



Original article

Antiobesity effects of *kimchi* in diet-induced obese mice

Meizi Cui^a, Hee-Young Kim^a, Kyung Hee Lee^a, Ji-Kang Jeong^{a, b}, Ji-Hee Hwang^c,
Kyu-Young Yeo^c, Byung-Hee Ryu^c, Jung-Ho Choi^c, Kun-Young Park^{a, b, *}

^a Department of Food Science and Nutrition, Pusan National University, Busan, South Korea

^b Kimchi Research Institute, Pusan National University, Busan, South Korea

^c Daesang FNF Corporation R&D Center, Icheon, Gyeonggi, South Korea

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ABSTRACT

Background: The present study was investigated to confirm the antiobesity effect of *kimchi* in high-fat diet-induced obese C57BL/6 mice.

Methods: Mice in the high-fat diet (HFD) group, standardized *kimchi* (S-Kimchi) group, and Korean commercial *kimchi* (D-Kimchi) group, but not in the normal-diet group, were fed a high-fat diet (HFD) for the first 4 weeks to induce obesity. From the 5th to 8th weeks, the S- and D-Kimchi groups were fed an HFD containing 10% of S-Kimchi or D-Kimchi, respectively. After 8 weeks, mice were sacrificed and obesity-related factors were determined.

Results: Body and adipose tissue weights were significantly lower in the *kimchi*-treated groups than in the HFD group. In particular, in the D-Kimchi group, serum levels of triglyceride, total cholesterol, low-density lipoprotein-cholesterol, insulin, and leptin were significantly lower, and serum levels of high-density lipoprotein-cholesterol and adiponectin were markedly higher than those in the HFD group. Moreover, hepatic mRNA expression of adipogenesis-related genes (CCAAT/enhance-binding protein- α , peroxisome proliferator-activated receptor- γ , sterol regulatory element-binding protein-1c, and fatty acid synthase) in the *kimchi*-treated groups were lower than those in the HFD group, but fatty acid oxidation-related carnitine palmitoyltransferase-1 expressions were higher. In addition, *kimchi* decreased the mRNA levels of the inflammation-related monocyte chemoattractant protein-1 and interleukin-6 in epididymal fat tissue.

Conclusion: Administration of *kimchi*, especially of D-Kimchi, which contained *Leuconostoc mesenteroides* DRC 0211 starter and other subingredients, exhibited antiobesity activity by reducing body weight gains and adipose tissue weights; modulating serum lipid profiles and hepatic lipogenesis; regulating serum insulin, leptin, and adiponectin levels; and reducing adipocyte size and inflammatory response in epididymal fat tissues.

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1. Introduction

Kimchi is a traditional Korean fermented vegetable food prepared with *baechu* cabbage and other beneficial subingredients by lactic acid bacterial fermentation at a low temperature (4°C) [1]. *Kimchi* is low in calories (~18 kcal/100 g) and contains high levels of vitamins (such as vitamins A, C, B complex, K, and others), β -carotene, minerals (such as Na, Ca, K, Fe, and P), dietary fiber, and

functional phytochemicals (such as benzyl isothiocyanate, indoles, thiocyanates, and sitosterols) that promote human health [1].

Many authors have reported that *kimchi* has beneficial properties, which include antimutagenic [2], anticancer [3], antioxidant [4], antiaging [5], antiatherogenic [6], and antidiabetic [7] activities, and fibrinolytic effects [8]. Furthermore, many studies have demonstrated the antiobesity effect of *kimchi* in animals [9,10] and humans [11]. Recently, it was reported that subingredients can improve the health benefits of *kimchi* [12,13], and that the inoculation of a pure culture starter, with *Weissella koreensis* or *Leuconostoc (Leu.) citreum*, increases the antiobesity effects of *kimchi* in high-fat diet-induced obese (DIO) mice [9], and improves the shelf life and quality of *kimchi* [14].

* Corresponding author. Department of Food Science and Nutrition, Pusan National University, 2 Busandaehak-ro, 63-bunkil, Geumjeong-gu, Busan 609-735, South Korea.

E-mail address: kunypark@pusan.ac.kr (K.-Y. Park).

Over recent years, the consumer trend is toward commercial *kimchi*. According to one report [15], over the past 7 years, the amount of *kimchi* consumed in Korea has remained constant, but the percentage accounted for by home-made *kimchi* has decreased (64.6% in 2007 and 60.0% in 2013), whereas commercial *kimchi* consumption has increased (35.3% in 2007 and 40.0% in 2013). Owing to the expanding commercial market, studies on *kimchi*-related probiotics and starter cultures have resulted in the development of commercial *kimchis* with added vegetables and in the use of lactic acid bacteria strains as a starter, such as *Leu. mesenteroides*, *Leu. citreum*, or *Lactobacillus plantarum*, with constant quality, enhanced tastes, and health-promoting benefits.

Obesity, which is a component of metabolic syndrome, is associated with excess energy intake and low energy expenditure, and is characterized by weight gain, type 2 diabetes, hypertension, nonalcoholic fatty liver, glucose intolerance, inflammatory response, and coronary heart disease and cancer development associated with insulin resistance [16]. Obesity rates continue to increase worldwide and now exceed 30% in Mexico, New Zealand, and the United States. Thus, obesity is a major health problem worldwide [17].

