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Research Article

The Impact of Daily Kimchi Consumption: A Pilot Study

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Abstract

Background: Kimchi, a traditional fermented Korean food, contains prebiotics and probiotics, which have demonstrated ability to impact irregular gastrointestinal (GI) symptoms.

Objective: To evaluate the impact of daily kimchi consumption on GI symptoms, sensory characteristics and consumer acceptability of kimchi, and the microbial content in homemade and commercial kimchi.

Design: Dietary intervention study incorporating an experimental design. Participants consumed 75g (½ cup) of kimchi twice a day for 14 days. Instruments included 3-day food records, a modified Gastrointestinal Symptom Rating Scale (GSRS), stool diaries using the Bristol Stool Scale (BSS), and a 7-point Hedonic scale (for sensory analysis and consumer acceptability). Lactic Acid Bacteria (LAB) were enumerated via plating methods.

Participants/Setting: Participants (n=20) experiencing irregular GI symptoms were recruited from a Mountain West university community during fall 2017.

Main Outcome Measures: Main outcomes included GI symptoms, tracking of bowel movements, pre and post response to consumer acceptability, and LAB levels in homemade and commercial kimchi.

Analysis: Analysis included: 1) repeated measures ANOVA ($p<0.05$) for the GSRS and BSS with post-hoc testing for mean comparison between symptoms, 2) paired T-tests to assess mean differences in consumer acceptability and nutrient intake, and 3) culture-based microbial analysis with surface plating methods to determine bacterial counts.

Results: Participants reported a significant decrease in abdominal pain, heartburn, acid regurgitation, abdominal rumbling and distention, and eructation and gas production. Consumer acceptability and sensory characteristics questionnaires showed a majority of participants 'liked' kimchi and were willing to consume kimchi in the future. Bacterial analysis showed homemade kimchi had a lower concentration of LAB compared to commercial kimchi.

Conclusions: Kimchi is a nutrient dense probiotic source, acceptable among consumers in the study, with potential to impact irregular GI symptoms. Understanding consumer perception of kimchi provides valuable insight to when kimchi may be suggested as a method of probiotic and prebiotic intake.

Keywords: Kimchi; gastrointestinal; consumer acceptability; fermented foods; bacterial content; probiotics

Introduction

Fermentation has ancient roots in a variety of cultures. Kimchi, a fermented mixture of cabbage, salt, red peppers, radishes, and a variety of spices, has been a staple to Korean culture for over 4,000 years. [1,2] Lactic acid producing bacteria (LAB) produced during fermentation have been identified as factors that help maintain and improve gastrointestinal (GI) health. [3-5] Irregular GI symptoms affect 14.1% of the total U.S population. [6] The effects of irregular GI symptoms are associated with a severe decrease in quality of life, and a substantial financial burden on society. [6] The dysbiosis of the microbiome and resulting irregular GI symptoms may be induced by a wide variety of circumstances that include consumption of a Westernized diet which is typically high in fat and refined carbohydrates and low in dietary fibre. [7] Supplementation of probiotics may mitigate dysbiosis of the microbiome. [8] Probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host. [9] Research on the use of probiotics to alleviate dietary related GI disorders has shown potential. [3,4,10] With current research demonstrating positive effects with supplementation of LAB, [4,10] and the consumption of a variety of probiotics to maximize diversity and discourage the growth of harmful bacteria, [11] kimchi could provide a viable source of beneficial probiotics.

The bacteria promoted during kimchi fermentation have been demonstrated to act safely and effectively as probiotics. [12] Kimchi also contains prebiotics, such as inulin, a major food source for the growth of probiotic bacteria. Increased efficacy of probiotic supplementation has been demonstrated when prebiotics are present, lending credibility to claims that consumption of kimchi could positively affect the microbiome and improve irregular GI symptoms. [3,11] However, there is a paucity of literature addressing fermented foods in the Western diet and potential impact on the microbiome and GI symptoms. This pilot study examined 1) the impact of habitual consumption of kimchi on irregular GI symptoms and bowel form, 2) consumer acceptability and sensory characteristics of kimchi and 3) the microbial content in homemade and commercial kimchi.

