Nutr Res Pract. 2023 Dec;17(6):1201-1210
https://doi.org/10.4162/nrp.2023.17.6.1201
pISSN 1976-1457·eISSN 2005-6168

Nutrition Research and Practice

Original Research



# Food contributing to fermentable oligosaccharide, disaccharide, monosaccharide, and polyols intake in Korean adults

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**Received:** Apr 10, 2023
**Revised:** Aug 10, 2023
**Accepted:** Sep 27, 2023
**Published online:** Nov 20, 2023

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**Funding**
This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MSIP) (No. NRF-2020R1A2C1014177).

**Conflict of Interest**
The authors declare no potential conflicts of interests.

## ABSTRACT

**BACKGROUND/OBJECTIVES:** The dietary intake of foods with fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAP) is known to adversely affect patients with irritable bowel syndrome (IBS). However, the effects of FODMAP have been studied predominantly among Western populations. This study aimed to identify foods high in FODMAP content which form a part of the Korean adult diet and obtain basic data for the preparation of IBS guidelines.
**SUBJECTS/METHODS:** An online survey of 1,000 adults from the general population in the age group of 20 to 40 years was performed. Data from 787 participants (men, 386; women, 401) were analyzed. The general characteristics of the participants, health status, IBS diagnosis using the Rome III diagnostic criteria, semi-quantitative food frequency questionnaire findings, and food items causing symptoms were analyzed.
**RESULTS:** Overall, 169 participants (21.5%) had IBS. The contribution of the FODMAP nutrients in both IBS and healthy groups was as follows: fructan > lactose > excess fructose > sorbitol > mannitol > galacto-oligosaccharides (GOS). The fructan intake was 4.6 ± 2.2 g/day and 4.3 ± 2.5 g/day in the IBS and healthy groups ($P$ = 0.014), respectively. In the IBS group, the ratio of the intake of fructan to the total FODMAP intake was 39.5%, 29.8%, and 5.8% through onions, garlic, and bananas, respectively.
**CONCLUSIONS:** Fructan was the FODMAP nutrient most consumed by Korean adults. Therefore, given the difference in the dietary habits of each country's population, the dietary guidelines for IBS should be country specific.

**Keywords:** Nutrition assessment; FODMAP; irritable bowel syndrome; Korea

## INTRODUCTION

Irritable bowel syndrome (IBS) is characterized by abdominal pain, discomfort, diarrhea, and constipation. While the pathogenesis of the condition remains unclear, it is known to severely impair the quality of life of patients suffering from it [1]. Therefore, the primary goal of treatment is to provide symptomatic relief rather than to cure the disease. Relief from symptoms can be achieved by identifying the specific factors that exacerbate IBS and establishing an environment that can lower the impact of these factors.

**Author Contributions**

Conceptualization: Sohn C; Formal analysis: Na W; Investigation: Na W; Methodology: Na W, Sohn C; Supervision: Sohn C; Writing - original draft: Na W; Writing - review & editing: Sohn C.

The factors that exacerbate IBS include changes in gut motility and sensitivity, changes in the intestinal flora, dysregulation of the gut-brain axis, dietary factors, socio-psychological and genetic factors, and stress [2-5]. Dietary factors may indirectly affect the intestinal flora and can be modified by the individual patient [6]. Modifying dietary factors alone can contribute to a significant improvement in the patient's condition.

Highly fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAP) comprise the key dietary factors that cause IBS [7,8]. These short carbohydrate compounds are not easily absorbed in the intestine. Due to their small molecular size, they exert an osmotic effect and draw fluid through to the large bowel. Further, they are easily fermented by intestinal bacteria, leading to the production of gas and other symptoms of IBS [6,9]. To alleviate these symptoms, a low-FODMAP diet is recommended [10]. FODMAP are found in various food groups, except in naturally derived fish and meat [11-13]. Currently, a research team at MONASH University in Australia has provided information on FODMAP found in different food groups [11]. These food groups classified by the team largely include fruits, vegetables, grains, beans, dairy products, meat, processed meat, nuts, sweeteners, and sauce.

In Korea, following an increase in the proportion of patients with IBS, the number of studies investigating the different food groups and food products that cause IBS symptoms has increased [14-16]. However, there is currently no Korean database available on FODMAP-based food products [17]. In Asian countries, including Korea, onions, green onions, and garlic, which have a high FODMAP content, are commonly used as food seasoning [18]. In Western countries, there is a high intake of dairy products, fruits, and wheat, which also have a high FODMAP content [19,20]. This suggests that the foods affecting the IBS symptoms may vary across cultures. The current recommendations related to the consumption of a low-FODMAP diet by patients with IBS are mainly based on studies conducted among Western populations. Considering the dietary differences between countries, relevant information and dietary guidelines on FODMAP foods for patients with IBS in Asian countries should also be provided.

