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Pigmented Rice Bran and Plant Sterol Combination Reduces Serum Lipids in Overweight and Obese Adults

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Abstract

Objective—This study investigated the dietary effect of including pigmented rice bran with or without plant sterols on lipid profiles during energy restriction–induced weight loss in overweight and obese adults not taking cholesterol-lowering medication. In addition, the study examined the effect of intervention on biomarkers of oxidative stress and inflammation.

Methods—A group of 24 overweight and obese adults (age: 43 ± 6 years, body mass index 32 ± 1 kg/m², 18 females) were randomized to a 25% calorie-restricted diet containing either pigmented rice bran (RB) or the RB with addition of plant sterols (RB + PS) snack bars for 8 weeks. The individualized nutrient-balanced diet contained ~70% of daily energy needs assessed from indirect calorimetry measured resting energy expenditure (EE) and physical activity-related EE assessed using accelerometry. Anthropometrics, blood pressure, blood lipids, glucose, urinary F₂-isoprostanes, C-reactive protein, insulin, and leptin were measured at baseline and after 8 weeks of intervention.

Results—Participants lost approximately 4.7 ± 2.2 kg ($p < 0.001$). Weight loss was not significant between the RB + PS and RB group ($p = 0.056$). Changes in body fat corresponded to changes in body weight. Average decrease in total cholesterol was significantly higher in the RB + PS group than in the RB group (difference 36 ± 25 g/dL vs 7 ± 16 g/dL; $p = 0.044$). A similar pattern was observed for the decrease in low-density lipoprotein (LDL) cholesterol (difference 22.3 ± 25.2 g/dL vs 4.4 ± 18.9 g/dL; $p = 0.062$). Changes in systolic blood pressure, serum levels of leptin, and F₂-isoprostanes were significant between baseline values and after 8 weeks on the diet in both groups ($p < 0.05$) but did not differ between the 2 groups.

Conclusions—A nutrient-balanced and energy-restricted diet supplemented with rice bran and plant sterols resulted in a significant decrease in total and LDL cholesterol in overweight and obese adults.

Keywords

bioactive compounds; clinical trials; diets; general nutrition; obesity; preventative nutrition and chronic disease; supplements and functional foods

INTRODUCTION

The World Health Organization estimated in 2008 that 1.4 billion adults, aged 20 years and older, were overweight. Of these, over 200 million men and nearly 300 million women were identified as obese [1]. The health consequences of this condition are vast, because obesity is well known to contribute significantly to the development and progression of chronic diseases such as type 2 diabetes, coronary heart disease, hypertension, and some forms of cancer. Modest weight loss reduces risk factors for cardiovascular disease [2–5] and diabetes [6,7], independent of other risk factors [8–10]. In the United States, each year approximately 60% of overweight women and 36% of men initiate weight loss mostly by energy restriction [11].

However, though weight loss by energy restriction regimens may be associated with a decrease in oxidative stress, it alone may not be associated with a decrease in plasma lipids. High circulating concentrations of total cholesterol (TC), low-density lipoprotein (LDL) cholesterol, and triacylglycerol (TG) and depressed concentrations of high-density lipoprotein (HDL) cholesterol are established biomarkers of risk for cardiovascular disease [12–14]. The oxidative modification of LDL is important for the initiation of atherosclerosis, which is in turn strongly associated with inflammation [15]. Therefore, lowering LDL is a crucial component of reducing obesity-associated cardiovascular disease. According to World Health Organization data, the intentional weight loss of 10 kg in overweight persons may result in a 15% reduction in LDL cholesterol, 10% reduction in total cholesterol, 30% reduction in triglycerides, and 8% increase in HDL cholesterol—all of which are positive health adjustments. Such weight loss can also reduce total mortality by 20% [16].

