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Antiobesity Effect of *Baek-Kimchi* (Whitish *Baechu Kimchi*) in Rats Fed High Fat Diet

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Abstract

***Baek-kimchi* (whitish *baechu kimchi*) was evaluated for anti-obesity properties and effects on triglyceride (TG) and cholesterol in blood and adipose tissues in rats fed a high fat (20%) diet, and compared to the similar effects of *baechu kimchi*. *Baek-kimchi* does not use red pepper powder but contains higher levels of sliced radish and pear than *baechu kimchi*. SD rats were raised for four weeks on either a normal diet (ND, based on the AIN-93M diet), high fat diet (HFD, supplemented with 16% lard oil in the ND), or HFD containing 5% *baek-kimchi* or 5% *baechu kimchi*. Feed consumption was not different among the groups, but weight gains were significantly lower in the groups fed either the normal diet or HFD with *baek-kimchi* or *baechu kimchi* diets than the group fed HFD alone. The weights of liver and epididymal and perirenal fat pads in *baek-kimchi* and *baechu kimchi* diet groups were lower than those of the HFD groups, but the *baek-kimchi* diet group had lower epididymal and perirenal fat pad weights than the *baechu kimchi* diet group ($p < 0.05$). The *baechu kimchi* dietary group also had significantly lower triglyceride and cholesterol contents in liver and epididymal and perirenal fat, reversing the higher levels seen in HFD. *Baek-kimchi* and *baechu kimchi* diets were also effective in lowering serum triglyceride and cholesterol levels ($p < 0.05$). These results suggest that *baek-kimchi* and *baechu kimchi* consumption can reverse the effects of HFD on weight gain and blood and tissue lipids, and that *baek-kimchi* is more effective than *baechu kimchi*. The greater effect is probably due to the higher content of radish and pear used in *baek-kimchi*.**

Key words: *baek-kimchi*, *baechu kimchi*, high fat diet, rat, antiobesity

INTRODUCTION

Obesity is a global public health problem, affecting about 315 million people world-wide (1). The increasing prevalence of obesity is associated with a massive increase in metabolic disease, which is also a major public health problem (2). The major reason for the increase in these conditions is imbalance between energy intake and energy expenditure. This imbalance is largely due to increasing food availiability and intake (both of total energy and of fat) and a reduction in physical activity (3). High fat diets are especially implicated in body weight gain and increase the lipid and cholesterol content of organ tissues (4,5). Because metabolic syndrome and obesity are rapidly accelerating pandemics, a global since of urgency has resulted in intense research efforts to identify safe and effective dietary components with direct and/or indirect anti-obesity properties. Among traditional Korean foods, *kimchi* has attracted public attention. *Kimchi*, a traditional Korean fermented vegetable food, has been recongnized in recent years to be a health-promoting functional food. The most popular *kimchi* is '*baechu* (Korean cabbage) *kimchi*' made with *baechu* cabbage and secondary ingredients such as red pepper powder, green onion, ginger, garlic, radish, etc. *Kimchi* is a rich source of vitamins, minerals, dietary fiber, lactic acid bacteria and fermented phytochemicals (6). *Kimchi* is known to inhibit mutagenicity (7), carcinogenocity (8), oxidation processes (9) and atherosclerosis (10-12). *Kimchi* also enhances immune function (13), relieves toxicity in skin (14) and has antithrombotic effects (15). *Kimchi* was also reported to function as a regulator of lipid metabolism (16).

Due to the economic growth and westernized life style, many Koreans prefer processed animal food to *kimchi* and dislike of the hot taste of *kimchi* is increasing (17). *Baek-kimchi*, a watery Korean pickled cabbage prepared without a fish source or red pepper powder, is an alternative *kimchi* for people who dislike the strong flavor of *kimchi*. *Baek-kimchi* is neither salty nor hot, so it can be consumed in relatively large quantities without discomfort. Thus the use of *baek-kimchi* is expected to in-

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crease.

