Effects of Resistant Glucan Mixture on Bowel Movement in Female Volunteers

Norihisa HAMAGUCHI, Hirokazu HIRAI, Hiroyuki BITO and Koichi OGAWA
Nihon Shokuhin Kako Co., Ltd., 30 Tajima, Fuji 417–8530, Japan
(Received April 30, 2015)

Summary Resistant glucan (RG) is a water-soluble polysaccharide resistant to hydrolysis by digestive enzymes in the human gastrointestinal system. RG mixture (RGM) contains more than 75% RG as dietary fiber and other saccharides. The effects of ingestion of 3.3, 6.6, and 13.2 g/d of RGM (containing of 2.5, 5.0, and 10.0 g/d RG as dietary fiber) on the fecal properties and the frequency of defecation were investigated in 60 female volunteers with constipation. The study was designed as a randomized, single-blinded, and placebo-controlled parallel-group trial. Each subject consumed RGM or a placebo (digestible maltodextrin) for 2 wk. Questionnaire data on the effects on bowel movement were analyzed according to defecation days, defecation frequency, fecal volume, fecal shapes, fecal color, fecal odor, and fecal excretory feeling. The results showed significant increases in defecation frequency (p<0.05), defecation days (p<0.05), and fecal volume (p<0.05) during the 13.2 g/d RGM ingestion period. The effects of RGM on defecation days and frequency showed a dose-dependent increase (p<0.05). These results suggested that the intake of RGM increased defecation days, defecation frequency, and fecal volume. In the gastrointestinal tract, RGM is useful as a water-soluble dietary fiber for the improvement of bowel movements.

Key Words dietary fiber, bowel movement, defecation, resistant glucan mixture

Dietary fiber is known to have positive effects on gastrointestinal health and has been reported to reduce disease risk of coronary heart disease, colorectal cancer, and breast cancer (1). Furthermore, certain types of fiber can aid in laxation and alleviate constipation (2). The Ministry of Health, Labour, and Welfare of Japan recommends a reference intake level of dietary fiber of 20 g per day for men and 18 g per day for women between 18 and 69 y of age. However, many Japanese fail to consume an adequate amount of fiber, with an average daily intake of 14.2 g per day (3). Given these low intakes and the associated disease risk, the 2015 Dietary Guidelines for Japanese recognized fiber as a nutrient for which intake is lacking and encouraged efforts to increase dietary intake.

A lack of dietary fiber causes symptoms of constipation that over the long term can potentially promote bowel and metabolism diseases (4). Therefore, laxation is an important index for health. Generally, two classifications of fiber exist, soluble (e.g., gums, pectins) and insoluble (e.g., cellulose, wheat bran) (5). Both are found to improve bowel movement (6–8). However, insoluble and high-viscosity soluble fibers have problems such as texture and taste when used for foods or beverages. In recent years, various low-viscosity water-soluble dietary fibers, including resistant maltodextrin (RMD), polydextrose (PDX), and resistant glucan (RG), have been developed for use in healthy food and beverage products (9–11).

We recently developed a novel, simple and efficient procedure to obtain a type of water-soluble dietary fiber, resistant glucan mixture (RGM) from glucose syrup, using activated carbon as a catalyst of polycondensation reaction (9). RGM has several unique features: (i) RGM is a highly branched, randomly bonded polysaccharide composed of only glucose units. The molecule contains all possible combinations of α- and β-linked 1,2-, 1,3-, 1,4-, and 1,6-glycosidic linkages (Fig. 1); (ii) RGM has lower viscosity compared with other soluble dietary fibers such as pectin, gum and glucomannan; (iii) RGM has low color, a slightly sweet taste, and no odor, making it suitable for use in food; (iv) RGM, similar to polydextrose, is resistant to hydrolysis by mammalian digestive enzymes in the small intestine.

Laxation and alleviation of constipation by PDX and RMD has been reported (10–13). However, RGM is a new material and its physiological effects on humans are untested. The objective of the present study was to evaluate the effects of RGM (containing not less than 75% dietary fiber) on the frequency and feeling of defecation in human subjects.