Methods

During fall 2017, healthy participants (n=20) aged 18-40 years, experiencing irregular GI symptoms, but without history of mal-absorptive or inflammatory bowel disease were recruited for a dietary intervention. Exclusion criteria included one or more of the following: diagnosed hypertension (due to high sodium content of kimchi), antibiotic use within past 3 months, current consumption of fermented products, excessive alcohol consumption (>3 drinks/day) (due to potential impact on GI microbiome) [13] and suppressed immune function (due to presence of live bacteria in kimchi). A sample size of 20 was estimated to provide an effect size of 0.8. [14] After initial phone screening to confirm eligibility, written, informed consent was obtained. The study was approved by the Institutional Review Board at the University of Wyoming. For this pilot intervention, participants consumed 75 grams (~½ cup) of kimchi twice a day for 14 days. Gastrointestinal symptoms were assessed at initiation, day 7, and day 14 using the Gastrointestinal Symptom Rating Scale (GSRS) [18] to evaluate the presence and severity of common symptoms associated with food intake.

The GSRS measures abdominal pain, heartburn, acid reflux, nausea and vomiting, borborygmus (stomach rumbling), abdominal distention, eructation (belching), gas production, decreased or increased passage of stools, hard or loose stools, urgent need to defecate, and satisfaction of bowel movement. The GSRS was modified from initial scale (0-3) to allow for consistency with other study questionnaires and each symptom was rated using a 7-point Likert Scale, where 1=no discomfort/presence of symptom and 7=severe discomfort/high frequency. Participants were asked to evaluate each bowel movement over the 14-days using the BSS (a common clinical tool used to evaluate GI transit time). [16] The BSS is a visual scale that depicts 7 types of common bowel forms, ranging from watery diarrhea with no solids (type 7) to constipation depicted as hard, separate lumps (type 1). Bowel formation of 1 or 2 was categorized as slow, 3 or 4 was normal, and 5-7 was fast.

The total number of slow, normal, and fast were represented as a percentage of total bowel movements during the week. Sensory characteristics and overall palatability were assessed by a 7-point Hedonic scale (7=extremely like, 1=extremely dislike) to rate appearance, flavour, texture, aroma, mouthfeel, and overall acceptability. Consumer acceptability and feasibility of including kimchi in their typical diet was assessed using a 7-point Likert scale (7=strongly agree, 1=strongly disagree) for five statements: 'I enjoy consuming fermented foods as part of my regular diet', 'I am aware of different types of fermented foods and how to prepare them', 'I am interested in learning more [5] about the different types of fermented foods', 'I am willing to eat kimchi in the future', and 'I plan on consuming kimchi regularly'. [17] Participants recorded a three-day food diary (including two weekdays and one weekend day) during each week of the study. Training on tracking dietary intake, portion sizes, and guidance to continue with regular diet patterns was provided by the lead researcher and a registered dietitian prior to the initiation of the study.

Food records were examined at the exit interview with discrepancies in portion sizes or unclear entries clarified to increase accuracy. Diaries were utilized to compare and contrast oral dietary intake during the study period and to promote adherence to the kimchi intervention and avoidance of other fermented foods. Three-day food records were analyzed with dietary analysis software (ESHA Food Processor Nutrition Analysis Software, ESHA Products, Salem, OR 2018).

Bacterial Analysis

Culture-based microbial analysis of the fermented kimchi was conducted to enumerate LAB. Three major genera are known to predominate within traditionally fermented kimchi; *Leuconostoc, Lactobacillus*, and *Weissella*. [18] Bacterial enumeration was conducted using surface plating on de Man, Rogosa, and Sharpe (MRS) agar (Thermo Fischer Scientific). X-gal (5Bromo-4-Chloro-3-Indolyl β-D-Galactopyranoside) additive was purchased through Millipore Sigma, previously Sigma-Aldrich, St. Louis, MO. Ten grams of kimchi from the commercial product and homemade kimchi (prepared by a culinary-trained researcher in a controlled campus teaching kitchen) were resuspended in 100ml of sterile saline (0.85% saline) solution in a WhirlPak® (Nasco, Fort Atkinson WI). The samples were mixed by hand for five minutes followed by serial dilutions using saline dilution blanks.

