International Journal of Food and Nutritional Science

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Research Article

Effects of Soybean/Brown Rice Consumption on Body Fat and Blood Lipids in Overweight Postmenopausal Women

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Received Date: Feb 5, 2015
Accepted Date: April 9, 2015
Published Date: April 16, 2015

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Citation: Yi-Wen Chien. et al. Effects of Soybean/Brown Rice Consumption on Body Fat and Blood Lipids in Overweight Postmenopausal Women. (2015) J Food Nutr Sci 2(1): 64-69.

Keywords: Postmenopausal women; Soybean; Brown Rice, Body fat, Serum cholesterol

Abstract

A menopause-induced estrogen deficiency might increase body-fat accumulation, insulin resistance, and abnormal blood sugar and lipids. Thus, postmenopausal women have a high risk of cardiovascular diseases. Some studies indicated that soy can improve the syndrome of menopause, and whole-grain foods can reduce blood cholesterol concentrations. In the present study, under a 1200-kcal diet, overweight postmenopausal women ingested soybean/brown rice (SBR) as their grains for lunch for 12 weeks, and the effects on the anthropometric profile, body composition, blood profile, and plasma isoflavone levels were assessed. After 12 week of SBR intake, dietary fiber intake (21.5 ± 6.7 g) was higher than that of the control group. Body weight (BW), waist circumference (WC), hip circumference (HC), and the waist-hip ratio (WHR) had decreased in both groups. The body-fat percentage and android-fat percentage had also decreased in both groups. Blood glucose, insulin, homeostasis model assessment of insulin resistance (HOMA-IR) and quantitative insulin sensitivity check index (QUICKI) did not change during the intervention period. In the SBR and control groups, serum triglycerides (TGs) decreased, and high-density lipoprotein cholesterol (HDL-C) rose. In contrast, serum total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) had decreased in the SBR group at 12 weeks compared with week 0. Diastolic blood pressure (DBP) significantly decreased in the SBR group. Changes in dietary fiber and soy protein intake were significantly negatively correlated with the body-fat percentage and gynoid-fat percentage changes. In conclusion, under energy restriction, SBR intake can reduce serum TC, LDL-C, and DBP in overweight postmenopausal women.

Introduction

A menopause-induced estrogen deficiency is related to body weight and fat gains. Abdominal fat increases as a result of fat redistribution after menopause. The waist circumference (WC) is higher than that of premenopausal women[1]. Insulin resistance and abnormal plasma glucose and lipid levels were found, and may contribute to a high risk of cardiovascular disease (CVD) in postmenopausal women[2]. Hormone-replacement therapy (HRT) has beneficial effects on the body composition and blood profiles[3], whereas HRT may also have some adverse health effects[4].

Soybeans are a traditional Asian food. Soy food intake is negatively associated with waist circumference (WC) and diabetes risk[5,6]. Structures of isoflavones are similar to that of estrogen[7]. Isoflavones can prevent body fat gain in ovariectomized female rats, an animal model of menopause[8]. Soy protein and isoflavones can decrease plasma cholesterol and plasma glucose and reverse insulin resistance in both animal and clinical studies[9,10]. Soybeans contain some beneficial components for lowering cholesterol levels such as saponins and phytosterols[11].

Whole grains are rich in dietary fiber, vitamins, minerals, and antioxidants. Ingestion of whole grains is positively associated with lower serum cholesterol, blood pressure, and insulin sensitivity[12,13]. The risks of metabolic syndrome and CVDs were lower in subjects who ingested three servings of whole grains per day[14]. Thus, in the present study, we assessed the effects of soybean/brown rice (SBR) on anthropometric profiles, body composition, and blood profiles in postmenopausal women.

Subjects and Methods

Participants

In total, 34 postmenopausal women were screened for inclusion in the study. Subjects were ethnic Chinese (i.e., Taiwanese) menopausal women who had not had a menstrual cycle for at least 1 year, with serum follicle-stimulating hormone (FSH) level of > 40 IU, estradiol (E2) of < 30 pg/mL, and a body-mass index (BMI) of > 24 kg/m^2. Exclusion criteria were any unnatural features of menopause, the uterus, or ovaries, untreated hypothyroidism, kidney or liver diseases, current or previous (in the preceding 6 mo) use of estrogen therapy, treatment with insulin or oral hypoglycemic agents, smoking, malignancy, or cancer. Those with an allergy to soybeans, brown rice, or rice bran were also excluded.