Research into the functionalities of *kimchi* have largely focused on *baechu kimchi*. Thus, in this study we investigated the effect of *baek-kimchi* on body weight and organ lipids in male Sprague-Dawley rats fed 16% lard oil diets for 4 week. Body, organ and fat pad weights; as well as total lipids, triglycerides and cholesterol concentrations in blood and tissues, were compared and used to evaluated the relative antiobesity effects of *baek-kimchi* and *baechu kimchi*.

MATERIALS AND METHODS

Animal experiment

Twenty four 4 week old male Sprague-Dawley rats, weighting approximately 110 g, were purchased from the Korean Experimental Animal Center (Daegu, Korea). Rats were acclimated to the experimental facility for 1 week. The rats were divided into 4 groups of 6 and individually housed in polycarbonate cages in a room maintained at 22±1°C and 55±5% relative humidity. The room was exposed to alternating 12-hr periods of light and dark. All rats were allowed free access to their respective diets and drinking water for 4 weeks. Food intake was measured daily and body weight weekly.

Preparation of *baek-kimchi* and *baechu kimchi*

Kalackshin 1 ho *baechu* cabbages (cultivated in Gimhae, Korea), radish, red pepper powder (cultivated in Youngyang, Gyeongbuk, Korea), garlic, ginger, dropwort, pear, annchovy juice (Daesang Co., Chunan, Korea), and chunil salt (Wooil Co., Busan, Korea) were purchased from a local market in Busan, Korea.

Baechu cabbage was cut into 4 pieces, soaked in 10% brine for 10 hours, rinsed three times with tap water and then drained for 3 hours. The ingredients and their proportions for *baek-kimchi* and *baechu kimchi* are shown in Table 1. The final salt concentration of *baek-kimchi* was adjusted to 2.0% and for *baek-kimchi* juice to 0.9%. The final salt concentration of *baechu kimchi* was adjusted to 2.5%. *Baechu kimchi* was prepared by the standardized recipe of the Kimchi Institute (18). The *baek-kimchi* and *baechu kimchi* were fermented at 5°C to pH 4.3 (the optimally ripened *kimchi*). The fermented *baek-kimchi* and *baechu kimchi* were freeze-dried and powdered.

Table 1. Ingredients and composition (%) of *baek-kimchi* and *baechu kimchi*

	Baek-kimchi	*Baechu kimchi*
Baechu cabbage	100.0	100.0
Radish	20.0	13.0
Green onion	0.8	2.0
Garlic	0.8	1.4
Ginger	0.5	0.6
Red pepper powder	-	3.5
Anchovy juice	-	2.2
Sugar	-	1.0
Dropwort	1.4	-
Pear	3.6	-
Final salt concentration	2.0	2.5

Experimental diets

The experimental diets consisted of a normal diet (ND) based on the AIN-93M diet (19); high fat diet (HFD, ND supplemented with 16% lard oil); and the HFD with 5% *baek-kimchi* or *baechu kimchi*. Casein was purchased from PC&S, Korea. Starch, lard oil, cellulose (fiber), mineral, vitamin, L-cystein, methionine, TBHQ, soy bean oil and choline bitartrate were purchased from SIGMA Co., USA. Dextrinized corn starch, mineral and vitamin, were purchased from Dyåts Inc., USA. The compositions of the experimental diets are shown in Table 2.

Measurement of body weight and feed consumption

Body weight was measured every week and rounded to the second decimal place. Feed consumption was measured every day. Feed efficiency ratio (FER) was calculated as daily weight gain in grams divided by daily dietary intake in grams.

Preparation of organ tissues for lipid analyis

After 4 weeks on the experimental diets, the rats were anesthetized with dry ice. Blood samples were taken from the interior vena cava, and the plasma separated by centrifugation (Vision, VS-15CFU refrigerated centrifuge, Gyeonggi, 3000 rpm, for 15 min) and stored at -20°C until assayed. The liver, spleen, kidney, epididymal fat pad and perirenal fat pad were excised, weighed and stored at -20°C until assayed.