MATERIALS AND METHODS

Design and subjects. The study was carried out at C’est la vie Shinbashi Clinic (Tokyo, Japan) and was approved by the Institutional Review Board of C’est la vie Shinbashi Clinic (25 February 2014) before its launch. Furthermore, the study was conducted in accordance with the guidelines of the Declaration of Helsinki, and...
informed consent was obtained from all participants.

Participants. Study participants were female volunteers (n=60) who completed a questionnaire related to previous disease and administration of drugs, a physical, and a medical interview by a doctor. Participants between 20 and 60 y of age were recruited for the study according to fixed inclusion and exclusion criteria. The inclusion criteria were a tendency for constipation at two to four instances of defecation per week. The exclusion criteria included the following: use of drugs, functional foods, cosmetics, or instruments that may have influenced the outcomes of the study; consumption of large amounts of foods such as lactic acid bacteria beverage, food containing lactic acid bacteria or natto bacteria, lactic acid bacteria preparation, dietary fiber-enriched food, sugar alcohols, and oligosaccharides; current treatment for digestive diseases that affect the study outcomes; a surgical history involving the digestive system (except appendectomy); current pregnancy or suspected pregnancy; a current illness or the possibility of developing serious side effects; and inappropriacy, as deemed by a doctor.

Test samples. In this experiment, the RGM (product name: Fit Fiber #80P) was manufactured by Nihon Shokuhin Kako Co., Ltd. The dietary fiber content of the RGM in this experiment was 80.4% (as dried solid) determined by AOAC Official Method 2001.03, an enzymatic high-performance liquid chromatography method. The partial hydrolysates of starch Pinedex no.2, digestible maltodextrin, was from Matsutani Chemical Industry (Hyogo, Japan). The subjects consumed 13.2 g of the powdered dietary fiber or maltodextrin dissolved in 100 mL of water. Four types of test samples were prepared with RGM (0, 3.3, 6.6, and 13.2 g) and maltodextrin (13.2, 9.9, 6.6, and 0 g), respectively. To achieve equality of appearance and flavor, adequate volumes of caramel were added to the powder. Table 1 shows analysis values of the nutrient compositions.

Experimental design. The study was designed as a randomized, single-blinded, and placebo-controlled parallel-group trial. The RGM intake schedule is shown in Fig. 2 and participants’ characteristics are listed in Table 2. Participants were divided into four groups of 15 each. After a 2-wk observation period, each volunteer was administered a placebo (13.2 g of maltodextrin per day) for 2 wk. Following this period, each subject was administered 3.3, 6.6, or 13.2 g of RGM per day for 2 wk.

With respect to food intake, subjects were asked to keep to their habitual diet. However, because of the study substance probably affecting flora, other food products with similar effects were prohibited during the whole study. Therefore, food items containing pre- and pro-biotics, and fiber were not allowed. Subjects recorded a daily questionnaire on their diet, prescriptions and health status during the entire study period.

Subjects were asked to complete a questionnaire related to stool condition after ingestion at each dose level. Additionally, defecation conditions (defecation days, defecation frequency, fecal volume, fecal shape, fecal color, fecal odor, and fecal excretory feeling) were assessed in records.

Statistical analyses. Statistical analyses were performed using IBM SPSS Statistics, Version 21. The data

![Estimated structure of RG](image)

Fig. 1. Estimated structure of RG.
Table 2. Subject characteristics.

| Parameter               | Group I      | Group II     | Group III    | Group IV     | Total         |
|-------------------------|--------------|--------------|--------------|--------------|---------------|
| Number                  | 15           | 15           | 15           | 15           | 60            |
| Age (y)                 | 38.3±8.1     | 38.2±8.6     | 39.2±9.9     | 38.3±8.1     | 38.9±8.5      |
| Body height (cm)        | 158.3±4.6    | 157.9±4.8    | 157.5±5.0    | 157.4±6.1    | 157.8±5.0     |
| Body weight (kg)        | 53.1±4.9     | 52.7±4.9     | 52.8±5.8     | 52.5±5.2     | 52.8±5.1      |
| BMI (kg/m²)             | 21.2±1.6     | 21.1±1.6     | 21.3±2.0     | 21.2±1.6     | 21.2±1.7      |