MRS agar or MRS agar supplemented with X-gal were utilized for surface plating. The supplementation with X-gal (chromogenic substrate for β6 galactosidase) provided additional differential discrimination for *Leuconstoc* spp.19 *Leuconostoc* spp. are known to synthesize β-galactosidase enzyme, thus colonies precipitate a blue color upon plating. MRS is commonly used to isolate and enumerate LAB.20Incubation was performed inside an anaerobic chamber containing anaerobic sachets (Thermo Scientific Oxoid anaerogen 2.5L Sachet) at 37° C for 72 hrs. Plating was performed in triplicates and counts were averaged to estimate kimchi microbial load as log10 CFU/g.

Statistical Analysis

Descriptive statistics were performed on all variables. Repeated measures ANOVA was used to assess significant changes in symptoms reported on the GSRS with post-hoc testing (Least Significant Difference, LSD) for mean comparison between symptoms. Frequency of slow, normal, and fast bowel movements reported on the BSS diaries were compared between the first and second week to identify improvement or changes in typical bowel formation and analyzed using repeated measures ANOVA. Post-hoc testing using LSD determined differences between categories. Consumer acceptability pre- and post-intervention was analyzed using a paired T-test. Mean intake of key nutrients including macronutrients, dietary fibre, and sodium were compared from week 1 to week 2 of the study using paired T-test analysis. All statistics were performed using SPSS 24.0 (IBS SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp 2016). The statistical significance was defined as $p<0.05$ for all estimates.

Results

Table 1: Demographics of participants (n=21) consuming kimchi at a Mountain West university.

Characteristic	n (%)
Sex	
Male	9 (42.8%)
Female	12 (57.2%)
Age (years)	
18-20	2 (9.5%)
21-30	15 (71.4%)
31-40	4 (19.1%)
Ethnicity	
Caucasian	15 (71.4%)
Hispanic/Latino	2 (9.5%)
Asian/Pacific Islander	3 (14.3%)
Other	1 (4.8%)
Anthropometrics	**Mean(±SD)**
BMIa	
Male	27.23(±5.18)
Women	27.41(±6.23)
[a]BMI: kg/m^2	

Table 2: Changes in gastrointestinal symptoms as reported on the Gastrointestinal Symptom Rating Scale by participants.

Gastrointestinal Symptoms		Day 1 Mean (±SD)	Day 7 Mean (±SD)	Day 14 Mean (±SD)
Category 1	Abdominal Pain, Heart burn and Acid Regurgitation	8.2 (±3.1)	6.4(±4.3) **	5.2 (±2.9) **
Category 2	Nausea and Vomiting	2.2 (±1.6)	1.4 (±0.8)	1.4 (±0.7)
Category 3	Abdominal rumbling and Distention	7.8 (±2.7)	6 (±2.8) **	5.1 (±2.3) **
Category 4	Eructation (belching) and Increased gas production	7.6 (±2.8)	6.5 (±2.7)	5.2 (±1.9) **
Category 5	Decreased passage of stool, Presence of hard stool, and Feeling of incomplete evacuation	7.9 (±4.2)	7.1 (±2.8)	5.7 (±1.9)
Category 6	Increased passage of stool, Presence of loose stool, and Urgent need to defecate	7.9 (±4.2)	7.9 (±4.7)	7.9 (±3.4)

**Denotes significant difference from Day 1 ($p<0.001$).

Forty individuals were screened with twenty-one individuals meeting inclusion criteria. One participant was lost to attrition on day 6 of the intervention. The GSRS and BSS were collected from individuals who completed the study. Consumer acceptability and sensory [7] characteristics included all twenty-one participants. Participant demographics are displayed in Table 1. Study compliance was assessed using food records or feedback at the exit interview. Gastrointestinal symptoms on the GSRS were grouped into six major categories (Table 2). Symptoms in categories 1, 3, and 4 were improved ($p<0.01$) with kimchi consumption. Normal distribution was confirmed upon analysis using repeated measures ANOVA. Kimchi consumption had no measurable effect on typical stool form. The frequency of slow and normal bowel movements increased slightly, but not significantly ($p=0.673$).

