International Journal of Pharmacology

ISSN 1811-7775

science alert

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Asian Network for Scientific Information

International Journal of Pharmacology 9 (1): 42-49, 2013
ISSN 1811-7775 / DOI: 10.3923/ijp.2013.42.49

Aqueous Extracts of Purple Sweet Potato Attenuate Weight Gain in High Fat-fed Mice

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Abstract: Purple sweet potato is a widely consumed food around the world has been reported to possess antioxidant, antimutagenic and memory-enhancing effects. However, antiobesity effect of PSP is not clear. The objective of this study was to determine the effects of Purple Sweet Potato Extracts (PSPE) on serum and fecal lipid profiles, body weight gain, body fat percentage and hepatic lipogenesis. Mice were administered a standard chow diet, a 45% high-fat diet, or a high-fat diet with various doses of PSPE. Mice that were fed a high-fat diet containing PSPE were found to have lower increases in body and adipose tissue weights and lessened occurrences of hepatic steatosis than mice that were fed a high-fat diet without PSPE. The decreased adiposity induced by PSPE accounted for lower serum levels of leptin and a higher adiponectin/leptin ratio. PSPE administration also resulted in a significant decrease in serum and hepatic triglyceride and cholesterol levels and a significant increase in fecal triglyceride and cholesterol levels when compared to the high-fat group. To identify the mechanism by which PSPE induced its antiobesity effect, the expression of lipogenesis-related genes that were induced in high fat-fed mice was investigated. PSPE suppressed the expression of Sterol Regulatory Element-Binding Protein (SREBP)-1, Acyl-CoA Synthase (ACS), Glycerol-3-Phosphate Acyltransferase (GPAT), HMG-CoA Reductase (HMGR) and Fatty Acid Synthase (FAS) in liver tissue in mice provided the high-fat diet. These findings suggest that the antiobesity effect of PSPE in high fat-fed mice occurs through its modulation of lipogenesis in the liver and inhibition of dietary lipid absorption.

Key words: Purple sweet potato, high-fat diet, obesity, *de novo* lipogenesis, fecal lipid excretion

INTRODUCTION

Obesity results from an imbalance between fatty acid synthesis and oxidation. The World Health Organization estimates that more than 1 billion adults worldwide are overweight and at least 300 million of them are clinically obese. It increases the prevalence of insulin resistance, hepatic steatosis, hypertension and cancer (Unger, 2003). An excessive release of free fatty acids and adipocytokines such as leptin and Tumor Necrosis Factor (TNF)-α from adipocytes in visceral fat affects lipid metabolism in the liver (Mittra *et al*., 2008). Sterol Regulatory Element-Binding Proteins (SREBPs) are master transcription factors for *de novo* lipogenesis (Eberle *et al*., 2004). The three SREBP isoforms, SREBP-1a, SREBP-1c and SREBP-2, play different roles in lipid synthesis. Studies using transgenic and knockout mice suggest that SREBP-1c plays an essential role in the regulation of most lipogenic genes involved in fatty acid and triglyceride synthesis (Foretz *et al*., 1999; Horton *et al*., 2002), whereas SREBP-2 predominantly regulates cholesterol synthesis (Horton *et al*., 1998) and SREBP-1a is involved in both pathways (Horton *et al*., 2003). It has also been reported that peroxisome proliferator-activated receptor (PPAR)-γ increases the expression of lipogenic genes (Tontonoz *et al*., 1994).

