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Antiobesity Effect of Major Korean Spices (Red Pepper Powder, Garlic and Ginger) in Rats Fed High Fat Diet

Ji-Young Yoon, Keun-Ok Jung, Jeung-Ha Kil and Kun-Young Park†

Department of Food Science and Nutrition, Pusan National University, Busan 609-735, Korea

Abstract

Commonly used spices in Korean cooking (red pepper powder, garlic, ginger) were evaluated for antiobesity properties and effects on triglyceride (TG) and cholesterol in blood and adipose tissues in rats fed a high fat (20%) diet. 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 diets containing 5% red pepper powder (RPP), garlic or ginger. These spices significantly decreased weight gain compared to HFD, but garlic and ginger showed a greater effect on reducing weight gain than RPP. The weights of liver and epididymal and perirenal fat pads in garlic and ginger diet groups were lower than those of the HFD groups ($p < 0.05$). The garlic and ginger also decreased triglyceride and cholesterol contents in liver and epididymal and perirenal fat pad, reversing the higher levels seen in HFD. RPP, garlic and ginger supplemented diets were effective in lowering serum triglyceride and cholesterol levels ($p < 0.05$). These results indicated that garlic and ginger more effectively suppressed the effects of HFD on body fat gain and lipid values of adipose tissues and serum than RPP.

Key words: red pepper powder, garlic, ginger, high fat diet, antiobesity

INTRODUCTION

Obesity is the most prevalent nutritional disorder (1). Obesity is defined as an excess of body weight that is mainly attributable to an increased body fat accumulation and induced by an imbalance of energy intake and expenditure. Overweight carries an increased risk of health problems such as cardiovascular disease, insulin resistance, diabetes, hyperlipidemia, hypertension, gallbladder disease, certain cancers, and premature mortality (2). As such, the effects of dietary components on lipid metabolism have recently received considerable attention, thereby highlighting the importance of naturally occurring compounds as lipid metabolism regulators. From this point of view, Korean major spices such as red pepper powder, garlic and ginger have been attracted public attention.

Red pepper, especially red 'hot' pepper (*Capsicum annuum* L.), garlic (*Allium sativum* L.) and ginger (*Zingiber officinale* Rosc.) are commonly used Korean spices that have been used as a raw material in many traditional preparations since ancient times. Capsicum species, hot pepper, are important culinary plants and have been used world wide as food, spices and medicines. Red pepper has been shown to increase plasma catecholamine levels, induced lypolysis (3) and can reverse the effects of a high fat diet on body weight and blood and tissue lipids (4). Evidence from several studies points to the fact that garlic can exert the normalization of plasma lipids (5-7), enhancement of fibrinolytic activity (8), inhibition of platelet aggregation (9), and reduction of blood pressure (10) and glucose (11). Ginger is known to be effective as appetite enhancer, anti-cold, anti-inflammatory agent (12). Several studies have suggested that ginger could be used as an cholesterol-lowering (13), antihyperlipidemic (14), and antithrombotic agents (15).

In this study, we investigated the effect of three major Korean spices (red pepper powder, garlic and ginger) on body weight and organ lipids in male Sprague-Dawley rats fed 16% lard oil diet for 4 weeks. Body, organ and fat pad weights; and total lipids, triglycerides and cholesterol concentrations in blood and tissues, were compared and used to evaluate the relative antiobesity effect of the major Korean spices.

MATERIALS AND METHODS

Animal experiment

Twenty four 4 week old male Sprague-Dawley rats, weighting approximately 110 g, were purchased from the

†Corresponding author. E-mail: kunypark@pusan.ac.kr
Phone: +82-51-510-2839, Fax: +82-51-514-3138

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 spices

Red pepper (*Capsicum annum* L.) powder, garlic (*Allium stavinm* L.) and ginger (*Zingiber officinale* Rosc.) were purchased from a local market in Busan, Korea, freeze-dried, and powdered. Red pepper powder was cultivated Youngyang, Gyeongsangbuk-do, Korea. Garlic and gingers were cultivated in Namhae, Gyeongsangnam-do, Korea.