Food system components, such as white rice bran or rice bran oil, have also been reported to provide beneficial effects on postprandial lipidemia in healthy adults [17]. Unsaponifiable compounds present in rice bran oil in particular are effective at lowering both total and LDL-cholesterol [18]. The most notable of these compounds, γ -oryzanol, which is present in rice bran oil, can decrease cholesterol absorption and increase both fecal neutral sterol and bile acid excretion of both LDL and HDL in animal models [19,20], healthy adults [21], and hyperlipidemic patients [22]. The cholesterol-lowering activity of γ -oryzanol was manifested by the upregulation of both cholesterol synthesis (e.g., HMG-CoA reductase) and catabolism (LDL-receptor) activities. Rice bran is also rich in tocotrienols, the major components of which are β - and γ -tocotrienols [23]. It is postulated that tocotrienols, especially γ -tocotrienols, lower cholesterol by inhibiting 3-hydroxy-3-methyl-glutaryl-coenzyme A (HMG-CoA) reductase, the rate-limiting enzyme in endogenous cholesterol

synthesis [18,24]. Other studies involving anthocyanin-rich rice bran and outer layer fractions also reported significant reductions in serum lipid profiles and atherosclerotic plaque formation in hypercholesterolemic rabbits and Apo-E-deficient mice [25,26]. Black rice outer layer fraction is a good source of dietary fiber, oil, flavonoids, polyphenols, and anthocyanins, which also have been shown to contribute to antioxidant activity, assessed *in vitro* [27].

Recently, the effect of rice bran oil—in addition to a low-calorie diet—on blood lipids in hyperlipidemic patients was studied, and it was found that rice bran oil, along with a low-calorie and nutritious diet, was effective for decreasing risk factors associated with cardiovascular disease [28]. However, the effect of rice bran and plant sterol with a low-calorie diet on blood lipids has not yet been studied. Thus, the goal of the present study was to investigate the effect of a modest (25%) energy-restricted diet that included a snack bar containing pigmented rice bran, with or without plant sterols, on lipid profiles and markers of oxidative stress and inflammation in overweight and obese adults.

MATERIALS AND METHODS

Participants

Healthy males and females between the ages of 21 and 50 with a body mass index between 29 and 35 kg/m² were recruited through advertising at Vanderbilt University in Nashville, Tennessee. Other inclusion criteria were no weight loss of 5 kg or greater in the last 3 months, serum cholesterol 180–240 mg/dL, LDL < 90 mg/dL, HDL > 25 mg/dL, and triglycerides < 90th percentile when adjusted for age, gender, and race. Exclusion criteria included history of medical illness or risk factors, including diabetes requiring insulin or oral hypoglycemic agents, hypertension, renal disease or disease affecting renal function, liver disease, or heart disease. Potential participants were also ineligible if they were smokers, pregnant or lactating, taking medications or dietary supplements that affect body weight, taking lipid-lowering medications or thyroid hormone replacement, reported multiple food allergies, or regularly engaged in heavy or vigorous physical activities. Volunteers with known or suspected drug or alcohol abuse or with any clinical condition rendering them unfit to participate were also excluded from the study. The sample size and calculation was based on the information retrieved from the literature [29] and our previous studies with 25% energy-restricted diet [30,31]. We assumed that a meaningful decrease in weight loss of 2.5 ± 2.5 kg corresponded to a between-group difference of 0.8 standard deviations. To show such a difference, with a 2-sided type I 5% error and 90% power, 20 participants were required. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research, in accordance with the ethical principle of the Helsinki-II Declaration. The study was approved by the Institutional Review Board of Vanderbilt University, Nashville, Tennessee (approval number: 060763 valid until December 14, 2013). Each participant provided written consent before participating in the study.

Study Design

The study consisted of rice bran (RB) and rice bran plus plant sterols (RB + PS) groups. All participants received a 25% energy-restricted diet for 8 weeks. The study design illustrating the time course is shown in Fig. 1. Before entering the study, prospective participants were given detailed instructions on the study protocol and had sampled the formulated rice snack bars to determine whether they could eat the bars for 8 weeks. Fasting lipid panels were drawn for each potential participant to determine their eligibility for participation in the study. After taking baseline measurements, each participant was randomly assigned to a study group, RB or RB + PS, where the study dietitian (C.D.) assigned a randomization number to each subject enrolled in the trial (week 0). Participants were single masked to a bar composition and supplemented every day with 3 rice bran snack bars as a part of their diet provided by the Clinical Research Center metabolic kitchen. All study staff was single masked to the snack bar composition.