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Although, a number of drugs have been developed in recent years to treat obesity, only orlistat, an inhibitor of pancreatic lipases and sibutramin, a serotonin-noradrenalin reuptake inhibitor, have been approved for long-term use. However, sibutramin has been withdrawn from the market due to an increased risk of cardiovascular side effects such as myocardial infarction and stroke, leaving orlistat as the only drug currently available (James *et al*., 2010). Due to the limited success of pharmacotherapy, there is increasing interest in the exploration of natural products as alternative therapies. We have been searching for natural products that have weight and lipid-lowering effects. Recently, there has been increasing interest in the health benefits of purple sweet potato (PSP, *Ipomoea batatas* L.), a widely consumed food around the world. Studies using experimental models have demonstrated that PSP possesses antioxidant (Ye *et al*., 2010; Gan *et al*., 2012), antimutagenic (Yoshimoto *et al*., 1999) and memory-enhancing effects (Cho *et al*., 2003). PSP also reduces hepatic lipid accumulation in high fat-fed mice (Hwang *et al*., 2011), inhibits the uptake of oxidized Low-Density Lipoprotein (LDL) into human macrophages (Park *et al*., 2010) and reduces acetaminophen-induced liver damage (Yoshimoto *et al*., 1999). These beneficial effects of PSP are at least partly attributed to anthocyanin, which is abundant in PSP. However, an antiobesity effect of PSP has not yet been reported. Therefore, this study was conducted to examine the effectiveness of aqueous extracts from PSP (PSPE) for improving blood lipid profiles and reducing body fat accumulation in mice with obesity induced by a High-Fat Diet (HFD).

MATERIALS AND METHODS

Animals: Four-week-old male C57BL/6J mice were purchased from Central Lab Animal Inc. (Seoul, Korea). The mice were housed at 20°C, 50% relative humidity and under a 12-h light-dark cycle (light cycle from 6:00 AM to 6:00 PM) and were provided free access to drinking water. The animals were fed a Normal Diet (ND group: 16, 20 and 64% of energy from fat, protein and carbohydrate, respectively), a high-fat diet (HF group: 45, 20 and 35% of energy from fat, protein and carbohydrate, respectively), or a high-fat diet with PSPE (HF-PSPE group: 100, 250, or 500 mg kg^{-1}) for 16 weeks. The HF-PSPE group was initially fed the HF diet for 8 weeks and then administered PSPE for another 8 weeks via oral gavage two times per day. *Garcinia cambogia* extract (GCE) (250 mg kg^{-1}) was used as positive control (Heymsfield *et al*., 1998). All groups had 10 mice each. Diets were custom-made by research diets, detailed diet compositions are given in Table 1. Food consumption and body weight were recorded every 3 days. At the end of the experimental period, the animals were sacrificed by decapitation, after

Table 1: Composition of the diet

	Normal diet		High fat diet	
Fat (% energy)	16		45	
Carbohydrate (% energy)	64		35	
Protein (% energy)	20		20	
kcal kg^{-1}	4,000		4,000	
	Normal diet		High fat diet	
Ingredient	g kg^{-1}	kcal	g kg^{-1}	kcal
Casein (from milk)	200	800	200	800
Corn starch	397	1,590	155	620
Sucrose	100	400	50	200
Dextrose	132	528	132	528
Cellulose	50	-	50	-
Soybean oil	70	630	25	225
Mineral mixture	35	-	35	-
Vitamin mixture	10	40	10	40
L-cystine	3	12	3	12
Choline bitartrate	2.5	-	2.5	-
Lard	-	-	175	1,575

which blood samples were collected from the inferior vena cava. Adipose tissue (epididymal, subcutaneous and interscapular) and liver were removed, weighed, snap-frozen and stored at −80°C. Left lateral lobe of liver was used for liver TG and real time RT-PCR analyses. All experimental procedures were approved by the Institutional Animal Care and Use Committee at Chonbuk National University.

Preparation of PSPE: PSP was obtained from Jeonnam Biofood Technology Center in Naju, Korea. For extraction, 100 g of PSP was washed, sliced and then placed in boiling water for 90 min. Next, the sample was centrifuged at 4,410×g for 20 min and the supernatant was concentrated to 200 mL under reduced pressure. The concentrated supernatant was then freeze-dried to a final weight of 25.4 g and stored at −70°C until used.