Table 3. Effects of RGM intake administration on defecation conditions.

| Group | Number | Pre-observation period | Ingestion period 1 | Ingestion period 2 |
|-------|--------|------------------------|-------------------|-------------------|
| Defecation days per week | I 15 2.70±0.62 | 3.73±1.03 | 3.80±1.16 |
|       | II 15 2.70±0.65 | 3.37±1.14 | 3.70±1.21 |
|       | III 15 2.83±0.59 | 3.27±0.62 | 4.17±1.14* |
|       | IV 15 2.97±0.85 | 4.13±1.29 | 4.23±1.18 |

| Defecation frequency per week | I 15 3.13±0.99 | 4.13±1.30 | 4.43±1.70 |
|                              | II 15 2.93±0.73 | 3.87±1.46 | 4.17±1.62 |
|                              | III 15 3.20±0.92 | 3.67±1.16 | 4.57±1.41* |
|                              | IV 15 3.33±0.90 | 4.70±1.61 | 4.60±1.04 |

| Fecal volume (determined as no. of medium-sized eggs) | I 15 5.49±2.43 | 4.85±2.10 | 8.32±5.36 |
|                                                       | II 15 6.23±2.81 | 7.60±3.62 | 8.20±5.01 |
|                                                       | III 15 4.21±1.36 | 8.03±5.30 | 5.84±2.71* |
|                                                       | IV 15 5.43±2.78 | 8.46±5.90 | 7.32±2.54 |

| Fecal color (1: firm to 6: soft & watery) | I 15 2.57±0.61 | 2.60±0.60 | 2.62±0.67 |
|                                           | II 15 2.49±0.74 | 2.67±0.59 | 2.70±0.54 |
|                                           | III 15 2.31±0.76 | 2.59±0.88 | 2.73±0.88 |
|                                           | IV 15 2.36±0.65 | 2.71±0.46 | 2.76±0.57 |

| Fecal odor (1: yellow to 3: dark brown) | I 15 2.21±0.40 | 2.05±0.24 | 2.07±0.26 |
|                                          | II 15 2.18±0.25 | 2.16±0.31 | 2.11±0.22 |
|                                          | III 15 2.10±0.20 | 2.02±0.24 | 2.02±0.34 |
|                                          | IV 15 2.23±0.37 | 2.13±0.24 | 2.01±0.19 |

| Fecal odor (1: weak to 5: very strong) | I 15 2.87±0.36 | 2.92±0.57 | 2.78±0.53 |
|                                        | II 15 3.21±0.51 | 2.94±0.54 | 2.95±0.47 |
|                                        | III 15 3.35±0.53 | 3.26±0.61 | 3.33±0.62 |
|                                        | IV 15 2.91±0.72 | 2.92±0.41 | 2.86±0.54 |

| Fecal excretory feeling (1: feel fine to 3: incomplete evacuation) | I 15 2.08±0.24 | 1.98±0.16 | 2.01±0.26 |
|                                                                    | II 15 2.22±0.43 | 2.14±0.49 | 2.13±0.42 |
|                                                                    | III 15 2.08±0.50 | 1.97±0.50 | 1.96±0.48 |
|                                                                    | IV 15 2.21±0.41 | 2.09±0.39 | 2.02±0.38 |

Data represent means of 15 subjects/group. Values are means±SD. * Ingestion period 1 vs Ingestion period 2, p<0.05 by the Wilcoxon signed-rank test.
were analyzed by the Wilcoxon signed-rank test and analysis of variance (ANOVA, repeated measurement). For statistical analyses, the Williams test was performed using the statistics software MEPHAS (Osaka University, Osaka, Japan, August 16, 2015). Data were analyzed for dose-related trends by the Williams test. In terms of subject allocation, no items showed any significant difference. All of the reported p-values were one-tailed and considered statistically significant at the 0.05 level.