Specifically, an increase in the consumption of noodles, bread, and convenient food products has been observed in Korea [21]. These new trends in the intake of high-FODMAP food products may be related to the increase in IBS symptoms. Therefore, there was a need for studies that assess the foods and food products that contribute to the higher intake of a FODMAP-related diet by Korean adults. This study aimed to elucidate basic data on the food products that contribute to the FODMAP intake by Korean adults with IBS through a dietary intake survey. This data could be used to develop dietary intake guidelines for patients with IBS in Korea and to further collate it with data on FODMAP foods obtained from studies from other countries.

## SUBJECTS AND METHODS

### Study subjects

Data was collected through an online cross-sectional survey of adults aged between 20 and 40 years who responded that they agreed about the relationship between their intestinal health and dietary habits. The survey was conducted from April to August 2020. Subjects excluded from this survey were those with inflammatory bowel disease and those taking drugs that could seriously affect gastrointestinal motility (antibiotics, anticonvulsants, antipsychotics, and medications for Parkinson's). Data were collected from approximately 1,000 participants (men: 497, women: 503). Finally, we analyzed the data of 787 participants after excluding those who responded insincerely and those providing incomplete data, such as that related to their IBS diagnosis (n = 10), food frequency, or symptoms associated with specific foods (n = 68), stress status (n = 25), and those with an intake of less than 500 kcal or more than 6,000 kcal (n = 110). The questionnaire comprised questions on stools type (one question), food intake/symptom frequency according to food intake (118 questions), stress (five questions), and general information (11 questions). This study was approved by the Institutional Review Board of Wonkwang University (WKIRB-202004-SB-012) and all procedures were performed in accordance with the Helsinki Declaration.

### Dietary intake survey and FODMAP nutrient analysis

A survey on the dietary intake was conducted using a modified version of the semi-quantitative food frequency questionnaire (FFQ) from the Korea National Health and Nutrition Examination Survey. In the online semi-FFQ survey, information on each food item was provided based on dedicated containers for single-serving portions or publicly recognized reference portions to help individuals respond objectively about their intake. To analyze the intake of FODMAP according to participants' responses to the semi-FFQ, a FODMAP database of the total sugar, fructose, and lactose content was created using version 9.2 of the National Standard Food Ingredients Table of the Rural Development Administration. As the Korean FODMAP database had insufficient data, data on food and nutrients were obtained from the United States Department of Agriculture food database and previous reports [13,22-24]. Through previous studies, we collected information on the presence of certain FODMAP components in various foods. These components include excess fructose (7 types) found in mangoes, pears, and apples, sorbitol (43 types) found in strawberries, turnips, cabbage, mushrooms, corn, plums, and grapes, mannitol (29 types) found in tofu, soybeans, turnips, peaches, potatoes, and carrots, as well as raffinose (10 types) and stachyose (10 types) found in soybeans, tofu, onions, and other foods, and fructans (39 types) found in soybeans, tofu, garlic, onions, chives, cereals, and other foods (**Supplementary Table 1**).

### Diagnosis of IBS

The IBS Module (Korean version) of the Rome III Adult Questionnaire was used to diagnose IBS. The participants who satisfied 2 of the following three items related to bowel movement were diagnosed with IBS: Display of IBS symptoms in the past 6 months, experience of abdominal pain at least once a week in the past three months, and experience of pain unrelated to menstruation (in women) [25].

### Other health status questionnaire

The International Physical Activity Questionnaire was used to evaluate physical activity levels [26]. Also, the Brief Encounter Psychosocial Instrument (Korean version) was used to evaluate stress levels. The items were rated as "not at all," "rarely," "neutral," "often," or "very often." The low, moderate, and high-stress groups comprised participants with scores of 1.8, 1.8–2.8, and ≥ 2.8, respectively [27].

### Statistical analysis

The Statistical Package for Social Science version 26 (IBM Corp., Armonk, NY, USA) was used to analyze the total rate of FODMAP intake and food products high in FODMAP. To identify the food products contributing to FODMAP intake, the FODMAP nutrients of each food were analyzed. In addition, statistical analyses were performed using cross-analysis and the Mann-Whitney *U* test. All data was considered statistically significant at a level of less than 0.05.

# RESULTS

## General characteristics

The participant characteristics are presented in **Table 1**. A total of 169 (21.5%) participants (mean age, 30.5 ± 7.4 yrs) were diagnosed with IBS. In contrast, 618 (78.5%) participants (healthy group; mean age, 31.0 ± 7.9 yrs) were not diagnosed with IBS. Of the 169 participants diagnosed with IBS, 70 (41.4%) were male and 99 (58.6%) were female. The IBS group had significantly higher scores for stress status than those in the healthy group for both men and women ($P < 0.001$).