Nuclear magnetic resonance (NMR) measurement of body fat: The percentage of body fat was determined using a Bruker Minispec mq7.5 NMR analyzer (Bruker Optics, Ettlingen, Germany). Mice were placed in a clear, plastic cylinder (50 mm diameter) and kept immobile by insertion of a tight-fitting plunger into the cylinder. The tube was then lowered into the sample chamber of the instrument for the duration of the scan, which was approximately 2 min. The accuracy and precision of both instruments were cross-calibrated by measuring the same groups of mice with different adiposity.

Biochemical analysis: Serum levels of triglyceride, total cholesterol, HDL cholesterol, LDL cholesterol, AST and ALT were determined using a biochemical autoanalyzer (Hitachi 760-110, Autoanalyzer, Japan). Glucose, insulin, leptin and adiponectin were analyzed using commercially

available ELISA kits (Shibayagi, Japan). Insulin resistance was evaluated by the homeostasis model of insulin resistance (HOMA-IR) formula (Matthews *et al*., 1985):

$$\text{HOMA-IR} = \frac{\text{Serum glucose level (mg dL}^{-1}) \times \text{insulin level (mIU L}^{-1})}{405}$$

A high HOMA-IR score indicates high insulin resistance.

Measurement of hepatic and fecal lipid concentrations: Total lipids in the liver and feces were extracted according to the method of Folch *et al*. (1957). Aliquots of the extracted hepatic lipids were used for the measurement of the triglyceride and total cholesterol concentrations and the commercial assay kits were used for serum lipids. Feces were collected for 48 h during the final week of feeding and freeze-dried. The extracted total hepatic and fecal lipids were assayed with a commercial kit (Asan Pharm, Seoul, Korea).

RNA isolation and real-time RT-PCR: RNA was isolated from the liver tissue using Trizol reagent (Invitrogen, Carlsbad, CA, USA). RNA was then precipitated with isopropanol and dissolved in DEPC-treated distilled water. Next, total RNA (2 μg) was treated with RNase-free DNase (Invitrogen) and first-strand cDNA was generated using the random hexamer primer provided in the first-strand cDNA synthesis kit (Applied Biosystems, Foster City, CA, USA). Specific primers for each gene (Table 2) were designed using primer express software (Applied Biosystems). The sequence for the control 18S ribosomal RNA was purchased from Applied Biosystems and used as the invariant control. The real-time RT-PCR reaction, which was contained in a final volume of 10 μL, consisted of 10 ng of reverse transcribed total RNA, 167 nM of forward and reverse primers and 2×PCR master mixtures. The condition for PCR reaction was as follows: Denaturation at 95°C for 15 sec and annealing at 60°C for 1 min. The PCR reaction was performed in 384-well plates using the ABI Prism 7900 HT Sequence detection system (Applied Biosystems) (Lee *et al*., 2011). All reactions were conducted in triplicate.

Table 2: Sequences and accession numbers for primers used in real-time RT-PCR

Primer	Sequences for primers	Accession gene No.
ACS	GCTGAACTGACACACCTGGA AACTTGGCGACAAAGTTGCT	NM_019811
GPAT	TCCTCCGATATTCTTCTCCC ACTGGAGCCGAGCCTCAC	NM_018743
HMGR	CACAATAACTTCCCAGGGGT GGCCTCCATTGAGATCCG	NM_008255
FAS	TGATGTGGAACACAGCAAGG GGCTGTGGTGACTCTTAGTGATAA	NM_007988
SREBP-1	GGTTTTGAACGACATCGAAGA CGGGAAGTCACTGTCTTGGT	NM_011480
PPAR-γ	GAAAGACAACGGACAAATCACC GGGGGTGATATGTTTGAACTTG	NM_011146

ACS: Acyl CoA synthase, GPAT: Glycerol-3-phosphate acyltransferase, HMGR: HMG-CoA reductase, FAS: Fatty acid synthase, SREBP-1: Sterol regulatory element binding protein, PPAR-γ: Peroxisome proliferator-activated receptor-γ

Statistical analysis: Statistical analysis of the data was performed using one-way ANOVA followed by Duncan's test. Differences with a $p<0.05$ were considered statistically significant.