Study Design

The study was carried out strictly in accordance with ethical standards as outlined by Taipei Medical University. After screening with exclusion criteria and some withdrew due to allergy, in total, 23 overweight postmenopausal women were included and were randomly divided into two groups: an SBR group and a control group. The study intervention was 12 weeks, and anthropometric measurements, body composition, blood pressure, and blood profiles of subjects were measured at the baseline (0 week) and at 12 weeks.

Dietary Intervention

Two groups received diets restricted to 1200 kcal of energy. Subjects ingested one package of SBR as their grains at lunch in the SBR group. There was 213.1 ± 3.8 g of SBR per package which included 138.0 ± 12.7 g brown rice and 75.1 ± 10.1 g soybeans. The nutritional composition and isoflavone contents were analyzed by the Food Industry Research and Development Institute (FIDI, city, Taiwan) (Tables 1,2). Subjects consumed their habitual diets and received one-on-one dietary directions from a dietitian. They were asked to record 3 days of dietary intake including 2 weekdays and 1 weekend day at the baseline and at 12 weeks. Dietary nutritional intake was analyzed by E kitchen software.

Table 1: Nutritional composition of the soybean/brown rice used in the intervention [1]

Nutrient	Soybean/brown rice
Calories (kcal)	304.8 ± 5.4
Carbohydrates (g)	42.7 ± 0.8
Crude fat (g)	8.2 ± 0.1
Crude proteins (g)	15.1 ± 0.3
Crude fiber (g)	4.7 ± 0.1
Total dietary fiber (g)	10.3 ± 0.2
Moisture (g)	140.7 ± 2.5

[1] Amounts are per 213.1 ± 3.8 g.

Table 2: Crude protein and isoflavone contents in soybeans of the soybean/brown rice [1]

	Soybeans
Crude protein (g)	8.7 ± 1.2
Isoflavones (mg)	22.0 ± 3.0
Genistin (mg)	11.17 ± 1.51
Daidzin (mg)	4.19 ± 0.57
Glycitin (mg)	0.47 ± 0.06
Genistein (mg)	3.23 ± 0.44
Daidzein (mg)	1.55 ± 0.21
Glycitein (mg)	0.12 ± 0.02

[1] Soybeans in soybean/brown rice were 75.1 ± 10.1 g.

Measurements

Anthropometrics and Blood Pressure

Height was measured in a standing position without shoes using a wall-mounted stadiometer. The body weight (BW), BMI, and basal metabolic rate (BMR) were measured with an In Body 3.0 Body Composition Analyzer. The waist circumference (WC) was measured at the level midway between the lower rib margin and the iliac crest using a non-elastic tape with no pressure on the body surface. Hip circumference (HC) was measured at the level of the greater trochanters. Blood pressure was measured with a sphygmomanometer.

Body Composition

Body-fat weight (BF), lean body mass weight (LBM), total body-fat percentage (total BF), android-fat percentage (Android), gynoid fat percentage (Gynoid), and android to gynoid fat percentage ratio (A/G ratio) were measured by dual-energy x-ray absorptiometry (DEXA).

Blood Profiles

After a 24-h fast, blood samples were collected and centrifuged at 3000 rpm for 15 min at 4°C to separate the plasma. Serum FSH, E_2, and insulin concentrations were measured by a chemi luminescence immunoassay using an auto analyzer (Siemens Centaur, Germany). Serum total cholesterol (TC) and [triacylglycerol/triglyceride?] (TG) concentrations were measured by an enzymatic method (ref?). Low- (LDL-C) and high-density lipoprotein cholesterol (HDL-C) were measured by an elimination/catalase method. Blood glucose was measured by an enzymatic colorimetric method using hexokinase. The insulin resistance was calculated using the homeostasis model assessment method (HOMA-IR = insulin × glucose/22.5), and the insulin sensitivity was calculated using the quantitative insulin sensitivity check index (QUICKI = 1/(log insulin + log glycemia). Serum leptin and adiponectin concentrations were measured by a radioimmunoassay. Plasma isoflavone contents were measured by high-performance liquid chromatography (HPLC). Plasma samples were treated with a β-glucuronidase/sulfatase mixture to hydrolyze glucuronide and sulfate conjugates of isoflavones. After vortex-mixing for 30 s and centrifugation at 13,000 rpm for 5 min, plasma was purified using a solid-phase extraction cartridge. Plasma was purified by the method of Anupongsanugool et al.[15] Plasma samples were frozen and stored at -80°C until being analyzed by HPLC. The HPLC analysis was performed using an autosampler (Hitachi Autosampler L-7200, Hitachi Dump L-7100, Japan) and detected by ultraviolet absorption at 250 nm (Hitachi Diode Array Detector L-7455). The mobile phase was a C18 column (Luna 5u C18, 250 x 4.6 mm), and the reverse phase consisted of 100% acetonitrile (A) and 10 mM ammonium acetate (B).