## Intake of nutrients and FODMAP in the IBS and healthy groups

The results of the analysis of nutrient and FODMAP intake according to the IBS status are shown in **Table 2**. The energy intake in the IBS group was 2,813.3 ± 1,057.2 kcal/day while that in the healthy group was 2,739.0 ± 1,070.6 kcal/day. No significant difference was observed in the energy intake of the two groups. These results were common to both men and women. The fat intake in the IBS group was 73.8 ± 36.7 g/day, which was significantly higher than that in the healthy group (67.6 ± 35.5 g/day; $P = 0.015$). These results showed significant differences only among men (IBS group vs. healthy group: 78.0 vs. 69.6 g/day, $P = 0.033$). The total FODMAP intake was 11.2 ± 7.3 g/day and 10.8 ± 7.9 g/day in the IBS and healthy groups, respectively, with no significant difference between the groups ($P = 0.157$). However, the FODMAP nutrients with significant differences in intake between the groups were mannitol and fructan. The mannitol intake was significantly different between the 2 groups ($P = 0.013$), with no significant difference between men and women. The fructan intake in the IBS group was 4.6 ± 2.2 g/day

**Table 1.** Comparison of baseline characteristics between the IBS and healthy groups

| Variable | Total | | | Men | | | Women | | |
|---|---|---|---|---|---|---|---|---|---|
| | Healthy group (n = 618) | IBS group (n = 169) | *P*-value | Healthy group (n = 316) | IBS group (n = 70) | *P*-value | Healthy group (n = 302) | IBS group (n = 99) | *P*-value |
| Age (yrs) | 31.0 ± 7.9 | 30.5 ± 7.4 | 0.516 | 31.7 ± 7.8 | 32.5 ± 6.8 | 0.423 | 30.2 ± 8.1 | 29.1 ± 7.5 | 0.242 |
| BMI (kg/m²) | 23.1 ± 3.5 | 22.9 ± 4.0 | 0.507 | 24.7 ± 3.4 | 25.1 ± 4.0 | 0.390 | 21.4 ± 2.8 | 21.3 ± 3.1 | 0.773 |
| Obesity status | | | 0.613 | | | 0.920 | | | 0.952 |
| Normal | 332 (53.7) | 98 (58.0) | | 101 (32.0) | 21 (30.0) | | 231 (76.5) | 77 (77.8) | |
| Over-weight | 126 (20.4) | 31 (18.3) | | 92 (29.1) | 20 (28.6) | | 34 (11.3) | 11 (11.1) | |
| Obesity | 160 (25.9) | 40 (23.7) | | 123 (38.9) | 29 (41.4) | | 37 (12.3) | 11 (11.1) | |
| Stress status | | | < 0.001 | | | 0.005 | | | < 0.001 |
| Low | 201 (32.5) | 29 (17.2) | | 119 (37.7) | 14 (20.0) | | 82 (27.2) | 15 (15.2) | |
| Middle | 212 (34.3) | 43 (25.4) | | 100 (31.6) | 22 (31.4) | | 112 (37.1) | 21 (21.2) | |
| High | 205 (33.2) | 97 (57.4) | | 97 (30.7) | 34 (48.6) | | 108 (35.8) | 63 (63.6) | |
| Occupations | | | 0.569 | | | 0.259 | | | 0.493 |
| Student | 111 (18.0) | 30 (17.8) | | 62 (19.6) | 11 (15.7) | | 49 (16.2) | 19 (19.2) | |
| Employed | 404 (65.4) | 108 (63.9) | | 216 (68.4) | 45 (64.3) | | 188 (62.3) | 63 (63.6) | |
| Self-employed | 19 (3.1) | 9 (5.3) | | 14 (4.4) | 5 (7.1) | | 5 (1.7) | 4 (4.0) | |
| Housewives | 26 (4.2) | 5 (3.0) | | 1 (0.3) | 0 (0.0) | | 25 (8.3) | 5 (5.1) | |
| Unemployed | 32 (5.2) | 12 (7.1) | | 9 (2.8) | 6 (8.6) | | 23 (7.6) | 6 (6.1) | |
| Others | 26 (4.2) | 5 (3.0) | | 14 (4.4) | 3 (4.3) | | 12 (4.0) | 2 (2.0) | |
| IBS-type[1)] | | | | | | | | | |
| IBS-C | | 26 (15.4) | | | 8 (11.4) | | | 18 (18.2) | |
| IBS-D | | 60 (35.5) | | | 32 (45.7) | | | 28 (28.3) | |
| IBS-M | | 56 (33.1) | | | 18 (25.7) | | | 38 (38.4) | |
| IBS-U | | 27 (16.0) | | | 12 (17.1) | | | 15 (15.2) | |

Values are presented as number (%) or mean ± SD. *P*-values were calculated using Fisher's exact test or Mann-Whitney *U* test.
IBS, irritable bowel syndrome; BMI, body mass index; IBS-C, irritable bowel syndrome with constipation; IBS-D, irritable bowel syndrome with diarrhea; IBS-M, irritable bowel syndrome with mixed change bowel habits, IBS-U, irritable bowel syndrome unclassified.
[1)]Frequency analysis was conducted only in patients with IBS.


