

# Usefulness of Soluble Dietary Fiber for the Treatment of Diarrhea During Enteral Nutrition in Elderly Patients

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**OBJECTIVES:** We investigated the clinical usefulness of soluble dietary fiber (SDF) for the treatment of diarrhea during enteral nutrition in elderly patients.

**METHODS:** This study included 10 men and 10 women (mean age  $\pm$  standard deviation:  $79.3 \pm 5.1$  y) who had diarrhea during long-term nutrition management. When administering SDF, the initial dose was 7 g and thereafter gradually increased at 1-wk intervals. After 4 wk, the administration was discontinued for 2 wk to confirm the effects of SDF.

**RESULTS:** After the administration of SDF, serum diamine oxidase activity significantly increased ( $P < 0.001$ ): The water content of the feces decreased significantly after the administration of fiber ( $P < 0.01$ ). The frequency of daily bowel movements also decreased significantly ( $P < 0.05$ ). Simultaneously, the fecal features improved. Concerning intestinal flora, there were no significant changes in the total number of bacteria or the number of anaerobic bacteria. The fecal pH decreased significantly 4 wk after the administration of fiber ( $P < 0.05$ ). The total level of short-chain fatty acids increased significantly 4 wk after the administration of fiber ( $P < 0.05$ ). There were no significant changes in the various nutritional indices.

**CONCLUSIONS:** The administration of SDF is useful for controlling spontaneous, favorable bowel movement by improving symptoms of small intestinal mucosal atrophy and normalizing the intestinal flora. *Nutrition* 2002;18:35–39. ©Elsevier Science Inc. 2002

**KEY WORDS:** soluble dietary fiber, diarrhea, enteral nutrition, diamine oxidase

## INTRODUCTION

In the geriatric field, long-term parenteral nutrition recently was found to cause mucosal atrophy. In particular, nutritional management with semidigested formula is commonly used.<sup>1</sup> However, the administration of semidigested formula has been reported to induce small intestinal mucosal atrophy or the enhancement of intestinal tract permeability, because such a formula has low residue.<sup>2,3</sup> Problems such as diarrhea and loose stools are especially common. In general, strategies to prevent the development of diarrhea after the administration of enteral nutrients have included appropriate nutrient administration methods such as the regulation of the administration rate, concentration, temperature, and medication. In recent years, some studies have reported that the addition of dietary fiber helps normalize digestive function and prevent diarrhea.<sup>4–6</sup> However, the efficacy of such additional dietary fiber has not been examined in detail.

In this study, to improve small intestinal mucosal atrophy, we administered soluble dietary fiber to elderly patients in whom oral ingestion was impossible, and where small intestinal mucosal atrophy had developed during long-term parenteral nutrition so as to cause mucosal atrophy, thus resulting in loose stools or diarrhea.

The clinical usefulness of soluble dietary fiber was examined by measuring the serum diamine oxidase (DAO) activity, which is

an index of the morphologic change in small intestinal mucosa, fecal features, the frequency of bowel movements, the water content of feces, fecal pH, and fecal short-chain fatty acid (SCFA) levels; in addition, we examined the intestinal flora. Various serum biochemical parameters and oligodynamic trace minerals were also examined as nutritional indices.

## SUBJECTS AND METHODS

### *Subjects*

This study was based on an investigation of 20 elderly inpatients (10 men and 10 women; mean age  $\pm$  standard deviation:  $79.3 \pm 5.1$  y) at the Nagoya University Hospital Geriatrics Department who had no organic disorders of the digestive tract, had been bed-ridden for a prolonged period due to cerebral infarction or cerebral hemorrhaging, and demonstrated loose stool or diarrhea. In these patients, semidigested formula (Ensure Liquid, Dainabot Co., Ltd.) was administered with the use of a continuous pump (Table 1). The daily nutritional intake ranged from 900 to 1100 kcal, and the daily added water volumes ranged from 1500 to 2500 mL. The rate of administration was 60 mL/h. Before the study, informed consent was obtained from the patient or the patient's representative.