Anthropometrics and Body Composition

The National Health and Nutrition Examination Survey protocols were followed for all anthropometrical measurements [32]. Body weight was measured to within 0.1 kg using a calibrated beam platform scale (Detecto-Medic, Detecto Scales, Inc., Northbrook, IL). Height was measured at baseline within 0.5 cm using a calibrated, wall-mounted stadiometer (Perspective Enterprises, Portage, MI). Body composition was determined by dual-energy x-ray absorptiometry using narrow fan-beam technology (GE Lunar Prodigy, Madison, WI). Fat mass and fat-free mass were determined and fat-free mass was further divided into lean body mass and bone mineral content. For quality assurance and equilibration, a calibration block was scanned each morning. A spine phantom was scanned on a weekly basis with a coefficient of variation of 0.9%. All measurements were performed by the same investigator.

Resting Energy Expenditure

Resting energy expenditure (REE) was measured at week -2 using a metabolic cart (CPX Optima, MedGraphics, St. Paul, MN). REE was defined as the average energy expenditure during a 30-minute period of lying in a supine position after a 30-minute period of rest following an overnight fast (>10 hours). REE was calculated from measured rates of oxygen (O₂) consumption and carbon dioxide (CO₂) production using Weir's equation [33]. REE and energy expenditure of physical activity were used to determine the total dietary energy requirements in all subjects.

Dietary Intake

Formulation of Rice Bran Bar—Purple (black) rice (*Oryza sativa* L. *Indica*) obtained from Guangdong Province, China, was used as the source of rice bran in this study. Rice snack bars (30 g) were formulated with the rice bran containing 2% wood sterols (Forbes Medi-tech Inc., Vancouver, BC, Canada). Each bar contained 0.6 g of plant sterols, providing 1.8 g sterols/day/participant in 3 bars eaten as snacks after breakfast, lunch, and dinner. The bars were packaged in an aluminum pouch and tested for shelf-life (>6 months) prior to their distribution to study groups.

Proximate analysis of the formulated rice snack bars used in this study is shown in Table 1. The specific composition of the rice bran that was used to formulate the bars included protein (17 g/100 g dry mass), insoluble fiber (6.6 g/100 g dry mass) and soluble fiber (3.1 g/100 g dry mass), and total crude lipids (15 g/100 g dry mass) containing C16:0 (18.1%), C18:0 (2.2%), C18:1 (n-9; 37.4%), C18:2 (n-6; 35.6%), and ash (8.3 g/100 g dry mass). Energy content of the rice bran bar was approximately 434 calories/100 g dry mass (124 calories per bar). Nonnutrient content included oryzanol (3.8% total fat), anthocyanins-cyanidin-3-glucoside (30.6 mg/g), and peonidin-3-glucoside (1.24 mg/g). Antioxidant capacity of the pigmented rice bran included in both the RB and RB + PS snack bars was determined using ORAC_{FL} assay [34] and consisted of 225 mmol Trolox/g bran. The wood sterol mixture added to the bar formulation was determined to be 99.6% pure and contained beta-sitosterol (71.0%), sitostanol (6.0%), campesterol (2.0%), and campestanol (2.3%).

Energy-Restricted Diet—Study participants received an individualized energy- and nutrient-controlled diet provided by the Clinical Research Center metabolic kitchen. All foods (meals and snacks) were provided for consumption at home for the duration of the 8-week study. Total daily energy needs were calculated as the sum of REE measured using the metabolic cart, energy expenditure of physical activity measured using an RT3 accelerometer for 2 weeks before the study (week -2), and thermic effect of food estimated as 10% of REE. Intake data were analyzed for energy and nutrient content using the NDS-R database (NDS, St. Paul, MN). The individualized diet contained approximately 75% ($\pm$ 50 kcal) of daily energy requirements, 52%–54% of energy from carbohydrates, 26%–29% of energy from fat, 17%–21% of energy from protein, and 17–21 g of fiber. Each participant received a written list of foods at daily pick-up. Any uneaten foods and any additional foods eaten by the participants were reported on sheets collected daily. The study dietitian met with each participant weekly to discuss the diet, resolve any barriers or concerns related to food or specimen collection, and encourage compliance. To assure sufficient micronutrient content of the diet, participants received a multivitamin supplement (Centrum, Indianapolis, IN).