RESULTS

PSPE inhibited body weight and adipose tissue mass gain: In our preliminary study, PSPE supplementation at 100, 250, or 500 mg kg^{-1} for 4 weeks improved serum lipid parameters in mice fed HF diet (data not shown). We therefore hypothesized that PSPE supplementation might has an anti-obesity effect after longer period of HF diet. The body weight gain during the experimental period is shown in Fig. 1a. The body weight of the HF group was significantly higher than that of the ND group after 6 weeks of feeding and remained significantly higher for the duration of the experiment. The HF-PSPE group had significantly lower body weight than the HF group from the 10th week to the end of the experiment, indicating that PSPE reduced weight gain. In addition, at the end of the experiment, the weight gain of the HF group (23.7±2.3 g) was significantly greater than that of the ND group (17.1±2.2 g), although, this increase in weight gain was attenuated by PSPE consumption in a dose-dependent manner (Table 3). No significant difference in food intake

Table 3: Effects of PSPE supplementation on body weight, food intake and tissues weight in high fat fed mice

			HF-PSPE (mg kg^{-1})			
	ND	HF	100	250	500	GCE(250mg kg^{-1})
Initial body weight (g)	21.7±0.6	21.9±0.7	20.8±1.1	20.8±1.7	21.1±0.5	21.5±1.3
Final body weight (g)	38.8±2.8	45.6±3.0*	46.0±2.1	43.7±3.5	42.5±2.1#	45.0±2.7
Food intake (g day^{-1})	2.98±0.46	3.11±0.22	3.13±0.36	3.02±0.27	3.0±0.28	3.05±0.24
FER (×10^{-2})	5.31±0.18	7.34±0.21*	7.07±0.34	6.78±0.41#	6.36±0.32#	6.87±0.34#
Tissue weight (g 100 g^{-1}, but)						
Epididymal fat	2.70±0.23	5.56±0.84*	4.49±0.63	4.60±0.22#	3.60±0.43#	4.22±0.42#
Subcutaneous fat	1.43±0.17	2.90±0.16*	2.02±0.29#	2.38±0.11#	1.84±0.07#	2.09±0.24#
Interscapular fat	0.46±0.08	0.73±0.10*	0.82±0.07	0.77±0.06	0.61±0.11#	0.64±0.06#
Liver	2.73±0.34	4.52±0.36*	4.10±0.64	3.92±0.68	3.62±0.38#	3.94±0.72

FER: Feed efficiency ratio, Body weight gain/food intake, Values are Mean±SEM (n = 10), *p<0.05 vs. ND group, #p<0.05 vs. HF group

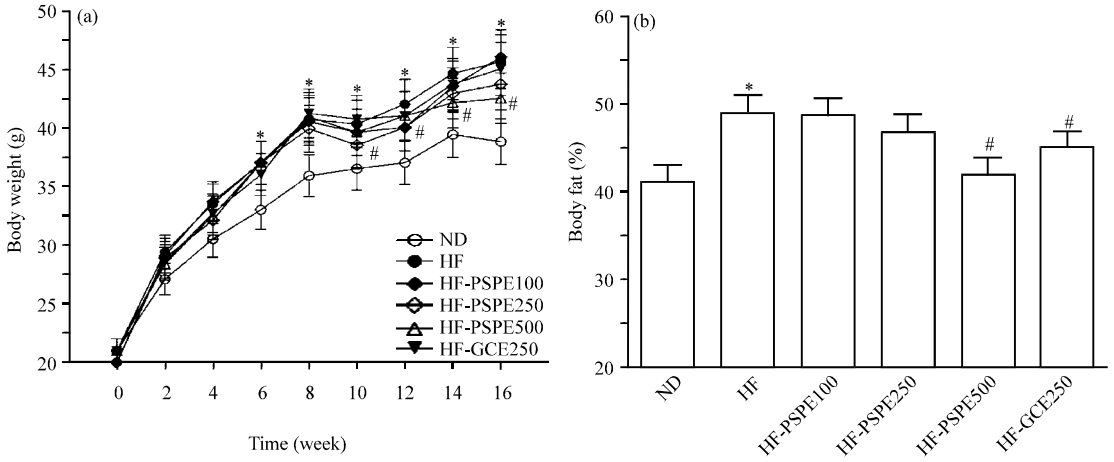

Fig. 1(a-b): (a) Effects of PSPE supplementation on weight gain and adiposity in high fat-fed mice and (b) Body fat percentage, Values are Mean±SEM (n = 10), *p<0.05 vs. ND group, #p<0.05 vs. HF group