After obtaining informed consent, additional fecal cultures were prepared to rule out bacterial diarrhea. For the determination of DAO activity and various serum biochemical parameters, blood was collected and centrifuged (1000g, 10 min), and the serum was

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TABLE 1.

ENTERAL NUTRITION FORMULAS ADMINISTERED (1000 kcal/1000 mL)	
Nutrient	Amount
Protein	35.2 g
Fat	35.20%
Vitamin A	2500 IU
Vitamin D	200 IU
Vitamin E	30 mg
Vitamin K	70 $\mu$ g
Vitamin C	152 mg
Vitamin B1	1.5 mg
Vitamin B2	1.7 mg
Vitamin B6	2 mg
Vitamin B12	6 mg
Choline	520 $\mu$ g
Folate	200 $\mu$ g
Niacin	20 mg
Pantothenic	5 mg
Biotin	152 $\mu$ g
Sodium	800 mg
Potassium	1480 mg
Chloride	1360 mg
Calcium	520 mg
Phosphate	520 mg
Magnesium	200 mg
Manganese	2 mg
Copper	1 mg
Zinc	15 mg
Iron	9 mg

stored in aliquots at  $-20^{\circ}\text{C}$  until used. The serum DAO activity was measured before the administration of soluble dietary fiber to confirm that the values had indeed decreased.

#### **Soluble Dietary Fiber**

A soluble dietary fiber product, Healsh Fiber (Ajinomoto Co., Ltd.), was used. It is a liquid containing 7 g of galactomannans per package (25 g). This product contains 17 mg of sodium, 16 mg of potassium, 2.0 mg of calcium, 21 mg of phosphorus, 2.0 mg of magnesium, and 0.4 mg of iron, has no calories, and can easily be added to various enteral nutritional formulas.

#### **Administration Period**

As a rule, the administration period was 4 wk. Thereafter, the soluble fiber was discontinued for 2 wk to confirm its effects.

#### **Administration Method**

The fiber was added to semidigested formula, mixed, and then shaken to guarantee even distribution. Thereafter, with the use of a transnasal gastric tube (12 F), the mixture was administered through a continuous injector at a rate of 60 mL/h.

#### **Administration Schedule**

The initial dose was one 25-g package per day (7 g of galactomannans), which was increased by one 25-g package each week as indicated by stool conditions, until the fourth week when the subjects were taking a maximum of four packages (100 g, 28 g of

galactomannan) per week. After 4 wk, the administration was discontinued for 2 wk.

#### **Observation Items**

**SERUM DAO ACTIVITY.** Three milliliters of blood was collected from the median cubital vein early in the morning after an overnight fast before the administration of fiber; 1, 2, 3 and 4 wk after administration; and 1 and 2 wk after discontinuation. The serum DAO activity was measured according to the high sensitivity colorimetric method described by Takagi et al.<sup>7</sup>

**FECAL FEATURES AND FREQUENCY OF BOWEL MOVEMENT.** The fecal features were classified as normal stool, loose stool, sludgy stool, and watery stool. The frequency of bowel movements per day was recorded.

**WATER CONTENT OF FECES.** Fecal specimens were collected before administration of the fiber; 1, 2, 3, and 4 wk after administration; and 1 and 2 wk after discontinuation. All specimens were mixed and shaken evenly. Approximately 0.5 g of stool was weighed, placed in a test tube, and then heated at  $105^{\circ}\text{C}$  for 2 h with the use of a heat bath to remove all water. Thereafter, the specimens were weighed and the water content of the feces was calculated.