Physical Activity

Daily physical activity was assessed using an RT3 accelerometer (StayHealthy, Monrovia, CA). Participants were each instructed to maintain their habitual physical activity level and wore an activity monitor on their right hip while awake for 7 days at weeks -2, 1, 4, and 8. Total and physical activity energy expenditures (kcal) were calculated using energy calculated from the monitor-measured movement.

Blood Pressure

Blood pressure was measured at weeks -2, 1, 2, 3, 4, and 8 in the supine position with an automatically inflating cuff (Critikon Dinamap, GE Healthcare, Waukesha, WI, USA) using a standard protocol.

Laboratory Analyses

Blood Analyses—Venous blood samples were drawn at baseline on the morning of the first day of the study and on the morning after the last day of the study. Participants arrived

after a 12-hour fast but were allowed to drink water (8 ounces). Blood for determination of insulin, leptin, TG, TC, HDL-C, LDL-C, and C-reactive protein (CRP) was centrifuged at $2800 \times g$ for 15 min at 4°C. Serum was extracted and the samples were stored at -80°C until further analyses were performed at the Vanderbilt University Medical Center Core laboratories. Plasma TG, TC, LDL-C, and HDL-C levels were measured using enzymatic kits from Cliniqa Corporation (San Marcos, CA). Free fatty acids were measured using the NEFA-C kit by Wako (Nneuss, Germany) and by gas chromatography. Glucose was measured using the Vitros chemistry analyzer. CRP was analyzed using standard methodologies. Insulin and leptin measurements were performed using radioimmunoassays.

Urine Analyses—The 24-hour urine samples were collected once per week. Urine volume and density was measured and a 2-mL sample was frozen at -80°C for further analyses. Urinary calcium, sodium, and potassium were measured using a Vitros 250 Analyzer (Ortho-Clinical Diagnostics, Rochester, NY). Urinary nitrogen content was measured using a nitrogen analyzer (Antek Instrument Nitrogen System 9000NS, Antek Instruments, Inc., Houston, TX). The nitrogen excretion in the urine was used as a biological marker for protein intake by multiplying the content of nitrogen in the urine by the factor 7.72. The urine sodium and potassium contents were used as biological markers of sodium and potassium intake, respectively [35]. Urinary F₂-isoprostane was analyzed at Prostaglandins Core Laboratory using gas chromatography/mass spectrometry, a previously described and validated method [36]. F₂-isoprostane represents oxidation of lipids that has been shown to provide one of the most accurate assessments of oxidative stress status [37].

Statistical Analysis

Descriptive statistics were presented as mean and standard deviation (SD). Continuous endpoints were compared between the RB and RB + PS groups using Wilcoxon's rank sum test. Linear regression after adjusting for baseline measurements was used to assess the treatment effect. The change within group was assessed using Wilcoxon's signed rank test. The level of statistical significance was set at $p < 0.05$. All analyses were done with STATA 11 (StataCorp, College Station, TX).

RESULTS

Study Participants and Compliance

Twenty-four of the 31 randomized individuals who entered into the trial (78%) completed randomized intervention. Reasons for study dropout ($n = 4$ in RB and $n = 3$ in RB + PS) were work-related, lack of time, an unspecified reason, and noncompliance ($n = 1$ in RB group). There were no apparent differences in personal characteristics between dropouts and completers. The characteristics of the participants are shown in Table 2. There were no significant changes in physical activity energy expenditure measured using an RT3 accelerometer at any point of the study (weeks 0, 4, and 8) in either group (Table 3). Adherence to the protocol by completers was good as measured by urinary biomarkers calculated as ratios of reported intake and excretion for protein (1.07 ± 0.35), sodium (0.93 ± 0.28), and potassium (1.03 ± 0.26).