Experimental diets

The experimental diets consisted of a normal diet (ND, containing 4% soybean oil) based on the AIN-93M diet (16); high fat diet (HFD, ND supplemented with 16% lard oil); and the HFD with 5% red pepper powder, garlic or ginger. Casein was purchased from PCS, Korea. Starch, lard oil, cellulose (fiber), mineral, vitamin, L-cystein, methionine, TBHQ (*tert*-butylhyroquinone), soy bean oil and choline bitartrate were purchased from Sigma Co., USA. Dextrinized corn starch, mineral and vitamin mix. were purchased from Dyts Inc., USA. Contributions of the spices to the compositions of the experimental diets compositions were confirmed by proximate analysis data (Table 1). The compositions of the experimental diets are shown in Table 2.

Measurement of body weight and food consumption

Body weight was measured every week and rounded to the second decimal place. Feed consumption was measured every day. Food 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

Table 1. Proximate analysis of freeze dried Korean major spices (Unit: %)

Item	Water	Crude protein	Crude fat	Crude carbohydrate	Crude fiber	Crude ash
Red pepper powder[1)]	19.8±0.03	12.9±0.3	8.6±0.9	26.0±0.4	26.7±0.3	6.1±0.5
Garlic	9.2±0.1	18.8±0.1	0.09±0.01	65.7±0.1	2.7±0.04	3.5±0.2
Ginger	14.6±0.2	13.0±0.1	4.5±0.2	45.5±0.09	14.1±0.1	8.3±0.1

[1)]Sun-dried and powdered product (Youngyang National Agricultural Cooperative Federation).

Table 2. Preparation and compositions of the normal diet, high fat diet and samples added to the high fat diets (g/100 g diet)

	ND[1)]	HFD[2)]	HFD+RPP[3)]	HFD+Garlic[4)]	HFD+Ginger[5)]
Casein	14.0	14.0	13.36*	13.06*	13.35*
L-Cystine	0.18	0.18	0.18	0.18	0.18
Corn starch	46.57	34.57	33.27*	31.28*	32.29*
Dextrinized corn starch	15.5	15.5	15.5	15.5	15.5
Sucrose	10.0	10.0	10.0	10.0	10.0
Fiber	5.0	5.0	4.50*	4.86*	4.30*
Soybean oil	4.0	4.0	3.93*	4.00*	3.77*
AIN-93 mineral mix.	3.5	3.5	3.5	3.5	3.5
AIN-93 vitamin mix.	1.0	1.0	1.0	1.0	1.0
Choline bitartrate	0.25	0.25	0.25	0.25	0.25
TBHQ[6)] (mg)	0.8	0.8	0.8	0.8	0.8
Lard oil		16.0	16.0	16.0	16.0
Red pepper powder[3)]			5.0		
Garlic				5.0	
Ginger					5.0
Total	101.8	102.8	102.09	101.43	101.94

[1)]Normal diet is based on the AIN-93M diet (14).
[2)]Contains 16% lard oil added to the normal diet.
[3)]High fat diet+5% red pepper powder.
[4)]High fat diet+5% garlic.
[5)]High fat diet+5% ginger.
[6)]*tert*-Butylhydroquinone.
*Adjusted quantities from the proximate analysis of 5% red pepper powder, ginger and garlic respectively.

from the interior vena cava, and the plasma separated by centrifugation (Vision, VS-15CFU refrigerated centrifuge, Gyeonggi, 3,000 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 and high-density lipoprotein (HDL) cholesterol

The concentrations of plasma triglyceride, cholesterol and HDL-cholesterol were assayed enzymatically using commercial kits (Asan pharms. Co., Korea). Total lipids in liver and adipose tissues were extracted by the method of Folch et al. (17) and weighed. Triglyceride and total cholesterol concentrations in liver and adipose tissues were assayed enzymatically using a commercial kits (Asan pharms. Co., Korea) with the aid of a detergent, triton X-100.