**INVESTIGATION OF INTESTINAL FLORA.** Intestinal flora were investigated with the method described by Endo et al.<sup>8</sup> Fecal specimens ranging from 0.5 to 1.0 g in weight were diluted with anaerobic diluent in 10 serial steps and smeared on to various selective or nonselective media. Aerobic or anaerobic cultures were then performed in accordance with the bacterial classes. An anaerobic culture was performed in an anaerobic globe box (Japan Air Tech Co., Ltd.; ABC1550,  $\text{N}_2:\text{H}_2:\text{CO}_2 = 80:10:10$ ). Aerobic and anaerobic bacteria were cultured at  $37^{\circ}\text{C}$  for 48 h. To culture sporulation bacteria, an equivalent volume of ethanol was added to the diluent for feces, treated for 45 min, and then smeared on the medium. After culture, each colony was isolated. After gram staining, the bacteria were identified by microscopy.

The number of colony-forming unit/units (CFU) per gram was calculated and expressed as a logarithm of CFU (log CFU/g).

**FECAL PH.** Fecal pH was measured with pH test paper (Advantec No. 20, Tokyo Roshi Kaisha Ltd.) after a portion of the stool was dissolved in a small volume of sterile purified water.

**FECAL SCFA LEVELS.** Fecal SCFA levels were analyzed by the ion-eliminated chromatography method described by Hoshi et al.<sup>9</sup> with minor modifications. Clotonic acid was used as the internal standard substance. SCFA was detected by postcolumn pH-buffered electric conductivity. Concerning the columns, two type-H positive ion exchange columns (Shim-pack SCR-102H, 8 mm inner diameter  $\times$  300 mm L; Shimadzu Seisakusho, Japan) with two guard columns (Shim-pack SCR-102H, 6 mm inner diameter  $\times$  50 mm L) were serially connected. The column temperature was established at  $45^{\circ}\text{C}$ . Five millimoles of *p*-toluene sulfonic acid solution (CDD-6A, Shimadzu Seisakusho) was used as the mobile phase. A polarity-positive electric conductivity detector (CDD-6A, Shimadzu Seisakusho) was used at  $48^{\circ}\text{C}$ . As a reagent, 20 mM of bis tris solution containing 5 mM of *p*-toluene sulfonic acid and 100  $\mu\text{mol/L}$  of ethylene-diaminetetraacetic acid

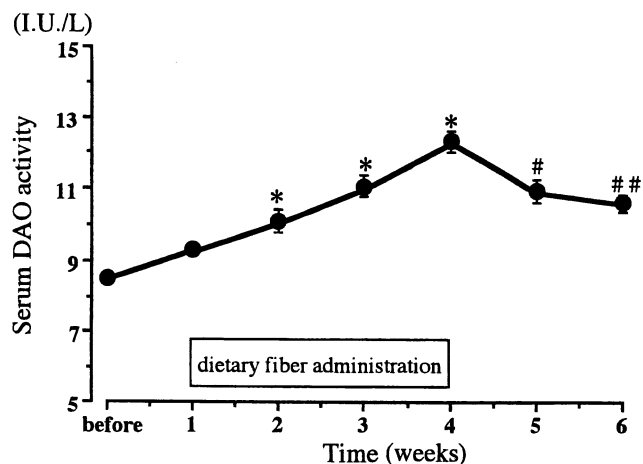


FIG. 1. Changes in serum DAO activation after ingestion of soluble dietary fiber. Values are presented as mean  $\pm$  standard error of the mean ( $n = 20$ ). The normal DAO levels of 50 volunteers were  $10.0 \pm 1.5$  IU/L. \* $P < 0.001$ , significantly different from the level before use. # $P < 0.01$ , ## $P < 0.001$ , significantly different from the level 4 wk after use. DAO, diamine oxidase.

was used (flow rate of 0.8 mL/min at 48°C). The sum of the acetic acid, propionic acid, and *n*-butyric acid levels was regarded as the total level of SCFAs.

**NUTRITIONAL PARAMETERS.** The nutritional parameters were body weight, serum total protein, prealbumin, transferrin, retinol-binding protein, total cholesterol, triacylglycerol, and serum oligodynamic trace minerals (iron, copper, and zinc). To measure these parameters, blood was collected from the median cubital vein daily early in the morning after overnight fasting before the administration of fiber, 1, 2, 3, and 4 wk after administration; and 1 and 2 wk after discontinuation.