The basic molecular imbalance driving obesity is that between lipogenesis and lipolysis. These processes are regulated in the liver and adipose tissues by multienzyme systems, such as CCAAT/enhance-binding protein- α (C/EBP- α), sterol regulatory element-binding protein-1c (SREBP-1c), peroxisome proliferator-activated receptor- γ (PPAR- γ), fatty acid synthase (FAS), and carnitine palmitoyltransferase-1 (CPT-1) [18,19].

Some drugs used to treat clinical obesity are associated with adverse effects such as nausea, insomnia, constipation, gastrointestinal problems, and potential adverse cardiovascular effects [20]. Therefore, efforts are being made to find and develop antiobesity foods and food ingredients that effectively reduce body fat accumulation, reduce the risk of obesity-related chronic diseases, and minimize the side effects in clinical treatment [21,22].

The present study was designed to investigate the antiobesity activities of home-made and commercial *kimchi* (containing *Leu. mesenteroides* DRC 0211 as starter and several subingredients) in high-fat DIO mice, by determining weight loss effects after 4 weeks of obesity induction, followed by 4 weeks of *kimchi* administration. In addition, mechanisms responsible for their antiobesity effects were also investigated.

2. Materials and methods

2.1. Sample preparation

Standardized *kimchi* (S-Kimchi) was developed by the Kimchi Research Institute at Pusan National University (Busan, Korea), and prepared using the following ingredients: 13.0 g radish, 2.0 g green onion, 3.5 g red pepper powder, 1.4 g garlic, 0.6 g ginger, 2.2 g anchovy juice, and 1.0 g sugar, in 100 g of brined *baechu* cabbage [23].

A Korean commercial *kimchi* manufactured by Daesang FNF (D-Kimchi; Icheon, Korea), which was the most consumed commercial *kimchi* in 2012 [24], was used in the present study. D-Kimchi is prepared using the following ingredients: 18.0 g radish, 3.5 g red pepper powder, 3.8 g garlic, 0.5 g ginger, 2.5 g leek (*Allium tuberosum*), 1.5 g green onion, 3.5 g anchovy juice, 3 g sea tangle extract, and 8 g rice starch in 100 g of brined *baechu* cabbage; it was inoculated with 10^6 colony-forming units/g *Leu. mesenteroides* DRC 0211.

Kimchi samples were fermented at 4°C until pH values reached 4.3 (optimum for the ripened state) and then freeze-dried to prepare the experimental diets.

2.2. Animals and treatment

Male C57BL/6J mice (6-week old, 18 ± 0.5 g) were purchased from Samtako Bio Korea (Osan, Korea) and housed under standard conditions (50–60% relative humidity, under a 12-hour dark/12-hour light cycle). Food and water were supplied *ad libitum*.

Animals were randomly divided into four groups of eight mice each: the ND group was administered a normal diet (ND; AIN-93G diet) for 8 weeks; the HFD group was provided a high-fat diet (HFD; 45% lard oil in AIN-93G diet) for 8 weeks, and the S- and D-Kimchi groups were fed the HFD diet for the first 4 weeks and the HFD diet containing 10% of freeze-dried S-Kimchi or D-Kimchi, respectively, for the remaining 4 weeks. Compositions of the experimental diets are provided in Table 1.

Body weights and food intakes were checked weekly, and animals were sacrificed on the last day of the 8-week experimental period. The protocol used in this study was approved by the Institutional Animal Care and Use Committee of Pusan National University (PNU-IACUC) (approval number PNU-2013-0455).

2.3. Serum and tissue preparation

At the end of the experiment, blood samples were collected from the inferior vena cava of each animal. Serum was separated from blood by centrifugation at 3,000g for 10 minutes at 4°C. Organs of interest, that is, liver, epididymal fat, and perirenal fat tissues, were surgically removed immediately, washed with cold normal saline, wiped with a paper towel, and weighed. Serum and organ samples were stored at -80°C for further study.

2.4. Serum lipid, insulin, leptin, and adiponectin analysis

Serum levels of triglyceride (TG), total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-c), and low-density lipoprotein-cholesterol (LDL-c) were measured using a commercial kit (Asan Pharmaceutical Co., Seoul, Korea), and serum levels of insulin, leptin, and adiponectin were measured using a commercial enzyme-linked immunosorbent assay kit (R&D System, Minneapolis, MN, USA).

Table 1

Compositions of experimental diets used in the animal study.

Ingredient (g/1,000 g diet)	Experimental diet		
	HFD	S-Kimchi	D-Kimchi
Casein	245	220.5	220.5
L-Cystine	3.5	3.15	3.15
Corn starch	85	76.5	76.5
Maltodextrin	115	103.5	103.5
Sucrose	200	180	180
Cellulose	58	52.2	52.2
Soybean oil	30	27	27
Lard	195	175.5	175.5
Mineral mix, AIN-93G-MX	43	38.7	38.7
Calcium phosphate, dibasic	3.4	3.06	3.06
Vitamin mix, AIN-93-VX	19	17.1	17.1
Choline bitartrate	3	2.7	2.7
Red food color	0.1	0.09	0.09
S-Kimchi	—	100	—
D-Kimchi	—	—	100
Calories (kcal)	4,659	4,659	4,659

The ND group received ND (AIN-93G diet), the HFD group received a high-fat diet for 8 weeks, the S-Kimchi group received an HFD for 4 weeks followed by the same HFD containing 10% standard *kimchi* for 4 weeks, and the D-Kimchi group received the HFD for 4 weeks and HFD containing 10% commercial D-Kimchi for the next 4 weeks.

D-Kimchi, Korean commercial *kimchi*; HFD, high-fat diet; ND, normal diet; S-Kimchi, standardized *kimchi*.

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