the present study was only 10 g/day during the control periods.

It has been reported that the increase in fecal weight by dietary fiber improves defecation (18). Favorable defecation stimulates the motor function of the gut as the fecal bulk and transit time appear to be inversely related (19). The effect of fiber intake on fecal bulk has been reported to be related not only with the water-holding capacity of the surviving residue, but also to stimulation of bacterial growth (4). Gel-forming dietary fibers, such as guar gum and pectin, may be effective in increasing the water-holding capacity. These gums are known to hold water ten times their weight (20) and may lead to an increase in fecal bulking action. This property of gums may be true only for the fiber residue left after bacterial fermentation in the colon. It is known, however, that guar gum administered in an amount of 18.2 g/day is completely fermented (21). Even after administration of 36 g of PHGG, the increase of the residual dietary fiber in feces was only 6 g (9). In light of this fact, the increase in fecal bulk was thought to be due to factors other than the water-holding capacity of PHGG. Partially Hydrolyzed Guar Gum is a fermentable material in the colon. Stephen and Cummings (3, 4) reported that bacterial cell mass usually contains 80% water which represents the major fraction of total fecal volume. It was thus suggested that the increase of fecal moisture from 69 to 74% by ingestion of PHGG might be due substantially to an increase in bacterial cell mass. The increase of fecal moisture by PHGG may lead to an increase in the frequency of defecation. The fecal wet and dry weight per day, however, remained essentially unchanged during the experimental periods. In the present study, feces were collected twice from each subject in each period. A long-term and more frequent collection of feces may be recommended to obtain well-defined results.

In the present study, a correlation between fecal pH and moisture was found. Additionally, the frequency of *Lactobacillus* spp. occurrence in the feces of the subjects was increased by the ingestion of PHGG. Short-chain fatty acids produced by fermentation of PHGG seems to be responsible for the lowering of fecal pH (13). Lowering pH in the large intestine may lead to the stimulation of *Lactobacillus* spp. growth, as these bacteria are known to grow at a lower pH than those for other intestinal bacteria (22). In the present investigation, however, the average number of *Lactobacillus* spp. in the feces remained essentially unchanged. Therefore, the observed increase in fecal moisture at a low pH may be due to the growth of bacteria other than *Lactobacillus* spp., since low pH conditions induce the growth of such strains (23). Various other effects of PHGG intake on human intestinal microflora are under study in detail and the results will be published elsewhere.

The daily impressions of the subjects themselves during the experimental periods were also recorded. The frequency of the sense of abdominal pain was almost unchanged during any period. The sense of flatulence was markedly

increased by the intake of PHGG. The flatulence, however, gradually decreased at the 2nd and 3rd week of the PHGG period. Full emptying sensation after excretion was obvious among all subjects, indicating improvement in output and a promising cure for constipation with the PHGG intake. We assumed that these phenomena were due to the increase of fecal moisture and the change of intestinal microflora by the intake of PHGG.

A gel-forming dietary fiber such as guar gum produced a viscosity 5–8 times higher, even at low concentrations, than that of starch (24). Unlike guar gum, PHGG is highly soluble in water and only raises viscosity about 10 centipoise at a 10% water solution (9). Therefore, a liquid type food or medical food containing PHGG for the treatment of constipation can be sterilized with heat because of the low viscosity of PHGG.

It can be concluded that the administration of PHGG results in soft feces, thus increasing the defecating frequency of constipated patients.

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