**STATISTICAL ANALYSIS.** Unless noted otherwise, all values are expressed as the mean  $\pm$  standard error of the mean. Significance was tested with the paired *t* test;  $P < 0.05$  was considered significant.

**RESULTS**

In 20 patients, the mean serum DAO activity before administration of the fiber was  $8.54 \pm 0.16$  IU/L, which was significantly lower than in control subjects ( $10.0 \pm 1.5$  IU/L). Serum DAO activity increased significantly between 2 and 4 wk after administration ( $P < 0.001$ ) but decreased significantly 1 and 2 wk after discontinuation compared with DAO activity 4 wk after administration ( $P < 0.001$ ; Fig. 1).

The water content of the feces decreased serially compared with that before fiber administration. The water content of the feces decreased significantly between 2 and 4 wk after administration ( $P < 0.05$  and 0.01, respectively; Fig. 2). In addition, the fecal features changed from watery stool to sludge or loose stools. Normal stool was observed 3 wk after fiber administration, showing a serial improvement in the fecal features (Fig. 2).

However, the water content of the feces increased significantly 2 wk after discontinuation compared with the water content 4 wk after administration ( $P < 0.05$ ). In addition, the fecal features deteriorated to loose, sludge, or watery stool (Fig. 2). Before the administration of fiber, the frequency of bowel movements was

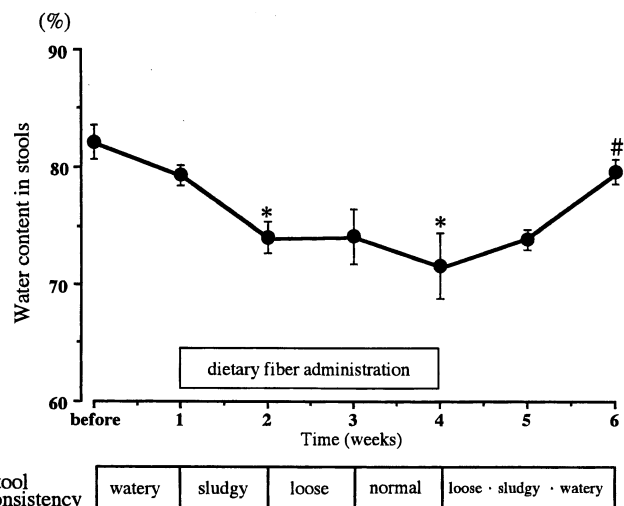


FIG. 2. Changes in water content of stool after ingestion of soluble dietary fiber. Values are mean  $\pm$  standard error of the mean ( $n = 20$ ). The normal water content of 17 volunteers was  $72.0 \pm 1.2$ . \* $P < 0.05$ , significantly different from the level before use. # $P < 0.05$ , significantly different from the level 4 wk after use.

$4.0 \pm 2.0$  times/d; however, the value decreased significantly to  $1.0 \pm 0.5$  times/d 4 wk after administration ( $P < 0.05$ ; Fig. 3). However, 2 wk after discontinuation, the frequency of bowel movements again increased to  $3.8 \pm 2.2$  times/d, thus demonstrating a significant difference from the value 4 wk after administration ( $P < 0.05$ ; Fig. 3). With respect to the intestinal flora, there were no significant changes in the total number of bacteria or number of anaerobic bacteria after fiber administration. However, the number of aerobic bacteria decreased significantly 4 wk after fiber administration ( $P < 0.05$ ). In addition, the number of aerobic bacteria 2 wk after discontinuation increased significantly compared with that 4 wk after administration ( $P < 0.05$ ; Fig. 4).