RESULTS

Exclusion from the study
No participant withdrew from the study during the examination period. Additionally, no potential participant was excluded on the basis of the exclusion criteria of the study. No abnormal symptoms related to the physical condition of the study participants were observed during any of the examination periods for RGM intake.

Effect on bowel movement
Table 3 shows the results of the defecation conditions. The data presented represent the mean values per week for each subject. When ingestion periods 1 and 2 are compared, the defecation days, defecation frequency, and fecal volume for the RGM 13.2 g/d intake group were significantly higher than for the placebo intake group (p<0.05). However, no significant differences in defecation frequency or defecation days between the placebo intake group and the RGM 3.3 g/d and 6.6 g/d intake groups were noted. The amount of change during ingestion period 2 is shown in Fig. 3. The effect of RGM on defecation days and defecation frequency was dose-dependent (p<0.05). There were no significant changes observed in fecal shape, color, odor, or excretory feeling in terms of fecal volume or visual characteristics.

DISCUSSION

In recent years, many people have suffered from constipation because of the stress of daily life and a lack of dietary fiber related to Western-style foods in Japan (14, 15). Constipation not only causes abdominal discomfort, but also increases the risk of colon cancer, given the increased spoilage substances producing harmful bacteria in the intestine and the increased contact time.

The effects of consuming 3.3, 6.6, and 13.2 g/d of RGM (containing of 2.5, 5.0, and 10 g/d RG as dietary fiber) on fecal properties and defecation frequency were investigated in 60 female participants with constipation. The defecation days and defecation frequency during the period of RGM supplementation as dietary fiber at a dose of 10 g/d were significantly higher than for the placebo intake group (p<0.05). Given the study blinding, these results are not psychological effects on the volunteers. During ingestion period 2, the effect of RGM on defecation days and frequency was dose-dependent.

PDX and RMD have beneficial effects on bowel function (16–19) by increasing stool bulk and frequency, improving stool consistency, and making defecation easier. Because of the highly branched chain structures containing α- and β-1,2-, 1,3-, 1,4- and 1,6-linkages, PDX and RMD are only partially degraded in the gut (12, 20). Therefore, increased stool weight is a result of increased indigestible mass in the gut, along with increments of total bacterial mass. We reported that RG shows resistance to hydrolysis by digestive enzymes in the human gastrointestinal system in vitro studies (9). We hypothesize that the structure of RGM was similar to that in PDX and most of the RG reaches the large intestine.

Fermentation of PDX and RMD leads to the growth of favorable microflora, diminished putrefactive microflora, enhanced production of short-chain fatty acids, and suppressed production of carcinogenic metabolites (12, 13). Additionally, PDX is known to have prebiotic effects (21). We presumed that part of the RGM is available for fermentation by intestinal bacteria in the same way as PDX and RMD, leading to the production of short-chain fatty acids. Accordingly, RGM decreases the pH in the large intestines and stimulates bowel peristalsis. Our future research will focus on the influence of the fermentation of RGM in the digestive tract.

These results suggest that the intake of RGM has beneficial effects for constipated females in increasing fecal volume, defecation days, and defecation frequency. RGM appears to be a safe, useful food material to compensate...
for the lack of dietary fiber.

REFERENCES

1) Vester Boler BM, Rossoni Serao MC, Bauer LL, Staeger MA, Boileau TW, Swanson KS, Fahey GC. 2011. Digestive physiological outcomes related to polydextrose and soluble maize fiber consumption by healthy adult men. *Br J Nutr* **106**: 1864–1871.

2) Holscher HD, Doligale JL, Bauer LL, Gourineni V, Pelkmann CL, Fahey GC, Swanson KS. 2014. Gastrointestinal tolerance and utilization of agave inulin by healthy adults. *Food Funct* **5**: 1142–1149.

3) Ministry of Health, Labour and Welfare. 2013. The National Health and Nutrition Survey in Japan. Ministry of Health Labour and Welfare, Tokyo.