Quantitation of total lipid, triglyceride, cholesterol

The concentrations of plasma triglyceride and cholesterol were assayed enzymatically using commercial kits (Asan pharms. Co., Korea). Total lipid in liver and adipose tissues were extracted by the method of Folch et al. (20) and weighed. Triglyceride and cholesterol concentration in liver and adipose tissues were assayed enzymatically by a commercial kits (Asan pharms. Co.,

Table 2. Proximate analysis of *baek-kimchi* and *baechu kimchi* (Unit: %)

Item	Water	Crude fat	Crude protein	Crude ash	Crude fiber
Baek-kimchi	15.66±0.14	1.01±0.10	15.62±0.57	15.62±0.57	6.37±0.13
Baechu kimchi	16.89±0.14	2.75±0.04	14.97±0.31	21.36±0.17	10.76±0.58

Table 3. Preparation and compositions of the normal diet, high fat diet (HFD) and samples added to the high fat diet (g/100 g diet)

	ND[1]	HFD[2]	HFD + *Baek-kimchi*[3]	HFD + *Baechu kimchi*[4]
Casein	14.0	14.0	13.22*	13.25*
L-cystein	0.18	0.18	0.18	0.18
Corn starch	46.57	30.57	28.95*	28.91*
Dextrinized corn starch	15.5	15.5	15.5	15.5
Sucrose	10.0	10.0	10.0	10.0
Fiber	5.0	5.0	4.68*	4.46*
Soybean oil	4.0	4.0	3.95*	3.86*
AIN-93 mineral Mix.	3.5	3.5	3.5	3.5
AIN-93 vitamin Mix.	1.0	1.0	1.0	1.0
Cholin bitartrate	0.25	0.25	0.25	0.25
TBHQ (mg)	0.8	0.8	0.8	0.8
Lard oil		16.0	16.0	16.0
Baek-kimchi			5.0	
Baechu kimchi				5.0
Total	101.8	102.8	102.71	103.03

[1]Normal diet is based on the AIN-93M diet (19).
[2]Contains 16% lard oil added to the normal diet.
[3]High fat diet+5% *baek-kimchi*.
[4]High fat diet+5% *baechu kimchi*.
*Adjusted quantities from the proximate analysis of 5% *baek-kimchi* and *baechu kimchi*, respectively.

Korea) with the aid of a detergent, triton X-100.

Statistical analysis

All statistical analyses were performed on a SAS program (SAS, 1997). Significant difference among the treatment means were determined using Duncan's multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Body weight of the rats

The group fed the HFD, containing 16% lard oil, had a significantly higher final body weight (342.2±3.3 g) than rats fed the normal diet (303.5±6.3 g, $p<0.05$). However, the final body weight of the group fed the HFD diet plus *baek-kimchi* was the same as that of the normal diet group. *Baechu kimchi* diet reduced weight gains to an intermediate value between normal and HFD. *Baek- kimchi*, which does not contain red pepper powder, was more effective than *baechu kimchi* for reducing weight gain. Thus other sub-ingredients of *baek-kimchi* may play a greater role than red pepper powder in preventing weight gain.

Weight of organs and fat pads

Weights of liver, epididymal and perirenal fat pad (g/100 g body weight) were significantly higher in HFD group than in ND group. The addition of *baek-kimchi* to the HFD negated the effect of HFD on liver weight, but *baechu kimchi* addition had an intermediate effect. Weights of epididymal and perirenal fat pads in *baek-kimchi* and *baechu kimchi* diet groups were significantly reduced. *Baek-kimchi* showed a greater effect than *baechu kimchi* in reducing fat pad weights. The weights of

Table 4. Changes in the body weight, food intake and food efficiency ratio (FER) of rats fed experimental diets