Table 3 contains a complete breakdown of sensory characteristics. More than half (57.1%) of the study population 'liked' the kimchi, and an additional 9.5% "extremely liked" it. Aroma and appearance had the highest occurrence of 'neither dislike nor like' with 28.6% reporting for each. Minor changes in consumer acceptability were seen over the two-week period. The only statement to demonstrate a significant increase was 'I enjoy consuming fermented foods as part of my regular diet' (p=0.007). Comparison of average intake of calories, fat, protein, carbohydrates (CHO), dietary fibre, and sodium (Na) are presented in Table 4. Sodium data for one substantial outlier was excluded from the analysis. No significant differences between week 1 and 2 were detected for any of the selected nutrients.

Table 3: Sensory characteristics reported by participants sampling kimchi at study initiation.

	'Dislike'	'Somewhat dislike'	'Neither dislike nor like'	'Somewhat like'	'Like'	'Extremely like'
Appearance	4.80%	23.80%	23.80%	23.80%	19%	4.80%
Aroma	0%	4.80%	28.60%	4.80%	38.10%	23.80%
Flavour	0%	14.30%	9.50%	38.10%	23.80%	14.30%
Mouthfeel	4.80%	0%	23.80%	14.30%	33.30%	23.80%
Texture	0%	4.80%	19.00%	14.30%	33.30%	28.60%
Overall	0%	0%	14.30%	19.00%	57.10%	9.50%

Table 4: Difference in average intake of selected nutrients between week 1 and week 2 as reported on 3-day food diary.

Nutrient	Recommended intake	Week 1 Intake	Week 2 Intake	p-value
Calories	Individualized	2355 ± 839	2200 ± 825	0.382
Carbohydrate	225-325 g	255 ± 112g	234 ± 92 g	0.302
Protein	50-175 g	88 ± 25g	91 ± 33 g	0.52
Fat	44-78 g	112 ± 54g	100 ± 54 g	0.261
Fibre	25 g women 38 g men	26 ± 10g	24 ± 9 g	0.359
Sodium	1,500 mg	4729 ±1567mg	4100 ±1190mg	0.07

**Denotes significant difference between week 1 and week 2 (p<0.05).

Consumption of ½ cup kimchi twice a day and no additional fermented food intake was confirmed via the food diaries or verbally at the exit interview microbial counts of LAB were determined for both commercial and homemade kimchi. Commercial kimchi found LAB content when plated on MRS agar to be approximately 5.31 log CFU/g. Commercial kimchi plated on MRS with the addition of X-gal found content to be approximately 5.26 log CFU/g. Based on results obtained from plating on X-gal supplemented media, no detectable levels of *Leuconostoc* spp. were discernible. Homemade kimchi plated on MRS and MRS + X-gal, presented slightly lower concentrations of 4.21 log CFU/g and 4.26 log CFU/g respectively with no *Leuconostoc* spp. detected.

Discussion

An emerging number of clinical studies have evaluated the use of probiotics to improve GI disorder. The majority of these studies place emphasis on encapsulated probiotic supplements or probiotic enriched fermented milks/yogurts containing a mixture of LAB and Bifidobacterium spp. A number of these studies have demonstrated subjective improvement with regards to GI symptoms such as belching-abdominal fullness, bloating after meals, difficulty with defecation, and stomach gurgling. [3,21,22] Further research has demonstrated increased efficacy of probiotic supplementation when combined with prebiotic food sources such as inulin compared to probiotics alone. [3,23] Little research is available on the potential of fermented foods to act as beneficial probiotic sources.

Microbiological evaluation of kimchi has demonstrated the presence of a wide variety of LAB with the ability to act safely as probiotics. [12,24] However, limited information is [11] available for the use of kimchi to improve GI symptoms. Studies of probiotic supplementation generally emphasize high concentrations of bacteria and a wide variety of probiotic strains to maximize alleviation of symptoms. [11] In the current study, significant subjective improvement for abdominal pain, heart burn, acid regurgitation, abdominal rumbling and distention, and belching and gas production was observed, which is consistent with other studies. [3,21,22] Stool form was not significantly affected which was corroborated with non-significant changes on participants' BSS. Previous studies have found that probiotic supplementation has little effect on typical stool forms. [4,22] Despite a recent rise in popularity of functional fermented foods, little is reported on consumer acceptability, sensory characteristics, and preference for kimchi. A previous study by Jang et al, evaluating the acceptability of kimchi presented similar findings to the current study in that there was an overall liking and perception of kimchi.25 Jang et al. found that in general, U.S. panelists gave overall liking scores of 6-7 on a 9-point hedonic scale.