4) Sugiyama Y, Kouzuma K, Yasumasu T, Tokimitsu I, Uematsu M, Hosoya T. 2008. Analysis of minimal effective dose of mixture of depolymerized sodium alginate and partially hydrolyzed guar gum in treatment of defecation and abdominal discomfort in functional constipation. *J Home Econ Japan* **59**: 143–153.

5) Dikeman CL, Murphy MR, Fahey GC. 2006. Dietary fibers affect viscosity of solutions and simulated human gastric and small intestinal digesta. *J Nutr* **136**: 913–919.

6) Yamamoto K, Kuwano K, Suzuki J, Mitamura T, Sekiya K. 1995. Effect of hydrolyzed guar gum on frequency and feeling of defecation in humans. *J Appl Glycosci* **42**: 251–257.

7) Hillman L, Peters S, Fisher A, Pomare EW. 1983. Dif-fering effects of pectin, cellulose and lignin on stool pH, transit time and weight. *Br J Nutr* **50**: 189–195.

8) Lawton CL, Walton J, Hoyland A, Howarth E, Allan P, Chesters D, Dye L. 2013. Short term (14 days) consumption of insoluble wheat bran fiber-containing breakfast cereals improves subjective digestive feelings, general wellbeing and bowel function in a dose dependent manner. *Nutrients* **5**: 1436–1455.

9) Hamaguchi N, Hirai H, Aizawa K, Takada M. 2015. Production of water-soluble indigestible polysaccharides using activated carbon. *J Appl Glycosci* **62**: 7–13.

10) Raninen K, Lappi J, Mykkänen H, Poutanen K. 2011. Dietary fiber type reflects physiological functionality comparison of grain fiber, inulin, and polydextrose. *Nutr Rev* **69**: 9–21.

11) Okuma K, Matsuda I, Katsuta Y, Kishimoto Y, Tsuji K. 2006. Development of indigestible dextrin. *J Appl Glycosci* **53**: 65–69.

12) Royotio H, Ouwehand AC. 2014. The fermentation of polydextrose in the large intestine and its beneficial effects. *Benef Microbes* **5**: 305–313.

13) Satouchi M, Wakabayashi S, Ohkuma K, Fujiwara K, Matsuoka A. 1993. Effects of indigestible dextrine on bowel movements. *Jpn J Nutr Diet* **51**: 31–37.

14) Takii Y, Nishimura S, Yoshida-Yamamoto S, Kobayashi Y, Nagayoshi E. 2013. Effects of intake of pickles containing *Lactobacillus brevis* on immune activity and bowel symptoms in female students. *J Nutr Sci Vitaminol* **59**: 402–411.

15) Yamamoto S, Nishimura S, Kobayashi Y, Takii Y. 2011. Improvement of constipation and fecal impaction for female students by daily taking in the pickled vegetables fermented with *Lactobacillus brevis* subsp. *coagulans* containing gamma-aminobutyric acid. *Food Clin Nutr* **6**: 9–20.

16) Hengst C, Ptok S, Roessler A, Fechner A, Jahreis G. 2008. Effects of polydextrose supplementation on different faecal parameters in healthy volunteers. *Int J Food Sci Nutr* **60**(6S): 96–105.

17) Raninen K, Lappi J, Mykkänen H, Poutanen K. 2011. Dietary fiber type reflects physiological functionality: comparison of grain fiber, inulin, and polydextrose. *Nutr Rev* **69**: 9–21.

18) Hamano T, Nakashima A, Ebihara S, Watamabe Y. 2004. The effect of beverage containing indigestible dextrin on the defecation of healthy volunteers and its safety. *J Nutr Food* **7**: 29–43.

19) Timm DA, Thomas W, Boileau TW, Williamson-Hughes PS, Slavin JL. 2013. Polydextrose and soluble corn fiber increase five-day fecal wet weight in healthy men and women. *J Nutr* **143**: 473–478.

20) Okuma K, Matsuda I. 2003. Production of indigestible dextrin from pyrodextrin. *J Appl Glycosci* **50**(3): 389–394.

21) Slavin J. 2013. Fiber and prebiotics: mechanisms and health benefits. *Nutrients* **5**: 1417–1435.