The fecal pH gradually and slightly decreased after fiber administration. Four weeks after administration, the fecal pH decreased significantly ( $P < 0.05$ ). However, 2 wk after discontinuation, the fecal pH was similar to that before fiber administration. The fecal level of each SCFA gradually and slightly increased after fiber administration. The total level of SCFAs also increased

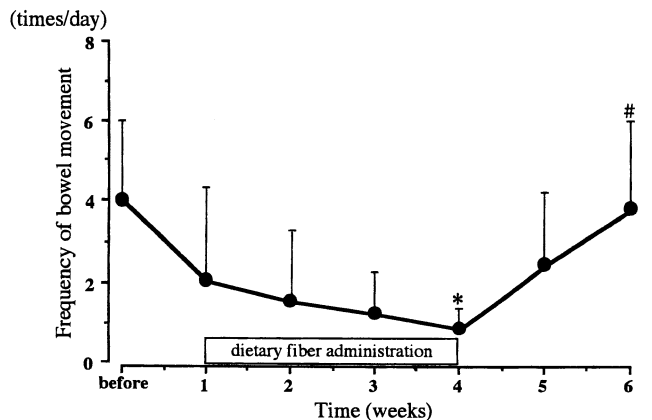


FIG. 3. Changes in stool frequency after ingestion of soluble dietary fiber. Values are mean  $\pm$  standard error of the mean ( $n = 20$ ). \* $P < 0.05$ , significantly different from the level before use. # $P < 0.05$ , significantly different from the level 4 wk after use.

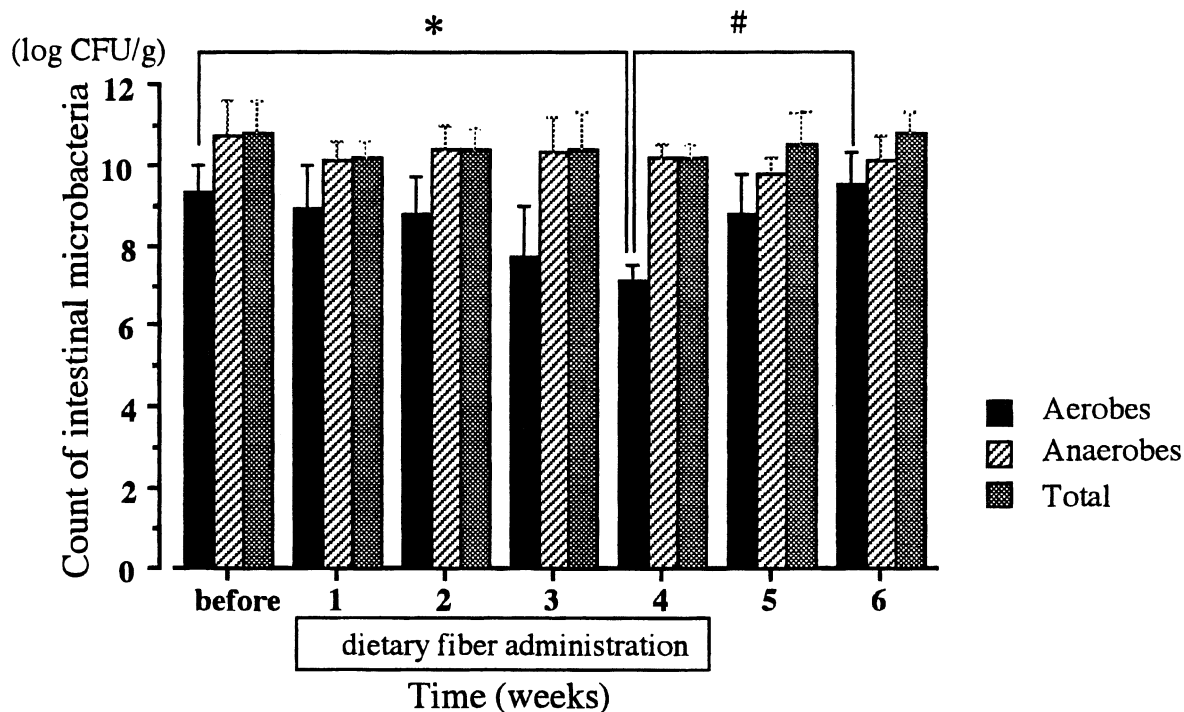


FIG. 4. Changes in intestinal flora after ingestion of soluble dietary fiber. Values are mean  $\pm$  standard error of the mean ( $n = 20$ ). \* $P < 0.05$ , significantly different from the level before use. # $P < 0.05$ , significantly different from the level 4 wk after use. CFU, colony-forming unit.