The author described this as the liking of kimchi to be 'slightly, to moderately pleasant.' It should be noted that the higher liking of kimchi could have been related to participant's preconceived notion about fermented foods and kimchi in general. It is plausible that some of the participants were attracted to the study due to the opportunity to incorporate kimchi into their regular diet. Food diaries provided insight about the typical diet of participants and allowed for comparison of key nutrients between each week. No significant changes in dietary intake of key nutrients was detected. Caloric intake is based on individual needs, so there are no set averages to assess participant caloric intake. According to the Institute of Medicine, Acceptable Macronutrient Distribution Range (AMDR), 20-35% of kcals should come from fat. [26] For the average 2278 kcal consumed by participants in this study, fat intake was 106 g which provided 41.8% of total kcal, [12] above AMDR recommendations.

The AMDR for protein is 10-35% of kcals. Participant protein intake was 90 g which provided 15.8% of total kcal, meeting the AMDR recommendation. Finally, the AMDR for CHO is 45-65% of kcals. Average CHO intake was 245g which provided 43.0% of kcal, just under the minimum recommendation. Diet, particularly dietary fibre, is a major component that influences GI function and microbiota. [27] Current recommendations for dietary fibre per day are 38g for men and 25g for women under age 50.26 Participant dietary fibre intake ranged from 13 g to 45 g with an average intake of 25g. The mean dietary fibre intake of all individuals 2 years and older in the U.S. population is 16g per day. [28] Kimchi contributed an additional 4g of dietary fibre per day per participant which contributed to dietary fibre intake higher than the national average.

Sodium consumption among participants was well above the 1,500 mg/day recommendation for both men and women, [29] with an average intake of 4,414mg. It was also above the average daily sodium intake (3,400 mg) for individuals over 2 years of age. [30] Consumption of kimchi contributed to this high average intake, as it added 1,400 mg of sodium per day. Kimchi has been evaluated for the impact an individual's health. [24,31-33] However, limited literature elucidates the potential for kimchi to act as a safe and effective probiotic source. [12,24,34] In the current study, bacterial evaluation denoted that the commercial kimchi had LAB concentrations of approximately 5. [31] log CFU/g, which is lower than the suggested concentrations found within traditional fermented kimchi (8log CFU/g) [35] and what is described on the commercial product packing (8.16 log CFU/g). Bacterial concentrations in kimchi are influenced by a variety of factors, specifically variations in raw materials such as vegetable type, harvesting area, season, and supplemental ingredients. [18] Furthermore, LAB has been described as comprising 68.7-98.1% of total bacteria present in kimchi. [35] This study was also not able to detect presence of 13 *Leuconostoc* spp. which are major contributors to the fermentation process.

The reasoning behind the lack of *Leuconostoc* spp. remains unclear. *Leuconostoc* spp. have been seen to predominate in the earlier stages of fermentation,18,36 thus microbial succession could be a reason. However, some strains such as, Le. *gasicomitatum*, have been seen to increase in later stages of fermentation, [37] which should be detectable by the plating methods utilized in our study due to their β-galactosidase activity.38 Despite the unclear reasoning for the lack of detectable *Leuconostoc* spp., this may prove to be advantageous for classifying kimchi as a probiotic rich food. *Leuconostoc* spp. have demonstrated low survival rates when passing through the GI tract31 which is vital for the classification as a probiotic. However, Lactococcus and Lactobacillus spp. have been validated to act as efficient probiotic bacteria. [24] While the microbial analysis followed previous literature for developing laboratory protocols [18,19] the study was limited to analysing presence of LAB, not total microbial content, thus estimations cannot be extrapolated to all commercial products. More so, while this study demonstrated improved symptoms, participants were aware of the intent of the study which could have induced the placebo effect.

Conclusions & Recommendations

Kimchi allows for inclusion of a nutrient dense vegetable source that has potential to impact GI health. Importantly, kimchi may provide a feasible and palatable method of supplementing probiotics within the diet and provides health professionals with an additional option to recommend to patients or clients. Further exploration of the impact of kimchi consumption would be beneficial in corroborating the evidence found within this study.

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