Table 4: Effects of PSPE supplementation on serum, liver and fecal lipid profiles

			HF-PSPE (mg kg^{-1})			
	ND	HF	100	250	500	GCE (250 mg kg^{-1})
Serum						
Triglyceride (mg dL^{-1})	61.3±5.6	79.0±6.3*	75.3±4.9	85.0±4.6	73.8±3.0#	80.3±17.1
Total cholesterol (mg dL^{-1})	174.5±16.6	253.7±34.9*	221.2±11.8	212.5±19.2#	201.0±12.6#	206.8±17.0#
LDL-cholesterol (mg dL^{-1})	48.3±5.3	113.6±9.4*	98.6±12.2	93.6±8.9#	86.6±11.0#	92.0±10.8#
HDL-cholesterol (mg dL^{-1})	77.2±12.6	85.4±19.0*	80.3±17.1	81.4±15.7	81.4±17.4	80.0±18.7
ALT (IU L^{-1})	56±8.5	122±12.6*	72.8±5.1#	97.3±20.2	96.0±6.2#	79.2±8.3#
AST (IU L^{-1})	92±17.2	181±14.4*	121±7.4#	142±9.1#	114.3±8.0#	107.0±8.7#
AI	1.26±0.10	1.97±0.18*	1.75±0.24	1.61±0.17#	1.46±0.15#	1.59±0.19#
Liver						
Cholesterol (mg g^{-1})	3.56±0.69	5.48±0.73*	4.48±0.37#	4.38±0.52#	4.16±0.39#	4.28±0.52#
Triglyceride (mg g^{-1})	44.7±4.5	69.4±4.9*	54.9±6.5#	52.7±11.3#	43.1±4.5#	51.5±10.6#
Feces (mg g^{-1}, dried feces)						
Cholesterol (mg g^{-1})	1.51±0.61	0.97±0.09*	0.96±0.09	0.92±0.05	2.82±0.15#	2.27±0.13#
Triglyceride (mg g^{-1})	1.15±0.11	0.98±0.07*	1.07±0.07	1.14±0.11	2.79±0.11#	2.25±0.20#

Values are Mean±SEM (n = 10), *p<0.05 vs. ND group, #p<0.05 vs. HF group, AI: Atherosclerosis Index; Total cholesterol-HDL cholesterol/HDL cholesterol ratio

was observed among groups, but the Feed-Efficiency Ratio (FER) was significantly lower in the HF-PSPE group than in the HF group (Table 3).

We next measured the organ weight and body fat percentage of mice. The wet weights of the epididymal, subcutaneous and interscapular fat pads in HF mice were significantly increased, by 2.06-, 2.03-, 1.59-fold, respectively, compared to those of the ND group (Table 3). In addition, the liver weight of the HF group was increased 1.66-fold (Table 3). Body fat percentage was measured using an NMR analyzer. Figure 1b shows that the body fat percentage of the HF group was significantly higher than that of the ND group. However, the supplementation of PSPE significantly decreased the weights of the fat pads and liver, as well as the body fat percentage.

PSPE improved the serum, hepatic and fecal lipid profiles: Mice in the HF group had significantly higher triglyceride (1.28-fold), total cholesterol (1.45-fold) and LDL-cholesterol (2.35-fold) levels than mice in the ND group (Table 4). However, PSPE supplementation resulted in the reversal of the serum lipid levels to values similar to those of the ND group. In addition, the serum activity of ALT and AST was increased in the HF group, but this was significantly lowered by PSPE supplementation, suggesting that PSPE decreases hepatic injury. Consistent with the serum lipid profiles, the levels of cholesterol and lipid in liver tissues were significantly downregulated by PSPE supplementation.