Weight Loss

Both groups had a significant loss in weight ($p < 0.05$). The average reduction in weight was 4.5 ± 2.7 and 6.1 ± 2.2 kg in the RB and RB + PS groups, respectively. There was a marginally higher weight loss in the RB + PS group than in the RB group (5.5 ± 1.6 kg vs 4.0 ± 2.4 kg, $p = 0.056$). Changes in body fat corresponded to changes in body weight. Table 2 shows the mean decrease in weight, body mass index, and percentage body fat changes in the study groups.

Changes in Lipid Concentrations, Blood Pressure, Hormones, and F₂ Isoprostanes

There was no significant effect of diet on serum triglyceride concentration (Table 4). However, the RB + PS group experienced significant decreases in both total cholesterol and LDL-C ($p < 0.05$). None of the time comparisons were significantly different between groups, except difference between the 2 groups for week 8, where LDL-C was marginally lower ($p = 0.062$). The RB group had a decrease in HDL-C across time (baseline and week 8). Though both groups experienced a significant decrease in systolic blood pressure, serum leptin, and urinary F₂-isoprostanes across time ($p < 0.05$), there were no significant differences between the 2 groups (Table 5). There were no significant changes in diastolic blood pressure, serum insulin, glucose, and CRP in both groups and no significant difference in these parameters existed between RB and RB + PS.

DISCUSSION

The major finding of this study is that a modest, energy-restricted diet (25%) supplemented with pigmented rice bran and plant sterols, was effective to cause a significant decrease in the concentration of plasma lipids, namely, total cholesterol and LDL-C. These decreases in plasma cholesterol are noteworthy because high LDL-C and, to a lesser extent, TC levels are associated with a more rapid progression of atherosclerosis and coronary heart disease.

Cholesterol absorption is a multistep process that involves micellization of free cholesterol with bile acids, reesterification by intestinal cells, and incorporation into chylomicrons prior to secretion into the circulation [38]. The main step involves the competition between plant sterols and cholesterol for the mixed micellar system in the intestinal lumen, based on the close chemical similarities that exist with both compounds. Plant sterols are relatively more hydrophobic than cholesterol, due to a bulkier side chain that enables relatively greater affinity to form mixed micelles in the small intestine, thus reducing the efficiency of both dietary and biliary cholesterol absorption [38]. In addition, the coprecipitation between plant sterols and cholesterol on the intestinal lumen might also reduce cholesterol absorption [39]. In the lumen, plant sterols interfere with intestinal transporter proteins (e.g., Niemann-PickC1-like 1 protein) [40], which ultimately contributes to a reduction in both serum total and LDL-C concentration. These results are in line with the dose-response relationship identified between the dietary intake of plant sterols (e.g., 0.85 to 3.26 g/day) and cholesterol-lowering effects established for total cholesterol (4.9%–6.8%), LDL-C (6.7%–9.9%), and the LDL/HDL cholesterol ratio (6.5%–7.9%) [41]. A meta-analysis of 84 randomized trials showed that a mean daily dose of 2.15 g of sterols was effective to decrease LDL-C by 8.8% with a maximal lowering effect of 12.7%. The larger lowering

effect was observed in subjects with the higher baseline LDL concentrations [42,43]. Plant sterols do not participate in cholesterol metabolism and remain below 1% of total sterols circulating in the human blood [39,42].

Other important findings of this study include an overall decrease in systolic blood pressure for both groups and a slightly higher weight loss in the RB + PS group than in the RB group. The decrease in systolic blood pressure was most likely caused by the weight loss. The benefits of the decrease in systolic blood pressure are apparent, because lower systolic blood pressure has been shown to lower risk of cardiovascular morbidity [15,16]. We did not observe significant changes in serum glucose or insulin concentration because, at least in part, diabetic patients were excluded from the study, and both glucose and insulin concentrations were in normal ranges at baseline.