Statistical analysis

All statistical analysis were performed on a SAS program (SAS 8.0). Significant difference among the treatment means were determined using ANOVA and Duncan's multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Body weight of the rats

Final body weights are shown in Table 3. Rats fed the HFD, containing 16% lard oil, had significantly higher final body weights (371.5±13.7 g) than rats fed the HFD with RPP, garlic or ginger. Spices in diets significantly reduced the weight gain compared to the HFD diet group. The garlic diet group gained the least body weight among the treated groups ($p<0.05$). Except for the garlic diet group, food intakes were not significantly different among the groups. Food intakes of the garlic diet group were smaller than those of other groups, this may be due to unpleasant smell of garlic. The food efficiency ratio (FER) of the HFD and RPP diet group was higher than that of the ND group. Ginger and garlic reduced FER which was increased by HFD. The high FER of the HFD group was due to an increase in body weight, and not to deceased feed consumption. The garlic diet group ate less than the others, while the FER of garlic group was the same as that of ND.

In this study, the RPP was less effective than garlic or ginger for reducing the weight gain. Choi et al. (4) reported that 10% RPP decreased the fatness of rats. However, 3% RPP in HFD did not reduce the body weight gain compared to controls (HFD, 18). Do et al. (19) reported that high-pungency red pepper extract might have a direct lypolytic activity in adipocytes that is mediated by capsaicin. Capsaicin is an active, hot, and characteristic compound found in red pepper powder that has established lipolytic activity (20,21). Especially, capsaicinoid concentrations of var. Youngyang used in this study were considerably lower than that of high-pungency RPP (var. Chungyang, 22). These results suggested that a high level of capsaicin in RPP might be required to decrease body fatness.

Garlic is almost always less than 5% of any daily meal. Sheo (23) reported that megadoses of dietary garlic up to 5% did not have any significant adverse effects on the body weight gain of rats. There were no abnormalities or apparent changes in the appearance and motility in 3% and 5% garlic diet groups. However, the animals fed 5% garlic showed mild erythema on their mucosal membrane of the stomach. So, the second experiment was carried out to examine antiobestic effect of garlic in low concentration. The experimental diets containing 1, 2, 5% garlic in HFD showed dose-dependent effects on reducing body fat gain in the rats fed

Table 3. Changes in body weight, food intake and food efficiency ratio (FER) of rats fed experimental diets

	ND[1]	HFD[2]	HFD+RPP[3]	HFD+Garlic[4]	HFD+Ginger[5]
Body weight					
Initial weight (g)	142.1±0.7[ns7]	136.9±8.0	134.2±14.5	140.5±6.2	141.1±1.6
Final weight (g)	324.4±3.9[c8]	371.5±13.7[a]	349.8±7.3[b]	287.2±7.4[d]	308.7±7.8[c]
Weight gain (g/day)	6.1±0.2[c]	7.8±0.5[a]	7.2±0.3[b]	4.9±0.1[e]	5.6±0.2[d]
Food intake (g/day) & FER					
Food intake (g/day)	18.6±0.3[a]	18.3±0.3[a]	18.3±0.3[a]	16.2±0.3[b]	18.3±0.4[a]
Food efficiency ratio[6]	0.31±0.01[b]	0.38±0.02[a]	0.39±0.01[a]	0.30±0.01[b]	0.31±0.01[b]

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

with HFD (data not shown). Therefore garlic seems to play a role in reducing weight gain.