The group pooled fecal excretion of cholesterol and triglyceride is shown in Table 4. Interestingly, fecal cholesterol and triglyceride levels were significantly increased in the PSPE supplemented group. Taken together, these results suggest that the PSPE-mediated decrease in body weight can be attributed to a reduction in fat and liver masses and to an increase in fecal fat excretion, independent of food intake.

Table 5: Effects of PSPE supplementation on insulin resistance related biomarkers

			HF-PSPE (mg kg^{-1})			
	ND	HF	100	250	500	GCE (250 mg kg^{-1})
Glucose (mg dL^{-1})	118.2±5.8	137.0±8.5*	130.1±11.5	126.8±5.7$^{\#}$	126.0±7.1$^{\#}$	127.6±4.5$^{\#}$
Insulin (μIU mL^{-1})	28.7±14.3	114.8±19.2*	94.7±23.9	100.5±24.3	57.4±14.6$^{\#}$	62.0±22.8$^{\#}$
HOMA-IR	8.37±3.5	38.8±8.4*	30.4±10.3	31.5±11.3	17.9±6.9$^{\#}$	19.5±7.8$^{\#}$
Leptin (ng mL^{-1})	13.2±6.6	46.3±10.4*	38.6±12.1	42.3±3.4	30.1±5.5$^{\#}$	25.8±5.0$^{\#}$
Adiponectin (ng mL^{-1})	54.0±1.4	48.2±3.3*	43.0±5.0	47.2±2.1	48.6±4.9	48.1±2.9
Adiponectin/leptin ratio	4.09±0.18	1.04±0.27*	1.13±0.31	1.12±0.14	1.62±0.25$^{\#}$	1.86±0.11$^{\#}$

Values are Mean±SEM (n = 10), *p<0.05 vs. ND group, $^{\#}$p<0.05 vs. HF group, HOMA-IR score: Fasting glucose (mg dL^{-1})×Fasting insulin (μIU mL^{-1})/405