Statistical Analysis

All data are presented as the mean ± standard deviation (SD). Data were compared between the SBR and control groups using Student's t-test at the baseline (0 week) and at 12 weeks. We compared the baseline and 12-week data within groups using a paired *t*-test. Statistical analyses were performed using SAS vers. 9.1.3 (Cary, NC, USA). p values of < 0.05 were considered significant.

Results

Subject Characteristics

Twenty-three postmenopausal women were enrolled in this study, 11 in the control group and 12 in the SBR group. FSH concentrations were > 40 IU/L and E2 concentrations were < 30

pg/mL in all subjects. At the baseline, BWs were 63.9 ± 9.7 and 62.7 ± 5.4 kg and BMIs were 26.4 ± 3.1 and 25.6 ± 1.7 kg/m^2, respectively (Table 3).

Table 3: Baseline characteristics of subjects[1]

	Control	Soybean/brown rice
Number	11	12
Age (year)	59.2 ± 5.5	57.0 ± 3.0
Height (cm)	155.4 ± 6.3	156.5 ± 6.2
Body weight (kg)	63.9 ± 9.7	62.7 ± 5.4
Body-mass index (kg/m^2)	26.4 ± 3.1	25.6 ± 1.7
Waist circumference (cm)	88.7 ± 6.3	88.5 ± 3.4
Hip circumference (cm)	104.4 ± 7.3	102.2 ± 4.0
Waist/hip ratio	0.85 ± 0.05	0.87 ± 0.04
Follicle-stimulating hormone (mIU/mL)	71.7 ± 24.0	62.7 ± 11.5
Estradiol (pg/mL)	29.2 ± 6.3	25.9 ± 11.7

[1] Data are expressed as the mean ± SD.

Dietary Intake

There were no significant differences between the control and SBR groups in the contents of energy, macronutrients, or dietary fiber at the baseline. However, after the 12-week intervention, energy (1226.4 ± 222.6 vs. 1149.8 ± 164.9 kcal, respectively) and carbohydrate intake were significantly lower than at the baseline ($p < 0.05$). Dietary fiber intake had significantly increased in the SBR group and was also higher than that of the control group ($p < 0.05$) (Table 4).

Table 4: Daily energy, macronutrient, and dietary fiber intake by postmenopausal women [1]

	Control (n = 11)	Soybean/brown rice (n = 12)	p value [2]
Energy (kcal)			
0 week	1507.7 ± 345.7	1492.4 ± 306.0	0.4384
12 weeks	1226.4 ± 222.6 *	1149.8 ± 164.9 *	0.2313
Protein (% Energy)			
0 week	15.7 ± 4.1	16.2 ± 2.4	0.4591
12 weeks	18.6 ± 3.9	18.0 ± 3.0	0.7248
Fat (% Energy)			
0 week	31.5 ± 9.5	31.6 ± 3.2	0.9864
12 weeks	38.8 ± 5.3	36.2 ± 5.8	0.2862
Carbohydrates (% Energy)			
0 week	52.7 ± 12.8	52.2 ± 3.0	0.9158
12 weeks	42.6 ± 5.8 *	44.2 ± 4.7 *	0.7513
Dietary fiber (g)			
0 week	18.6 ± 11.1	18.7 ± 7.5	0.7246
12 weeks	15.6 ± 3.8	21.5 ± 5.7 *	0.0289

[1]Data are expressed as the mean ± SD.
[2]Differences between the two groups in the same week.
*Significantly differs between 0 and 12 weeks in the same group, $p < 0.05$.