https://doi.org/10.4162/nrp.2023.17.6.1201

**Table 2.** Nutrients and FODMAP intake in the IBS and healthy groups

| Variable | Total | | | Men | | | Women | | |
|---|---|---|---|---|---|---|---|---|---|
| | Healthy group (n = 618) | IBS group (n = 169) | *P*-value | Healthy group (n = 316) | IBS group (n = 70) | *P*-value | Healthy group (n = 302) | IBS group (n = 99) | *P*-value |
| Energy (g) | 2,739.0 ± 1,070.6 | 2,813.3 ± 1,057.2 | 0.300 | 2,874.2 ± 1,076.6 | 3,027.7 ± 1,055.8 | 0.173 | 2,597.5 ± 1,047.4 | 2,661.7 ± 1,036.8 | 0.551 |
| Carbohydrate (g) | 408.3 ± 160.7 | 405.1 ± 151.6 | 0.915 | 425.2 ± 160.2 | 433.0 ± 144.8 | 0.389 | 390.7 ± 159.6 | 385.3 ± 153.9 | 0.814 |
| Sugar (g) | 66.9 ± 47.6 | 69.6 ± 51.4 | 0.242 | 65.9 ± 46.5 | 65.5 ± 42.3 | 0.588 | 68.0 ± 48.8 | 72.4 ± 57.0 | 0.339 |
| Fiber (g) | 19.3 ± 11.1 | 20.2 ± 11.3 | 0.129 | 19.1 ± 11.2 | 19.6 ± 10.2 | 0.276 | 19.4 ± 11.1 | 20.6 ± 12.1 | 0.315 |
| Water soluble dietary fiber (g) | 5.5 ± 4.0 | 5.7 ± 4.3 | 0.218 | 5.3 ± 4.0 | 5.3 ± 3.7 | 0.488 | 5.6 ± 4.0 | 6.0 ± 4.6 | 0.377 |
| Water insoluble dietary fiber (g) | 13.3 ± 7.1 | 14.0 ± 7.1 | 0.090 | 13.3 ± 7.2 | 13.9 ± 6.6 | 0.184 | 13.3 ± 7.0 | 14.1 ± 7.4 | 0.273 |
| Protein (g) | 103.6 ± 47.0 | 107.9 ± 47.5 | 0.157 | 108.4 ± 49.0 | 117.1 ± 48.1 | 0.065 | 98.6 ± 44.4 | 101.4 ± 46.3 | 0.531 |
| Fat (g) | 67.6 ± 35.5 | 73.8 ± 36.7 | 0.015 | 69.6 ± 35.3 | 78.0 ± 37.1 | 0.033 | 65.5 ± 35.8 | 70.8 ± 36.2 | 0.107 |
| Total FODMAP (g) | 10.8 ± 7.9 | 11.2 ± 7.3 | 0.157 | 10.9 ± 7.6 | 10.5 ± 5.5 | 0.498 | 10.8 ± 8.1 | 11.6 ± 8.4 | 0.195 |
| Lactose (g) | 4.4 ± 5.4 | 4.2 ± 4.7 | 0.590 | 4.3 ± 5.3 | 3.6 ± 4.1 | 0.586 | 4.4 ± 5.5 | 4.7 ± 5.1 | 0.258 |
| Excess fructose (g) | 0.9 ± 1.6 | 0.9 ± 1.9 | 0.997 | 0.8 ± 1.2 | 0.7 ± 0.8 | 0.682 | 1.0 ± 1.9 | 1.1 ± 2.4 | 0.890 |
| Sorbitol (g) | 0.8 ± 1.2 | 0.8 ± 1.4 | 0.804 | 0.7 ± 1.0 | 0.7 ± 0.9 | 0.496 | 0.8 ± 1.4 | 0.9 ± 1.7 | 0.914 |
| Mannitol (g) | 0.4 ± 0.6 | 0.4 ± 0.5 | 0.013 | 0.4 ± 0.4 | 0.5 ± 0.7 | 0.063 | 0.4 ± 0.7 | 0.4 ± 0.3 | 0.098 |
| Raffinose (g) | 0.1 ± 0.0 | 0.1 ± 0.0 | 0.107 | 0.1 ± 0.0 | 0.1 ± 0.0 | 0.224 | 0.1 ± 0.0 | 0.1 ± 0.0 | 0.172 |
| Stachyose (g) | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.922 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.266 | 0.0 ± 0.0 | 0.1 ± 0.1 | 0.281 |
| GOS (g) | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.305 | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.770 | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.234 |
| Fructan (g) | 4.3 ± 2.5 | 4.6 ± 2.2 | 0.014 | 4.6 ± 2.8 | 5.0 ± 2.4 | 0.026 | 4.1 ± 2.3 | 4.4 ± 2.0 | 0.119 |

Values are presented as mean ± SD. *P*-values were calculated using the Mann-Whitney *U* test.
FODMAP, fermentable oligosaccharides, disaccharides, monosaccharides, and polyols; IBS, irritable bowel syndrome; GOS, galacto-oligosaccharides.

while that in the healthy group was 4.3 ± 2.5 g/day ($P = 0.014$), with significant differences only among men (IBS group vs. healthy group: 4.6 vs. 5.0 g/day, $P = 0.026$).