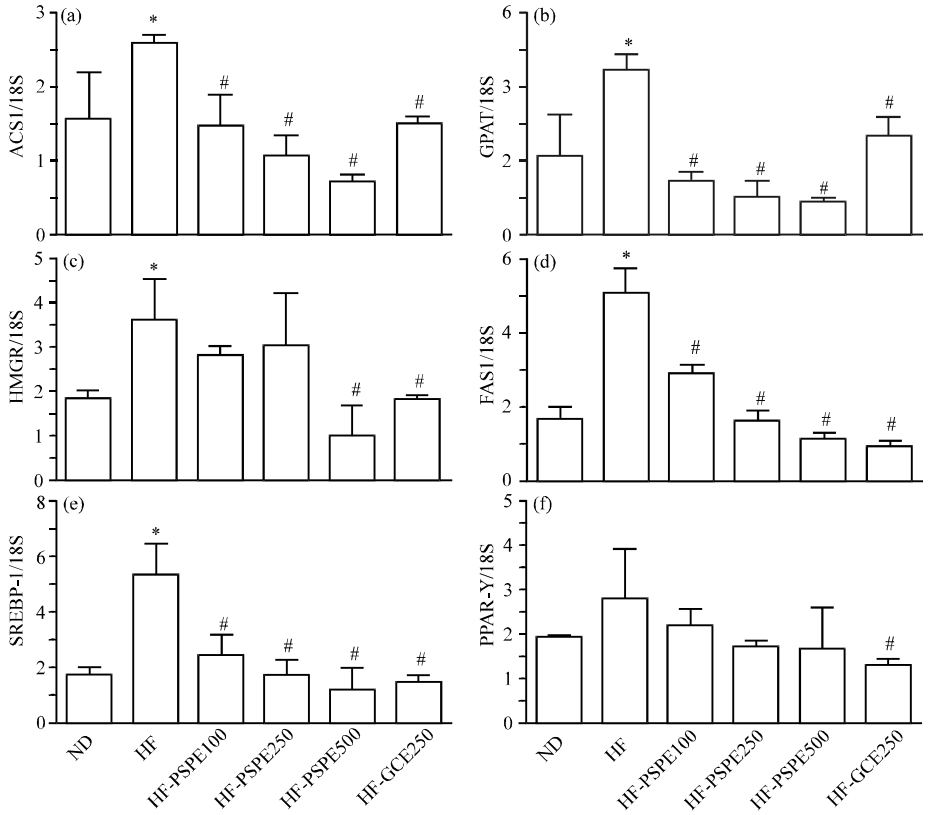

Fig. 2(a-f): Real-time PCR analyses of lipogenesis-related genes, the amount of each type of mRNA was normalized to 18S and is expressed as a percentage of the corresponding amount in the normal group. Values Mean±SEM (n = 10), *p<0.05 vs. ND group, $^{\#}$p<0.05 vs. HF group. ACS: Acyl-CoA synthase, GPAT: Glycerol-3-phosphate acyltransferase, HMGR: HMG-CoA reductase, FAS: Fatty Acid Synthase, SREBP: Sterol regulatory element-binding protein, PPAR-γ: Peroxisome proliferator-activated receptor-γ

PSPE lowered insulin resistance-related biomarkers: Excessive visceral fat accumulation during high-fat feeding causes a disturbance of glucose metabolism and is involved in the pathogenesis of insulin resistance. Therefore, we measured insulin resistance-related biomarkers (Table 5). High fat-fed mice exhibited a mild increase in fasting blood glucose, a high serum insulin level and a high HOMA-IR. Consistent with increased adiposity, the serum level of leptin was significantly increased in the HF group, whereas the adiponectin level tended to decrease slightly in the HF group. However, PSPE supplementation returned the aforementioned parameters to levels similar to those of the ND group.

PSPE reduced the expression of de novo lipogenesis genes in the liver: Having observed the suppressive effect of PSPE on body fat accumulation and serum lipid profiles, we further evaluated the effect of PSPE on the expression of lipogenic genes. Mice that were provided with the high-fat diet had higher mRNA levels of Acyl-CoA Synthase (ACS), glycerol-3-phosphate acyltransferase (GPAT), HMG-CoA reductase (HMGR), Fatty Acid Synthase (FAS) and SREBP-1 in their liver tissues than animals in the ND group (Fig. 2). However, the expression of lipogenic genes was reduced in a dose-dependent manner in animals given PSPE supplementation compared to those of the HD group. The

expression of PPAR-γ, a very important lipogenic receptor responsible for fat accumulation, was not altered by PSPE supplementation.

DISCUSSION

This study was designed to elucidate the potential effects of PSPE on high fat diet-induced obese animal model. Results showed that PSPE reduced body weight gain without affecting food intake and lowered the wet weights of liver and adipose tissues and the percentage of body fat. In addition, PSPE increased the fecal excretion of cholesterol and triglyceride and improved serum lipid profiles. PSPE decreased the ratio of leptin to adiponectin and attenuated the increase in serum glucose and insulin concentration. These beneficial effects of PSPE correlate with decreased *de novo* lipogenesis. We therefore conclude that PSPE has an antiobesity effect.

Mice that were fed a high-fat diet had a greater body weight gain and body fat percentage than those that were fed the standard chow diet. However, PSPE supplementation suppressed fat accumulation, especially in the fat pads and in liver tissue, without suppressing food intake. Additionally, PSPE supplementation significantly reduced the levels of biochemical markers of liver function, including serum AST and ALT. These results suggest that PSPE protects against the development of HFD induced obesity and hepatic steatosis. Consistent with the change in body weight, supplementing high fat-fed mice with PSPE also ameliorated the increases of serum triglyceride, total cholesterol and LDL cholesterol. As a result, PSPE reduced the ratio of non-HDL to HDL cholesterol, commonly used as an index of risk for coronary heart disease, mainly by reducing the total cholesterol level rather than increasing the HDL cholesterol level. PSPE also significantly increased the fecal excretion of total lipids and cholesterol. Thus, PSPE-mediated reductions in serum lipid profiles and organ weights may be partly regulated at the intestinal absorption level, thereby decreasing serum and hepatic triglyceride and cholesterol levels.