Effects of SBR on Anthropometric Measurements and Blood Pressure

Anthropometric measurements and blood pressure data are shown in Table 5. At 12 weeks, the BW, BMI, WC, HC, WHR, and BMR were significantly reduced in both groups ($p < 0.05$), but there were no significant differences between groups. In contrast, DBP was significantly reduced at 12 weeks in the SBR group and was significantly lower than that of the control group ($p < 0.05$).

Table 5: Anthropometric measurements and blood pressure in groups during the intervention period [1]

	Control (n = 11)	Soybean/brown rice (n = 12)	p value [2]
Body weight (kg)			
0 week	63.9 ± 9.7	62.7 ± 5.4	0.6008
12 weeks	60.8 ± 10.0 *	59.5 ± 4.9 *	0.8535
Body-mass index (kg/m^2)			
0 week	26.4 ± 3.1	25.6 ± 1.7	0.6888
12 weeks	25.1 ± 3.4 *	24.3 ± 1.9 *	0.8288
Waist circumference (cm)			
0 week	88.7 ± 6.3	88.5 ± 3.4	0.9181
12 weeks	80.3 ± 7.7 *	81.4 ± 2.9 *	0.9079
Hip circumference (cm)			
0 week	104.4 ± 7.3	102.2 ± 4.0	0.3918
12 weeks	99.8 ± 7.3 *	99.2 ± 4.6 *	0.5525
Waist/hip ratio			
0 week	0.85 ± 0.05	0.87 ± 0.04	0.3529
12 weeks	0.80 ± 0.04 *	0.82 ± 0.04 *	0.5374
BMR (kcal)			
0 week	1126.3 ± 83.1	1124.9 ± 79.8	0.9654
12 weeks	1106.0 ± 83.1 *	1113.0 ± 73.0 *	0.7251
SBP (mmHg)			
0 week	124.1 ± 13.1	127.3 ± 9.8	0.5237
12 weeks	124.8 ± 14.0	122.3 ± 13.3	0.8795
DBP (mmHg)			
0 week	73.8 ± 5.5	73.3 ± 7.7	0.8625
12 week	76.4 ± 7.4	68.3 ± 6.5 *	0.0104

[1] Data are expressed as the mean ± SD. BMR, basal metabolic rate; SBP, systolic blood pressure; DBP, diastolic blood pressure.
[2] Differences between the two groups in the same week.
* Significantly differs between 0 and 12 weeks in the same group, $p < 0.05$.

Effects of SBR on the Body Composition and Serum Adipokine Concentrations

Body composition and serum adipokine concentration data are presented in Table 6. BF, LBM, total BF, Android, Gynoid, and the A/G ratio did not significantly differ at the baseline. At 12 weeks, BF was significantly lower in both groups ($p < 0.05$). Android was reduced in both groups, although the reduction was greater in the SBR group, but there was no significant difference between the SBR and control groups. Gynoid was significantly lower in the SBR group but not the control group ($p < 0.05$). The A/G ratio and LBM did not change after SBR intake.

Table 6: Body composition measured by DEXA and serum adipokine concentrations [1]

	Control (n = 11)	Soybean/brown rice (n = 12)	p value [2]
Body fat (kg)			
0 week	23.8 ± 7.2	22.4 ± 3.9	0.5795
12 weeks	22.7 ± 8.0 *	21.1 ± 3.5 *	0.7118
Lean body mass (kg)			
0 week	36.7 ± 3.9	36.6 ± 2.9	0.9761
12 weeks	36.5 ± 3.5	36.8 ± 3.2	0.6528
Total body fat (%)			
0 week	38.7 ± 6.2	37.8 ± 4.5	0.6887
12 weeks	37.5 ± 7.0 *	36.4 ± 4.5 *	0.0828
Android (%)			
0 week	46.7 ± 6.3	45.9 ± 4.3	0.7087
12 weeks	44.8 ± 6.6 *	43.4 ± 4.1 *	0.7682
Gynoid (%)			
0 week	44.0 ± 6.2	43.5 ± 5.5	0.8463
12 weeks	42.7 ± 6.8	41.9 ± 5.9 *	0.6549
A/G ratio			
0 week	1.07 ± 0.11	1.06 ± 0.12	0.8047
12 weeks	1.06 ± 0.13	1.05 ± 0.18	0.6658
Leptin (ng/mL)			
0 week	12.1 ± 5.8	12.6 ± 5.6	0.6666
12 weeks	9.8 ± 7.1*	9.7 ± 5.8	0.9264
Adiponectin (ng/mL)			
0 week	14.3 ± 2.9	14.1 ± 5.6	0.9214
12 weeks	16.8 ± 3.6 *	16.8 ± 7.0 *	0.9883