Lipid contents in blood

Plasma triglyceride and cholesterol concentrations were high in HFD diet, but the effect of HFD was significantly reduced groups also receiving RPP, garlic and ginger (Table 4). The greatest reduction was observed in the garlic group. HDL-cholesterol concentrations in the HFD group were significantly lower than the ND group ($p<0.05$). HDL-cholesterol levels of RPP, garlic and ginger groups were almost the same as that of the ND group. Kwon et al. (24) reported that red pepper decreased total serum triglyceride and cholesterol, and increased HDL-cholesterol in cholesterol-fed rabbits. Red pepper had been shown to increase plasma catecholamine levels and induced lipolysis in rats (3). Yoshioka et al. (25) reported that the addition of red pepper to high-fat meals significantly increased diet-induced thermogenesis and lipid oxidation in humans, while capsaicin stimulated lipid mobilization from adipose tissue and lowered the serum triglyceride concentration in lard-fed rats (26). Garlic supplementation and allyl-containing sulfides in garlic enhance thermogenesis by increasing uncoupling protein in interscapular brown adipose tissue, and noradrenaline and adrenaline secretion, that is, garlic stimulates triglyceride metabolism and exerts a hypotriglyceridemic effect (5). Focke et al. (27) reported allicin especially inhibits acetyl CoA synthesis and diallyl sulfide inhibits 3-hydroxy 3-methyl glutaryl CoA reductase activity thus contributing to the reduction of blood cholesterol. These data suggested that RPP and garlic increases catecholamine-mediated thermogenesis and the serum triglyceride lowering properties of RPP and garlic might be due to stimulation of triglyceride metabolism by capsaicin and allylsulfides, respectively.

It is reported that ginger significantly reduced cholesterol and triglyceride concentration in serum, and HDL-cholesterol concentrations in rats (13,14). Further study is needed to identify the active compounds in ginger and to elucidate their roles in the reduction of serum lipids.

Weight of organs and fat pads

Garlic and ginger supplementation in HFD significantly reduced liver weight (g/100 g body weight) and RPP had an intermediate value between the HFD and garlic group (Table 5). Weights of epididymal and perirenal fat pads in the HFD group were significantly higher than those in the ND group ($p<0.05$). The garlic and ginger groups were the same as the ND group. However the RPP group exhibited no reduction in the weights of epididymal fat pad and perirenal fat pad compared to

Table 4. The effects of various diets on serum (mg/dL) lipid concentrations in rats

	ND[1]	HFD[2]	HFD + RPP[3]	HFD + Garlic[4]	HFD + Ginger[5]
Triglyceride	167.5 ± 14.9^{bc}[6]	270.5 ± 58.7^{a}	202.6 ± 14.0^{b}	117.2 ± 16.4^{c}	166.2 ± 22.6^{bc}
Total cholesterol	83.0 ± 1.5^{d}	116.3 ± 4.3^{a}	97.6 ± 6.5^{b}	88.5 ± 3.5^{cd}	93.3 ± 4.6^{bc}
HDL-cholesterol	27.6 ± 3.0^{a}	19.3 ± 5.4^{b}	25.3 ± 1.5^{a}	27.5 ± 1.0^{a}	26.3 ± 0.9^{a}

[1]Normal diet (AIN-93M).
[2]High fat diet.
[3]High fat diet + 5% red pepper powder.
[4]High fat diet + 5% garlic.
[5]High fat diet + 5% ginger.
[6]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 + RPP[3]	HFD + Garlic[4]	HFD + Ginger[5]
Liver	4.00 ± 0.05^{ab}[6]	4.37 ± 0.05^{a}	4.19 ± 0.25^{ab}	3.94 ± 0.15^{b}	3.98 ± 0.30^{b}
Spleen	0.21 ± 0.03^{ns}[7]	0.31 ± 0.21	0.22 ± 0.03	0.27 ± 0.04	0.22 ± 0.02
Kidney	0.81 ± 0.04^{ns}	0.76 ± 0.03	0.79 ± 0.03	0.79 ± 0.05	0.79 ± 0.02
Epididymal fat pad	1.13 ± 0.50^{b}	1.65 ± 0.19^{a}	1.59 ± 0.11^{ab}	1.14 ± 0.08^{b}	1.16 ± 0.09^{b}
Perirenal fat pad	1.23 ± 0.23^{b}	2.16 ± 0.36^{a}	1.92 ± 0.40^{a}	1.27 ± 0.11^{b}	1.69 ± 0.13^{ab}

[1]Normal diet (AIN-93M).
[2]High fat diet.
[3]High fat diet + 5% red pepper powder.
[4]High fat diet + 5% garlic.
[5]High fat diet + 5% ginger.
[6]Means with different letters in the same row are significantly different ($p<0.05$) by Duncan's multiple range test.
[7]Not significant.