We have shown recently that moderate energy restriction alone can produce body fat loss and a parallel decrease in the serum F₂-isoprostane [31]. In this study, we did not observe significant changes in urinary F₂-isoprostane. Plausible explanations are differences between serum and urine and relatively low baseline F₂-isoprostane level at baseline. There is a possibility that the level changed during the run-in period (2 weeks) in which we did not collect urine and analyze the F₂-isoprostane level. Diet in both study arms contained the same antioxidant capacity from the components present in the pigmented rice bran. Major strengths of this study were a double-blind randomized clinical trial design, for the exclusion of individuals with diseases or conditions that may have altered metabolism, and targeted population. Our study population was overweight and obese adults not requiring pharmacologic intervention for dyslipidemia and not participating in any strenuous exercise program. A limitation of this study is the relatively low number of participants. Though the study was powered based on expected weight loss, a larger study might have allowed us to examine changes in several biochemical markers of oxidative stress and inflammation. Another potential limitation of this study is the relatively short dietary intervention period (8 weeks). Though this interval did allow for an average weight loss of 5.28 ± 2.58 kg (3.55% total body fat), it did not allow for the assessment of long-term effects, which should be considered in future studies with rice bran. Perhaps a longer study would generate more weight and fat loss and would have produced more significant effects on blood pressure, dyslipidemia, and oxidative stress. We did not analyze concentration of plasma plant sterols as a marker of adherence to the dietary protocol during the course of the study; however, we did confirm adherence by measuring urinary protein, sodium, and potassium.

In conclusion, we report the results of a randomized controlled trial that compared the effect of feeding snack foods containing rice bran with and without plant sterols as part of an energy-restricted diet (25% reduction of total energy requirement per day) on weight loss and markers of metabolic syndrome, inflammation, and oxidative stress in overweight adults. The addition of pigmented rice bran and plant sterols to a nutritionally balanced, energy-restricted diet decreased the LDL-C and total cholesterol levels in overweight and obese adults. Participants in the present study were overweight and obese males and females potentially at risk for developing metabolic syndrome and chronic diseases such as diabetes type 2 and cardiovascular diseases. Energy restriction is essential to reduce these risks and has been proven to be effective in weight reduction and maintenance in humans. Though the

rice bran and plant sterol supplementation was not intended to replace pharmacologic intervention [44], the results showed that their addition to energy restriction may be beneficial in individuals who desire to lose weight and avoid the medical complications associated with being overweight and/or hypercholesterolemic.

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Experimental Design

Fig. 1.
Experimental design. (Color figure available online).

Table 1Nutrient Composition of Formulated Rice Bran Snack Bars¹

Component	Rice Bran	Rice Bran + Plant Sterols
Energy (kcal)	124.3 (422.6)	124.3 (413.8)
Carbohydrate (g)	20.0 (68.0)	20.0 (65.5)
Saccharose (g)	8.1 (27.5)	8.1 (26.8)
Protein (g)	2.1 (7.14)	2.1 (6.9)
Total fat (g)	4.3 (14.6)	4.3 (14.4)
Saturated fat (g)	0.8 (2.7)	0.8 (2.6)
Plant sterols (g)	0.0 (0.0)	2.0 (6.7)
Fiber (g)	1.4 (4.8)	1.4 (4.7)
Sodium (mg)	21.9 (74.5)	21.9 (72.9)
Vitamin A (IU)	44.7 (152.0)	44.7 (149)
Vitamin C (mg)	1.0 (3.4)	1.0 (3.5)
Iron (mg)	0.8 (2.7)	0.8 (2.5)
Calcium (mg)	8.6 (29.2)	8.6 (28.8)

¹ Rice bran bar = 29.4 g serving, including 16.7% rice bran; rice bran + plant sterol bar = 30 g serving including 16.7% rice bran and 2% plant sterols. Plant sterols contained 71% beta-sitosterol, 16% sitostanol, 6% campasterol, 2.0% campestanol, and 2.3% unidentified minor sterols. Values in parentheses represent ingredient level per 100 g.

Table 2

Characteristics of Study Participants at Baseline and after 8 Weeks of Energy-Restricted Diet¹.