	ND[1]	HFD[2]	HFD + *Baek-kimchi*[3]	HFD + *Baechu kimchi*[4]
Body weight				
Initial weight (g)	150.7±6.2[NS6]	143.9±24.7	152.5±9.6	151.6±7.6
Final weight	303.5±6.3[c7]	342.2±3.3[a]	318.9±9.1[bc]	329.6±12.5[ab]
Weight gain (g/day)	5.1±0.1[b]	6.6±0.8[a]	5.5±0.2[b]	5.9±0.4[ab]
Food intake (g/day) & FER				
Food intake (g/day)	19.8±0.2[NS]	19.8±0.3	19.8±0.2	19.3±0.2
Food efficiency ratio[5]	0.26±0.01[b]	0.33±0.05[a]	0.28±0.01[b]	0.28±0.02[b]

[1]Normal diet (AIN-93M).
[2]High fat diet.
[3]High fat diet+5% *baek-kimchi*.
[4]High fat diet+5% *baechu kimchi*.
[5]Calculated as daily weight gain/daily dietary intake.
[6]NS: Not significant.
[7]Means with different letters in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.

Table 5. The weight ratio of liver, spleen, kidney and adipose tissue in rats fed experimental diets for 4 weeks

Organ weight (g/100 g BW)	ND[1)]	HFD[2)]	HFD + *Baek-kimchi*[3)]	HFD + *Baechu kimchi*[4)]
Liver	3.0±0.2[b5)]	3.8±0.3[a]	3.3±0.3[b]	3.4±0.1[ab]
Spleen	0.2±0.1[NS6)]	0.2±0.0	0.2±0.0	0.2±0.0
Kidney	1.0±0.0[NS]	0.9±0.0	0.9±0.1	0.9±0.0
Epididymal fat pad	0.9±0.3[c]	2.1±0.1[a]	1.1±0.1[c]	1.6±0.2[b]
Perirenal fat pad	1.0±0.0[c]	1.8±0.1[a]	0.9±0.1[c]	1.2±0.1[b]

[1)]Normal diet (AIN-93M).
[2)]High fat diet.
[3)]High fat diet+5% *baek-kimchi*.
[4)]High fat diet+5% *baechu kimchi*.
[5)]Means with different letters in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.
[6)]NS: Not significant.

Table 6. Effect of *kimchi* diet on total lipid in liver, epididymal fat pad, and perirenal fat pad in rats

	ND[1)]	HFD[2)]	HFD + *Baek-kimchi*[3)]	HFD + *Baechu kimchi*[4)]
Liver (mg/g, wet wt)				
Total lipid	4.3±0.6[c5)]	6.5±0.3[a]	4.3±0.4[c]	5.2±0.5[b]
Triglyceride	110±11.2[c]	190.2±2.5[a]	99.3±3.0[c]	131.1±13.7[b]
Cholesterol	21.6±1.9[bc]	43.7±4.8[a]	20.0±1.1[c]	25.5±1.2[b]
Epididymal fat pad (mg/g, wet wt)				
Total lipid	61.6±6.8[c]	81.7±4.2[a]	68.6±3.0[bc]	72.4±0.9[b]
Triglyceride	95.0±5.2[c]	140.9±8.0[a]	103.0±6.4[bc]	109.6±3.2[b]
Cholesterol	23.9±1.3[c]	45.3±5.8[a]	21.6±0.5[c]	35.6±4.2[b]
Perirenal fat pad (mg/g, wet wt)				
Total lipid	64.4±2.0[c]	76.9±2.5[a]	65.7±2.0[bc]	69.3±1.2[b]
Triglyceride	135.5±11.2[b]	198.8±10.9[a]	136.9±8.7[b]	142.3±11.0[b]
Cholesterol	25.1±2.8[c]	41.2±2.1[a]	25.7±0.8[bc]	28.9±1.0[b]

[1)]Normal diet (AIN-93M).
[2)]High fat diet.
[3)]High fat diet+5% *baek-kimchi*.
[4)]High fat diet+5% *baechu kimchi*.
[5)]Means with different letters in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.

epididymal and perirenal fat pad were almost identical in the *baek-kimchi* and normal diet, suggesting that *baek-kimchi* completely reversed the effect of HFD ($p<0.05$).