Table 6. Effect of various diets on total lipids in liver, epididymal fat pad, perirenal fat pad in rats

	ND[1)]	HFD[2)]	HFD+RPP[3)]	HFD+Garlic[4)]	HFD+Ginger[5)]
Liver (mg/g, Wet wt)					
Total lipid	4.1±0.2[c6)]	6.1±0.2[a]	5.5±0.9[ab]	4.6±0.4[bc]	5.4±0.4[ab]
Triglyceride	10.4±0.1[c]	19.6±0.4[a]	13.3±0.8[b]	8.8±0.5[d]	10.0±0.4[c]
Total cholesterol	117.6±1.6[c]	166.2±18.2[a]	132.8±8.9[bc]	130.6±5.6[bc]	143.4±17.8[b]
Epididymal fat pad (mg/g, Wet wt)					
Total lipid	66.0±1.5[bc]	82.1±4.6[a]	71.2±2.3[b]	66.7±3.1[bc]	63.5±4.0[bc]
Triglyceride	156.1±8.1[c]	371.8±92.3[a]	300.2±25.6[ab]	152.5±18.8[c]	249.8±27.6[b]
Total cholesterol	63.4±14.6[e]	190.2±44.7[a]	142.7±17.6[b]	87.1±3.2[d]	101.7±1.0[c]
Perirenal fat pad (mg/g, Wet wt)					
Total lipid	63.21±5.61[b]	77.58±3.38[a]	67.74±2.51[b]	63.58±4.75[b]	65.59±6.98[b]
Triglyceride	25.4±0.5[d]	51.4±1.2[a]	38.9±3.2[b]	26.1±5.1[d]	31.9±0.6[c]
Total cholesterol	105.0±5.7[c]	225.7±12.9[a]	185.0±21.6[ab]	123.4±23.2[c]	144.7±37.4[bc]

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

the HFD group. Ginger and garlic groups showed a greater effect than RPP in reducing the fat pad weights ($p<0.05$). The weights of epididymal and perirenal fat pads were almost identical among the groups fed ginger, garlic and normal diets, suggesting that ginger and garlic completely reversed the effect of HFD ($p<0.05$).

Lipid contents in liver, epididymal and perirenal fat pad

Hepatic triglyceride and cholesterol in all treated group were significantly lower than those in the HFD group; the lowest concentrations were in the garlic group (Table 6). Total lipid, triglyceride and cholesterol contents in fat pads of the groups fed diets containing the spices were significantly lower compared to the HFD group ($p<0.05$), but the effect was the greatest in the garlic diet group. These results indicated that RPP, ginger and garlic stimulate lipid metabolism in adipose tissues and effectively inhibit adipose lipid accumulation caused by HFD. Feeding ginger to rats with ginger significantly elevated the activity of hepatic cholesterol 7 α-hydroxylase (28), which converts cholesterol into bile acids, an important pathway for elimination of cholesterol from the body (29).

In this study, we compared the antiobesity effects of major Korean spices in HFD. 5% RPP in the HFD reduced body weight gain and lipid values of adipose tissues and serum, whereas it did not decrease the weight of epididymal and perirenal fat pads. Garlic and ginger had more suppressive effects on body fat gain and lipid values of the adipose tissues and serum than did RPP. Further study is needed to identify the phytochemicals involved, in garlic and ginger and elucidate their mechanisms in the antiobestic effect and improvement of the lipid content.

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