[1]Data are expressed as the mean ± SD. Android, android fat percentage; Gynoid, gynoid fat percentage; A/G ratio, android to gynoid fat percentage ratio.
[2] Differences between the two groups in the same week.
* Significantly differs between 0 and 12 weeks in the same group, $p < 0.05$.

Serum leptin and adiponectin concentrations did not significantly differ between groups at the baseline. The serum leptin concentration was significantly lower in the control group, and the adiponectin concentration was significantly lower in both groups ($p < 0.05$).

Effects of SBR on Blood Lipids Profiles, and Glucose and Insulin Concentrations

Blood lipid profiles, and glucose and insulin concentration data are shown in Table 7. Serum TC, LDL-C, HDL-C, and TG concentrations did not significantly differ at the baseline. In the SBR group, after ingestion of SBR for 12 weeks, serum TC and LDL-C concentrations were significantly lower ($p < 0.05$). Serum TG concentrations were significantly reduced in both groups ($p < 0.05$), although that of the SBR group was higher than the control, but the difference was non-significant. HDL-C concentrations were higher in both groups. Neither plasma glucose or serum insulin concentrations, nor HOMA-IR or QUICKI had changed.

Table 7: Blood lipid profiles, fasting blood sugar, insulin concentration, insulin resistance, insulin sensitivity, and plasma isoflavone concentrations at the baseline and 12 weeks [1]

	Control (n = 11)	Soybean/brown rice (n = 12)	p value [2]
Total cholesterol (mg/dL)			
0 week	213.9 ± 16.0	229.1 ± 53.3	0.7119
12 weeks	207.0 ± 18.8	206.3 ± 31.9 *	0.6225
Triglycerides (mg/dL)			
0 week	99.5 ± 25.6	127.6 ± 40.0	0.0524
12 weeks	66.1 ± 15.0 *	87.3 ± 26.9 *	0.0421
LDL-C (mg/dL)			
0 week	131.8 ± 17.7	150.1 ± 44.2	0.3888
12 weeks	122.1 ± 19.1	125.6 ± 28.8 *	0.8293
HDL-C (mg/dL)			
0 week	63.1 ± 7.9	58.8 ± 11.2	0.3009
12 weeks	69.4 ± 7.0 *	64.7 ± 12.9 *	0.8392
Blood sugar (mg/dL)			
0 week	96.7 ± 9.1	102.5 ± 9.5	0.1509
12 weeks	100.9 ± 6.9	103.6 ± 11.8	0.2097
Insulin (mU/L)			
0 week	6.2 ± 1.7	9.0 ± 4.6	0.2069
12 weeks	5.9 ± 1.9	6.6 ± 2.9	0.4600
HOMA-IR			
0 week	1.5 ± 0.5	2.3 ± 1.3	0.1757
12 weeks	1.5 ± 0.5	1.7 ± 0.7	0.2678
QUICKI			
0 week	0.36 ± 0.02	0.35 ± 0.03	0.2383
12 weeks	0.36 ± 0.02	0.36 ± 0.04	0.2698
Isoflavones (nmol/L)			
0 week	43.3 ± 14.8	45.8 ± 32.4	0.8122
12 weeks	71.8 ± 32.3 *	139.3 ± 93.7 *	0.0342

[1]Data are expressed as the mean ± SD. LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment of insulin resistance; QUICKI, quantitative insulin sensitivity check index.
[2] Differences between the two groups in the same week.
* Significantly differs between 0 and 12 weeks in the same group, $p < 0.05$.

Effects of SBR on Plasma Isoflavone Concentrations

Plasma isoflavone concentrations significantly increased in both the control and SBR groups after 12 weeks of SBR consumption ($p < 0.05$), whereas those of the SBR group were significant higher than those of the control group ($p < 0.05$) (Table 7).