Excessive visceral fat accumulation during high-fat feeding causes a disturbance in cytokine secretion from adipose tissue and is involved in the pathogenesis of insulin resistance (Unger, 2003). We therefore evaluated the two most important adipocytokines, leptin and adiponectin. Leptin behaves as a potent antiobesity hormone that regulates food intake and energy expenditure (Unger, 2004). In this study, the serum leptin level was increased in the HF group and PSPE decreased it to approximately the level observed in the ND group. The lower leptin level could be attributed to a decrease in the fat mass of mice. These changes in leptin and adiposity are in agreement with the results of previous studies that evaluated the relationship between serum leptin and the extent of adiposity in rodents and humans (Maffei *et al*., 1995). Adiponectin is a hormone that modulates a number of metabolic processes, including glucose and lipid homeostasis and insulin sensitivity (Berg *et al*., 2001; Yamauchi *et al*., 2001). Obesity-related decreases in serum adiponectin levels have been reported in humans (Golledge *et al*., 2007) and experimental animals (Maeda *et al*., 2002; Shklyaev *et al*., 2003) and adiponectin has been shown to improve insulin resistance by decreasing fat content in muscle and liver tissues of obese mice (Berg *et al*., 2001; Yamauchi *et al*., 2001; Yamauchi *et al*., 2002). In the present study, significant differences in serum adiponectin levels were not observed among the groups. However, PSPE supplementation improved insulin sensitivity, as demonstrated by a significant reduction in serum insulin and glucose levels and HOMA-IR. The decreased ratio of leptin to adiponectin may explain the possible insulin-sensitizing and glucose-lowering effects of PSPE.

To clarify the mechanism of the antiobesity activity of PSPE, we analyzed the hepatic expression of genes involved in lipid metabolism using real-time RT-PCR. PSPE supplementation led to reduced expression of lipogenic enzymes (SREBP-1, FAS and ACC1), cholesterol biosynthesis (HMG-CoA reductase) and TG biosynthesis (GPAT) in the liver tissue of mice that were fed a high-fat diet. These gene expression levels are well correlated with serum lipid profiles. Given that SREBP-1 plays a crucial role in the dietary regulation of most hepatic lipogenic genes (Eberle *et al*., 2004), the present findings suggest that the metabolic effects of dietary PSPE are due to the suppression of the SREBP-1-mediated lipogenic pathway. A recent study by Hwang *et al*. (2011) showed that anthocyanins from PSP inhibit hepatic lipid accumulation through AMP kinase (AMPK) activation. The activated AMPK further phosphorylates acetyl-CoA carboxylase, which switches off fatty acid synthesis and accelerates the transport of long-chain fatty acyl groups into the mitochondria to undergo β-oxidation (Tomas *et al*., 2002). Therefore, we cannot exclude the possibility that PSPE reduced body fat accumulation and improved serum lipid profiles by activating the AMPK signaling pathway.

In conclusion, the results of this study suggest that PSPE reduces body weight gain and improves the blood lipid profiles of mice that were provided a high-fat diet. Because of the limitations of currently available drugs, there is an increasing need for safe and effective dietary supplements to control body sweight. Although,

furtherresearch is required to confirm that similar effects occur in humans, PSPE may be of particular benefit to individuals who are unable or unwilling to reduce their intake of high-fat foods.

ACKNOWLEDGMENT

This work was supported by National Research Foundation of Korea grants funded by the Korean Government (No. 2012-0009319 and 2008-0582).

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