## Proportion of specific FODMAP content in the total FODMAP intake

The intake ratio of the FODMAP components to total FODMAP is shown in **Fig. 1**. The contribution of FODMAP nutrients in the diagnosis of IBS was analyzed to be in the following order: fructan > lactose > excess fructose > sorbitol > mannitol > galacto-oligosaccharides (GOS) in men, and lactose > fructan > excess fructose > sorbitol > mannitol > GOS in women. Fructan accounted for the highest proportion of the FODMAP intake in the IBS group at 47.6% for men and 37.9% for women. Lactose accounted for 34.3% of the FODMAP intake in males and 40.5% in females, thus showing gender-based differences in FODMAP nutrients with a high intake rate.

## Proportion of specific FODMAP content intake from specific foods

The results of the analysis of the contribution of FODMAP intake to food intake are presented in **Supplementary Table 2**. The results by gender are presented in **Supplementary Table 3**. In the IBS group, for fructan, which had the highest intake to total FODMAP intake ratio, the intake contribution was 39.5% due to onions, 29.8% by garlic, 5.8% by bananas, 5.8% by rice cake (mostly rice), 5.7% by carrots, 3.2% by chives, 2.8% by white bread, and 1.8% by watermelons. In the healthy group, the contribution of onions was 39.5%, garlic 30.0%, carrot 6.0%, banana 5.9%, rice cake (mostly rice) 4.5%, chives 3.6%, white bread 2.4%, and watermelons 1.9%. In the case of lactose, there was a slight difference in the order of food contribution between the IBS and healthy groups. In the IBS group, the lactose contributions of various foods were as follows: milk (74.7%) > ice cream (8.9%) > yogurt (3.4%) > liquid yogurt (3.4%) > chocolate (3.0%) > butter (1.3%) > canned pineapple (1.2%) > ice milk (1.2%). The following order of contribution was observed in the healthy group: milk (75.1%) > ice cream (9.9%) > yogurt (3.7%) > liquid yogurt (3.2%) > chocolate (2.2%) > ice milk (1.3%) > canned pineapple (1.2%) > butter (1.0%).

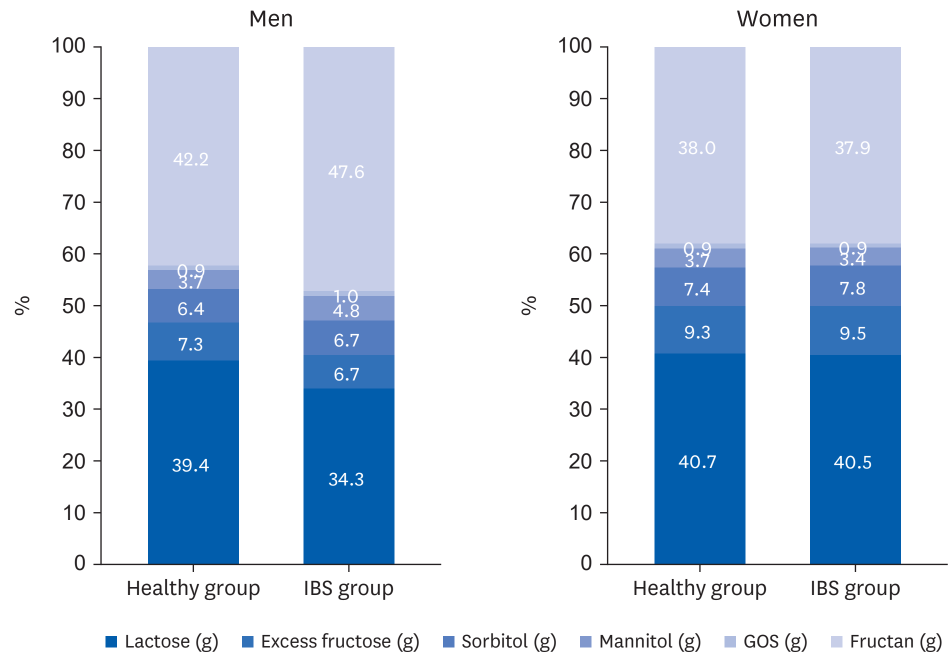


**Fig. 1.** The intake ratio of the FODMAP components to total FODMAP.
FODMAP, fermentable oligosaccharides, disaccharides, monosaccharides, and polyols; IBS, irritable bowel syndrome; GOS, galacto-oligosaccharides.

# DISCUSSION

This study aimed to obtain baseline data for the preparation of dietary guidelines for the clinical nutritional treatment of patients with IBS in Korea. We analyzed the FODMAP intake and food products contributing to FODMAP intake by Korean adults using a food intake questionnaire. In the IBS group, the total FODMAP intake was 11.2 g/day, and fructan (4.6 g) had the highest FODMAP nutrient to total FODMAP ratio.