Discussion

In the present study, under a restricted diet with only 1200 kcal of energy, overweight postmenopausal women were asked to consume SBR as their grains at lunch for 12 weeks, and their BW, BMI, WC, HC, WHR, total body, Android and Gynoid fat percentages were significantly reduced. One study showed that with a low-energy diet, soy protein-based meal replacements produced greater body weight and body fat reductions than a casein-based diet[16]. However, soy protein and isoflavones of soybeans might play an important role. Supplementa-

tion with 15 g soy protein and 100 mg isoflavones affected the BW, BMI, and body fat reductions in Chinese postmenopausal women[17]. In our study, there were 8.7 ± 1.2 g of soy protein and 22.0 ± 3.0 mg of isoflavones in the SBR supplement; these contents were lower than supplements given in the above study. Although plasma isoflavone concentrations in the SBR group were higher than those of the control group, they ultimately did not affect BW or body fat. Dietary fiber can also reduce body fat. Postmenopausal women ingested a low-fat diet, and the dietary fiber intake increased from 16 to 23 g, BW was reduced by 6 kg, and body fat was reduced by 2.7%[18]. The intake of dietary fiber in the SBR group was higher than that of the control group, but the BW and body fat were not further reduced. We did not use a low-fat diet in this study, so the effects of dietary fiber on body fat may have been limited. At 12 weeks, energy intake levels were respectively reduced to 281.3 ± 351.2 and 342.6 ± 335.1 kcal in the control and SBR groups, and body fat was reduced in both groups, but there was no significant difference between groups. So, a low-calorie diet may be the main reason for the reduction in body fat.

In this study, the gynoid fat percentage in the control group tended to decrease but was not significant. And A/G ratio, HC, and WHR exhibited no significant differences between the two groups; therefore, it was assumed that android and gynoid fat levels both decreased in the SBR and control groups. Animal experiments showed that soy protein can increase insulin sensitivity[19]. One study indicated that insulin sensitivity was negatively associated with abdominal fat[20]. Thus, lowering insulin resistance may result in decreased abdominal fat and may reduce the A/G ratio. A study by Katcher *et al*. reported that by ingesting five servings of whole grains every day, one consumes 13 g of dietary fiber per 1000 kcal, and the abdominal fat percentage was significantly lower than that of the group that consumed refined grains[21]. There were three servings of brown rice in the SBR used in this study, and the dietary intake was 21.5 g (18.7 g per 1000 kcal), and total, android, and gynoid fat percentages were all reduced in the SBR group.

Ingestion of SBR for 12 weeks decreased serum TC and LDL-C concentrations. This can possibly be attributed to many cholesterol-lowering components in soybeans, such as soy protein, isoflavones, phytosterol, saponins, and phytate[11]. The mechanism through which soy protein affects cholesterol concentrations is that soy protein regulates sterol regulatory element-binding protein (SREBP)-2, a key transcription factor of cholesterol biosynthesis. Thereby, the activity of HMG-CoA reductase and LDL receptors were regulated, and levels of TC and LDL-C were reduced[22].

A meta-analysis study reported that with consumption of 47 g soy protein per day, serum TC and LDL-C concentrations were reduced[23]. Supplementation with 96 mg of isoflavones a day can also decrease the serum LDL-C level, and the reduction was greater in subjects that initially had higher serum cholesterol levels[10]. We provided whole soybeans, and despite the fact that the soy protein and isoflavones were not as concentrated as in supplements, the saponins, phytosterol, and phytate in the soybeans can lower the absorption of cholesterol and may have resulted in decreased serum cholesterol concentrations[24,25]. On the other hand, dietary fiber can also lower cholesterol absorption in the intestines and increase secondary bile acid excretion[26]. Serum TC and LDL-C were reduced in the SBR group which can possibly be attributed to a higher dietary fiber intake.

In conclusion, under a low-calorie diet, overweight postmenopausal women ingested SBR as their grains at lunch, and the BW, WC, HC, WHR, total body fat and android fat percentages, and serum TC and LDL-C concentrations significantly decreased. These would have favorable effects on lowering risks of cardiovascular disease.

Acknowledgment:

We would like to thank all subjects for participating in this study. This study was provided by grant 100TMU-SHH-09.

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Online ISSN: 2377-0619
Journal Title: International Journal Food and Nutritional Science
Journal Short Name: Int J Food Nutr Sci

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