significantly 3 and 4 wk after administration ( $P < 0.05$  and  $0.05$ , respectively). Among the SCFAs, the acetic acid and propionic acid levels showed significant increases ( $P < 0.05$ ). Further, the total level of SCFAs 2 wk after discontinuation decreased significantly compared with the level 4 wk after administration ( $P < 0.05$ ; Fig. 5).

Body weight was used as an indicator of the nutritional state. Before taking fiber, the mean ( $\pm$  standard deviation [SD]) body weights were 44 kg ( $\pm 4.1$  SD) for males and 41 kg ( $\pm 3.8$  SD) for females; thus, there was no significant change 4 wk after taking fiber (males:  $44.5 \pm 3.8$  SD; females:  $42.0 \pm 3.5$  SD). There were also no significant changes in total serum protein, prealbumin,

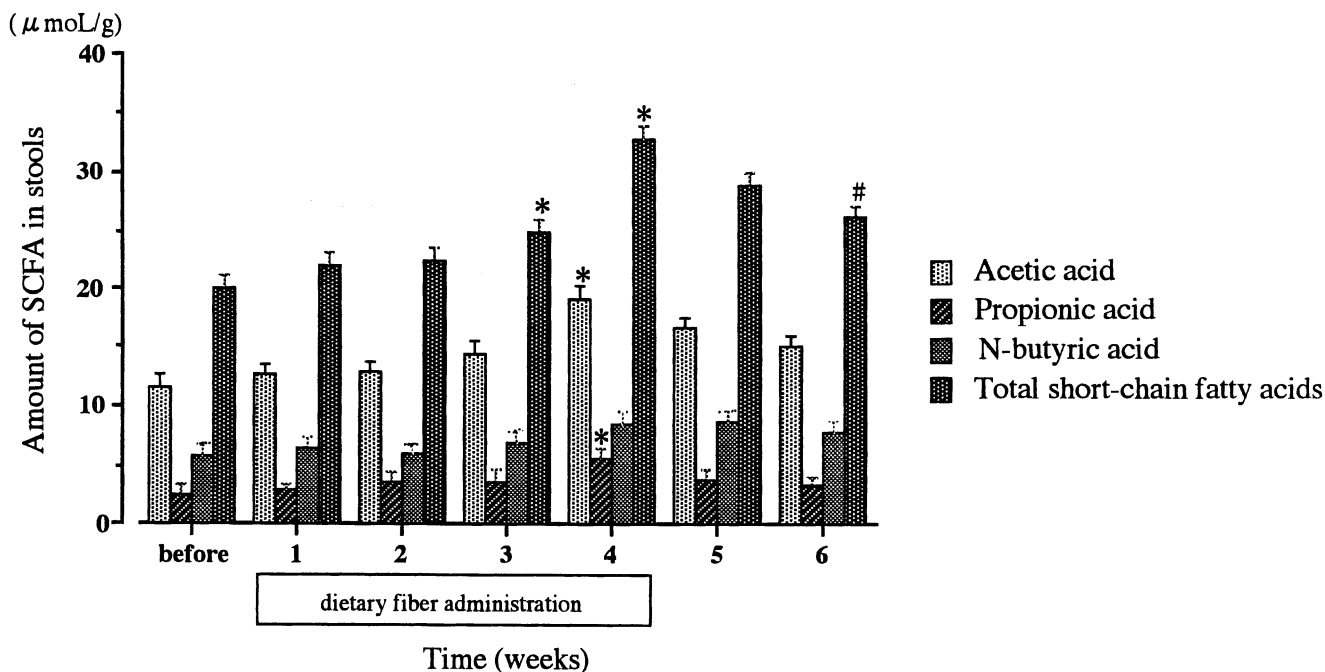


FIG. 5. Changes in the amount of SCFA in stools after ingestion of soluble dietary fiber. Values are mean  $\pm$  standard error of the mean ( $n = 20$ ). \* $P < 0.05$ , significantly different from the level before use. # $P < 0.05$ , significantly different from the level 4 wk after use. SCFA, short-chain fatty acid.

transferrin, retinol-binding protein, total cholesterol, or triacylglycerols after fiber administration. In contrast, the levels of oligodynamic trace minerals, iron, copper, and zinc, increased after fiber administration compared with the pretreatment values in all patients, although no significant differences were observed.