In Asian countries, including Korea, the number of studies evaluating FODMAP intake is limited. Most studies have been conducted in Europe, the U.S., and Australia, etc. In the UK, a study on IBS patients with a regular daily diet reported a FODMAP intake of 29.6 g [28]. Also, O'Keeffe *et al.* [29] reported a daily FODMAP intake of 29.4 g. A study analyzing large-scale data in Spain showed an average FODMAP intake of 21.4 g in adults aged 18–74 years [30]. In Australia, the average daily intake of FODMAP was found to be 23.7 g [6], which is somewhat different from the results of this study.

Interestingly, our results show that the intake of fructan accounted for the highest proportion of the total FODMAP intake in the IBS group. This finding is in contrast to those of previous studies, which showed different composition ratios of FODMAP. In the study conducted by Miranda *et al.* [30], the lactose intake was 16 g, accounting for 77% of the total FODMAP intake of 21.4 g. Another study on 117 adults in Sweden reported a total FODMAP intake of 19.4 g, lactose intake of 14.2 g, and fructan intake of 3.46 g, showing similar ratios [31]. Additionally, Barret and colleagues [32] from Australia reported that of a total FODMAP intake of 23.0 g, the lactose intake was 17.7 g and the fructan intake was 3.0 g. In contrast, in our study, the lactose and fructan intakes by the IBS group were 4.2 g and 4.6 g, respectively.

The main factor contributing to such differences in results may be the primary food source of FODMAP in European countries, which differs from that in Korea.

The lactose intake observed in our study was different from that observed in previous studies in Western countries. An analysis of the global consumption of milk, which is the main source of lactose, reported 1.59 servings of milk per day in Central and South America [33]. In contrast, East Asia and Oceania consumed approximately 0.25 servings of milk per day. The average milk intake by individuals aged 12–18 years in Korea is reportedly 0.44 servings of milk per day. It has been found to decrease with age to 0.24 servings of milk per day among those aged 50–64 years, which supports the findings of this study.

According to our analysis, onions (1.8189 g, 39.5%) and garlic (1.3719 g, 29.8%) contributed approximately 70% of the total fructan intake in the IBS group. This finding is inconsistent with the findings of Miranda and colleagues [30] who observed that 0.17 g, 0.16 g, 0.14 g, and 0.08 g of fructan were consumed from white bread, onions, garlic, and sponge cakes, respectively. The contribution of food and the order of contribution observed by Miranda *et al.* [30] differed from those observed in our study. This difference is likely related to the food culture. In Korea, ingredients with high fructan content, such as onions, garlic, and green onions, are often used as sauces in various food recipes. According to the 2019 National Nutrition Statistic data, the average daily intake of onions, green onions, and garlic was 33.88 g (2nd highest), 11.24 g (6th highest), and 4.27 g (18th highest), respectively. Therefore, future studies should assess the effects of Korean diets on Korean patients with IBS.

The total intake of FODMAPs reported in our study was less than half of the 20–30 g reported in previous studies. The intake rates and food sources of FODMAP were also different from those reported in Western countries. Thus, future studies should actively establish a FODMAP database in Korea, assess intestinal sensitivity to each FODMAP nutrient in Korean IBS patients, and evaluate the severity of symptoms associated with the type of food intake in Korean IBS patients. These findings would help elucidate the role of inadequate nutrient intake in IBS and aid in the preparation of dietary guidelines. Specifically, patients with little knowledge regarding IBS may, even without a diagnosis, avoid consuming food products with FODMAP because of the possible development of symptoms and discomfort after ingestion. As continued ignorance of IBS symptoms may lead to malnutrition or decreased quality of life, it is essential to establish dietary guidelines for patients with IBS in Korea.

This study focused on the intake of FODMAP and the contribution of FODMAP foods to IBS in the Korean population. Nevertheless, it is also necessary to pay attention to the fact that fat intake was significantly higher in the IBS group than in the healthy group. Adequate fat intake has been consistently recommended for patients with IBS [14]. Therefore, to prevent IBS symptoms, appropriate FODMAP and fat intakes should be recommended through dietary guidelines that reflect the food culture and dietary habits of each individual country, enabling easy implementation of these guidelines in individual dietary habits.

Since this study confirmed that the intake of FODMAP in Korean IBS patients is different from that of IBS patients from other countries, it is necessary to determine the effect of Korean dietary patterns on the symptoms of IBS patients in future studies.

Several limitations must be considered when interpreting the present findings. First, we analyzed FODMAP and food intake through a food intake survey conducted among Korean adults. However, the absence of a comprehensive FODMAP database for Korean foods, and the use of data obtained from patients with IBS living in Western countries may have led to an incorrect assessment of the nutrient content of the Korean food items which could vary from their Western counterparts depending on various factors, such as soil quality, production, supply method, and cooking method. Subsequently, the accuracy of the results may have been affected. Follow-up studies must establish a FODMAP database for the gradually increasing number of IBS patients in Korea. Second, we conducted a semi-quantitative dietary intake survey to assess dietary intake. Therefore, it is possible that the participants' memories may have led to inaccurate responses, and the 118 food items may not account for all foods consumed.