Lipid contents in liver, epididymal and perirenal fat pad

Hepatic total lipids, triglyceride and cholesterol in the groups fed *baek-kimchi* and *baechu kimchi* were significantly lower than in the HFD group; the lowest concentrations were in the *baek-kimchi* group.

Lipid, triglyceride and cholesterol contents in fat pads of groups fed diets containing both *baek-kimchi* and *baechu kimchi* were significantly lower compared to the HFD group ($p<0.05$), but again the effect was the greatest in the *baek-kimchi* diet group. These results indicated that *baek-kimchi* and *baechu kimchi* stimulate lipid metabolism in adipose tissues and effectively inhibit adipose lipid accumulation caused by HFD.

Lipid contents in blood

Plasma triglyceride and cholesterol concentrations in the HFD group were higher than those in the normal group. Triglyceride concentrations of the *baek-kimchi* and *baechu kimchi* diet groups were the same as the normal diet group ($p<0.05$). Cholesterol concentrations were showed similar tendency as triglyceride, but the

Table 7. The effect of *kimchi* diets on serum lipid concentrations in rat

	ND[1)]	HFD[2)]	HFD + *Baek-kimchi*[3)]	HFD + *Baechu kimchi*[4)]
Triglyceride	68.1±9.8[b5)]	99.1±7.2[a]	70.7±8.2[b]	85.3±5.5[b]
Cholesterol	44.8±3.2[c]	66.3±11.0[a]	47.5±0.5[bc]	51.2±1.1[ab]

[1)]Normal diet (AIN-93M).
[2)]High fat diet.
[3)]High fat diet+5% *baek-kimchi*.
[4)]High fat diet+5% *baechu kimchi*.
[5)]Means with different letters in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.

baek-kimchi group had lower cholesterol concentration than did the *baechu kimchi* group.

In this study, we compared the antiobesity effects of *baek-kimchi* and *baechu kimchi*. Both *kimchis* decreased body fatness and lipid content in tissues of rats. However, *baek-kimchi* had an even greater anti-obesity activity than did *baechu kimchi*. It is common knowledge that *kimchi* decreases total lipids, triglycerides and cholesterol in serum, liver and fat pad by increasing lipid metabolism and lipid excretion via feces (21-23). However in this experiment *baechu kimchi* did not show the greater effect, this may be because *baechu kimchi* amounted to only 5% of the diet. It may also be due to a difference in the sub-ingredient content between *baek-kimchi* and *baechu kimchi*. *Baek-kimchi* contains 7% more radish and 3.6% pear, which is not in *baechu kimchi* (Table 1). Radish was reported as an antiobesity vegetable (24). Dietary fiber in radish decreased total lipids, triglycerides and cholesterol concentration in plasma by fecal exceretion of lipid. It has also been suggested that flavonoids such as keamferol have hypolipidemic effect (24). It has also been suggested that flavoniods interfere with intestinal absorption of lipid (25, 26). In this experiment, freeze-dried radish did not contain more dietary fiber than other ingredients (Table 2). Thus, phytochemicals such as flavonoids may have contributed to the hypolipidemic effect. Flavonoids also inhibit HMG-CoA reductase activity and probably exert an influence on steroid metabolism thus contributing to the reduction of blood cholesterol (27). It was also reported that the polyphenol fraction isolated from pear reduces fat accumulation (28). Further study is needed to identify the phytochmicals and interactions among sub-ingredients in *baek-kimchi* to elucidate its anti-obesity and hypolipidemic properties.

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