## DISCUSSION

Hosoda et al. conducted an animal experiment and reported that intravenous hyperalimentation and nutritional management with certain kinds of enteral nutrients and non-physiologic component nutrients cause atrophy of the digestive tract mucosa, whereas the administration of dietary fiber prevents atrophy of the mucosal epithelium.<sup>10</sup> Because the soluble dietary fiber product used in our clinical study, Healsh Fiber, is liquid, this preparation can be easily and evenly mixed with other enteral nutrients. In our patients, after administration of the fiber, the serum DAO activity, an index of morphologic changes in the small intestinal villous tissues, significantly increased, whereas the water content of the feces decreased. In addition to the decrease in water content, fecal features improved, and the frequency of bowel movements decreased significantly. Therefore, the fiber may have some preventive effect on mucosal epithelial atrophy in the intestine. Most soluble dietary fiber is used as an energy source of bacteria and converted to various substances.<sup>11</sup> When the intestinal flora were investigated, the soluble dietary fiber administered was found to decrease significantly the number of aerobic bacteria, thus making anaerobic bacteria predominant in the intestinal flora. In general, anaerobic bacteria are thought to play a protective role in intestinal flora. Therefore, the administration of the fiber may help normalize the intestinal flora.

Moreover, SCFAs such as acetic acid, propionic acid, and butyric acid are produced mainly by enteric bacteria in the process of digesting dietary fiber. These fatty acids comprise approximately 80% to 90% of the overall SCFAs produced in the digestive tract.

Quantitatively, the acetic acid level was the highest, followed by butyric acid and propionic acid, in agreement with the results of Cherbut et al.<sup>12</sup> In our patients, fecal pH decreased slightly because the acetic and propionic acid levels increased significantly after fiber administration. In addition, 95% or more of the SCFAs are absorbed by the large intestine and thus promote the proliferation of digestive tract mucosal epithelial cells, which are then used as an energy source for the digestive tract.<sup>13</sup> The availability of butyric acid has been reported to be the highest, followed by propionic acid and acetic acid.<sup>14-16</sup> Further, SCFAs promote water absorption and the absorption of sodium, calcium, and magnesium.<sup>17</sup>

Therefore, the administration of soluble dietary fiber may activate intestinal fermentation, promote the proliferation of small and large intestinal mucosal epithelial cells, and improve atrophy. As a result, they may increase serum DAO activity, an index of morphologic changes in the small intestinal villous tissues. Further, the water content of feces decreased because the administration of soluble dietary fiber promoted water absorption.<sup>18</sup> In addition, the fecal features improved, and the frequency of bowel movements decreased.

Many studies have reported that the ingestion of dietary fiber reduces nutritional parameters and the apparent absorption rates for oligodynamic trace minerals.<sup>19-21</sup> However, ingestion of highly fermented dietary fiber and components that are not easily digested have been reported to increase the absorption rates for

calcium and magnesium.<sup>22</sup> In our patients, there were no significant increases in the nutritional parameters after the administration of soluble dietary fibers, although, among the oligodynamic trace minerals, iron, copper, and zinc levels increased slightly over pretreatment values. These findings suggest that the administration of soluble dietary fiber to geriatric patients who develop small intestinal mucosal atrophy and loose stools or diarrhea during long-term nutritional management with semidigested formula is useful for improving fecal passage management by ameliorating the symptoms of small intestinal mucosal atrophy and normalizing the intestinal flora.

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