Nevertheless, this study is significant in that it objectively assessed the differences in FODMAP intake patterns between Western and Korean adults by collecting baseline data from Korean IBS patients through a dietary intake survey.

## SUPPLEMENTARY MATERIALS

### Supplementary Table 1

FODMAP content in foods (g/100 g)

Click here to view

### Supplementary Table 2

Foods contributing according to the FODMAPs components

Click here to view

### Supplementary Table 3

Foods contributing according to the FODMAPs components by gender

Click here to view

## REFERENCES

1. Buono JL, Carson RT, Flores NM. Health-related quality of life, work productivity, and indirect costs among patients with irritable bowel syndrome with diarrhea. Health Qual Life Outcomes 2017;15:35.
PUBMED | CROSSREF
2. Dong YY, Zuo XL, Li CQ, Yu YB, Zhao QJ, Li YQ. Prevalence of irritable bowel syndrome in Chinese college and university students assessed using Rome III criteria. World J Gastroenterol 2010;16:4221-6.
PUBMED | CROSSREF
3. Alsuwailm WA, Al-Qahtani MM, Al-Hulaibi AA, Al-Hadi MA, Ali SI, Shehabeldeen SA. Irritable bowel syndrome among medical students and interns in King Faisal University. Open J Prev Med 2017;7:235-46.
CROSSREF
4. Quigley EM. Bacterial flora in irritable bowel syndrome: role in pathophysiology, implications for management. J Dig Dis 2007;8:2-7.
PUBMED | CROSSREF
5. Quigley EM. The gut-brain axis and the microbiome: clues to pathophysiology and opportunities for novel management strategies in irritable bowel syndrome (IBS). J Clin Med 2018;7:6.
PUBMED | CROSSREF

6. Halmos EP, Christophersen CT, Bird AR, Shepherd SJ, Gibson PR, Muir JG. Diets that differ in their FODMAP content alter the colonic luminal microenvironment. Gut 2015;64:93-100.
PUBMED | CROSSREF

7. Clausen MR, Jørgensen J, Mortensen PB. Comparison of diarrhea induced by ingestion of fructooligosaccharide Idolax and disaccharide lactulose: role of osmolarity versus fermentation of malabsorbed carbohydrate. Dig Dis Sci 1998;43:2696-707.
PUBMED | CROSSREF

8. Staudacher HM, Irving PM, Lomer MC, Whelan K. Mechanisms and efficacy of dietary FODMAP restriction in IBS. Nat Rev Gastroenterol Hepatol 2014;11:256-66.
PUBMED | CROSSREF

9. Gibson PR, Shepherd SJ. Evidence-based dietary management of functional gastrointestinal symptoms: the FODMAP approach. J Gastroenterol Hepatol 2010;25:252-8.
PUBMED | CROSSREF

10. Whigham L, Joyce T, Harper G, Irving PM, Staudacher HM, Whelan K, Lomer MC. Clinical effectiveness and economic costs of group versus one-to-one education for short-chain fermentable carbohydrate restriction (low FODMAP diet) in the management of irritable bowel syndrome. J Hum Nutr Diet 2015;28:687-96.
PUBMED | CROSSREF

11. Monash University. The low FODMAP diet. Melbourne: Monash University; 2019 [cited 2021 January 15]. Available from: https://www.monashfodmap.com/.

12. Muir JG, Shepherd SJ, Rosella O, Rose R, Barrett JS, Gibson PR. Fructan and free fructose content of common Australian vegetables and fruit. J Agric Food Chem 2007;55:6619-27.
PUBMED | CROSSREF

13. Muir JG, Rose R, Rosella O, Liels K, Barrett JS, Shepherd SJ, Gibson PR. Measurement of short-chain carbohydrates in common Australian vegetables and fruits by high-performance liquid chromatography (HPLC). J Agric Food Chem 2009;57:554-65.
PUBMED | CROSSREF

14. McKenzie YA, Bowyer RK, Leach H, Gulia P, Horobin J, O'Sullivan NA, Pettitt C, Reeves LB, Seamark L, Williams M, et al. British Dietetic Association systematic review and evidence-based practice guidelines for the dietary management of irritable bowel syndrome in adults (2016 update). J Hum Nutr Diet 2016;29:549-75.
PUBMED | CROSSREF

15. Park JH, Byeon JS, Shin WG, Yoon YH, Cheon JH, Lee KJ, Park J; Korean Society of Neurogastroenterology and Motility. Diagnosis of irritable bowel syndrome: a systematic review. Korean J Gastroenterol 2010;55:308-15.
PUBMED | CROSSREF

16. Kwon JG, Park KS, Park JH, Park JM, Park CH, Lee KJ, Park HJ, Rhee JC; Korean Society of Neurogastroenterology and Motility. Guidelines for the treatment of irritable bowel syndrome. Korean J Gastroenterol 2011;57:82-99.
PUBMED | CROSSREF

17. Kim HJ. What is the FODMAP? Korean J Med 2015;89:179-85.
CROSSREF

18. Iacovou M, Tan V, Muir JG, Gibson PR. The low FODMAP diet and its application in East and Southeast Asia. J Neurogastroenterol Motil 2015;21:459-70.
PUBMED | CROSSREF

19. Wang Y, Li S. Worldwide trends in dairy production and consumption and calcium intake: is promoting consumption of dairy products a sustainable solution for inadequate calcium intake? Food Nutr Bull 2008;29:172-85.
PUBMED | CROSSREF

20. Micha R, Khatibzadeh S, Shi P, Andrews KG, Engell RE, Mozaffarian D; Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE). Global, regional and national consumption of major food groups in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys worldwide. BMJ Open 2015;5:e008705.
PUBMED | CROSSREF

21. Shim JS, Shim SY, Cha HJ, Kim J, Kim HC. Socioeconomic characteristics and trends in the consumption of ultra-processed foods in Korea from 2010 to 2018. Nutrients 2021;13:1120.
PUBMED | CROSSREF

22. Biesiekierski JR, Rosella O, Rose R, Liels K, Barrett JS, Shepherd SJ, Gibson PR, Muir JG. Quantification of fructans, galacto-oligosacharides and other short-chain carbohydrates in processed grains and cereals. J Hum Nutr Diet 2011;24:154-76.
PUBMED | CROSSREF

23. Kalala G, Kambashi B, Everaert N, Beckers Y, Richel A, Pachikian B, Neyrinck AM, Delzenne NM, Bindelle J. Characterization of fructans and dietary fibre profiles in raw and steamed vegetables. Int J Food Sci Nutr 2018;69:682-9.
PUBMED | CROSSREF
24. Yao CK, Tan HL, van Langenberg DR, Barrett JS, Rose R, Liels K, Gibson PR, Muir JG. Dietary sorbitol and mannitol: food content and distinct absorption patterns between healthy individuals and patients with irritable bowel syndrome. J Hum Nutr Diet 2014;27 Suppl 2:263-75.
PUBMED | CROSSREF
25. Song KH, Jung HK, Min BH, Youn YH, Choi KD, Keum BR, Huh KC. Development and validation of the Korean Rome III questionnaire for diagnosis of functional gastrointestinal disorders. J Neurogastroenterol Motil 2013;19:509-15.
PUBMED | CROSSREF
26. Oh JY, Yang YJ, Kim BS, Kang JH. Validity and reliability of Korean version of International Physical Activity Questionnaire (IPAQ) short form. J Korean Acad Fam Med 2007;28:532-41.
27. Kim KN, Park JY, Shin TS, Jun KJ, Choi EY, Kim HJ, Lee SH, Yoo TW, Huh BY. Degree of stress and stress-related factors by the Korean version of the BEPSI. J Korean Acad Fam Med 1998;19:559-70.
28. Staudacher HM, Lomer MC, Anderson JL, Barrett JS, Muir JG, Irving PM, Whelan K. Fermentable carbohydrate restriction reduces luminal bifidobacteria and gastrointestinal symptoms in patients with irritable bowel syndrome. J Nutr 2012;142:1510-8.
PUBMED | CROSSREF
29. O'Keeffe M, Jansen C, Martin L, Williams M, Seamark L, Staudacher HM, Irving PM, Whelan K, Lomer MC. Long-term impact of the low-FODMAP diet on gastrointestinal symptoms, dietary intake, patient acceptability, and healthcare utilization in irritable bowel syndrome. Neurogastroenterol Motil 2018;30:e13154.
PUBMED | CROSSREF
30. Miranda J, Vázquez-Polo M, Pérez-Junkera G, Fernández-Gil MD, Bustamante MÁ, Navarro V, Simón E, Martínez O. FODMAP intake in Spanish population: open approach for risk assessment. Int J Environ Res Public Health 2020;17:5882.
PUBMED | CROSSREF
31. Liljebo T, Störsrud S, Andreasson A. Presence of fermentable oligo-, di-, monosaccharides, and polyols (FODMAPs) in commonly eaten foods: extension of a database to indicate dietary FODMAP content and calculation of intake in the general population from food diary data. BMC Nutr 2020;6:47.
PUBMED | CROSSREF
32. Barrett JS, Gibson PR. Development and validation of a comprehensive semi-quantitative food frequency questionnaire that includes FODMAP intake and glycemic index. J Am Diet Assoc 2010;110:1469-76.
PUBMED | CROSSREF
33. Singh GM, Micha R, Khatibzadeh S, Shi P, Lim S, Andrews KG, Engell RE, Ezzati M, Mozaffarian D; Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE). Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. PLoS One 2015;10:e0124845.
PUBMED | CROSSREF