Variable	Rice Bran (<i>n</i> = 12)			Rice Bran + Plant Sterols (<i>n</i> = 12)			Total <i>p</i> Value ³
	Baseline	8 Weeks	<i>p</i> Value ²	Baseline	8 Weeks	<i>p</i> Value ²	
Gender (male/female)	2/10	—		3/9	—		
Age (years)	42.7 ± 7.1			43.2 ± 6.0	—		
Body weight (kg)	94.5 ± 13.6	90.6 ± 13.9	0.002	90.7 ± 6.0	85.2 ± 11.8	<0.0001	0.0995
Body mass index (kg/m ²)	32.7 ± 2.3	31.3 ± 2.5	<0.0001	31.5 ± 3.7	31.3 ± 2.5	0.0004	0.0567
Body fat (%)	45.5 ± 4.3	44.4 ± 4.2	0.0303	45.8 ± 6.4	43.5 ± 9.2	0.0289 ³	0.2249
Fat-free mass (kg)	53.3 ± 11.3	51.9 ± 11.0	0.0342	50.6 ± 9.2	49.4 ± 9.5	0.0058	0.8055
Bone mineral density (g/cm ³)	1.31 ± 0.11	1.30 ± 0.11	0.1451	1.28 ± 0.04	1.27 ± 0.05	0.4337	0.8174
Race/ethnicity							
White		9			8		
African American		2			3		
Other		1			1		

¹ Values are means ± standard deviation (SD).

² *p* Value for comparison within each diet group.

³ *p* Value for comparison between diet groups after adjusting for baseline measurement using Wilcoxon rank sum test.

Table 3Total and Physical Activity Energy Expenditure at Baseline and after 8 Weeks of Energy-Restricted Diet¹

Week	Rice Bran (<i>n</i> = 12)	
	Total EE (kcal/day)	Physical Activity EE (kcal/day)
Baseline (–2)	2619 ± 337.9	750 ± 177.4
Week 1	2625.6 ± 442.7	705.9 ± 241.3
Week 4	2536.7 ± 364.8	674.1 ± 196.3
Week 8	2536.3 ± 343.3	729.5 ± 180.7
Rice Bran + Plant Sterols (<i>n</i> = 12)		
Baseline (–2)	2417.5 ± 470.7	639.9 ± 218.3
Week 1	2578.8 ± 460.6	679.7 ± 193.3
Week 4	2640.2 ± 478.3	708.8 ± 254.4
Week 8	2506.1 ± 446.5	654.1 ± 284.2

EE = energy expenditure.

¹ Values are means ± standard deviation (SD).

Table 4

Changes in Blood Lipid Concentrations at Baseline and after 8 Weeks of Energy-Restricted Diet¹

	Rice Bran		<i>p</i> Value ²	Rice Bran + Plant Sterols		<i>p</i> Value ³
	Baseline (<i>n</i> = 12)	8 Weeks (<i>n</i> = 12)		Baseline (<i>n</i> = 12)	8 Weeks (<i>n</i> = 12)	
Total cholesterol (mg/dL)	195.5 ± 25.2	190 ± 27.1	0.3103	196.2 ± 21.8 ^b	170.9 ± 27.1 ^b	0.0120
LDL cholesterol (mg/dL)	122.3 ± 21.4	117.8 ± 23.4	0.4365	120.8 ± 19.4 ^b	98.4 ± 24.5 ^b	0.0108
HDL cholesterol (mg/dL)	48.9 ± 11.5 ^a	42.1 ± 6.4 ^a	0.0224	45.1 ± 9.7	43.8 ± 7.5	0.1505
Triglycerides (mg/dL)	140.1 ± 106.4	151.0 ± 68.2	0.6288	155.0 ± 103.7	142.7 ± 59.1	0.4739

LDL = low-density lipoprotein, HDL = high-density lipoprotein.

¹ Values are expressed as means ± standard deviation (SD). Difference between groups using linear regression after adjusting for baseline measurement.

² *p* Value of comparison across time within rice bran group.

³ *p* Value of comparison across time within rice bran + plant sterol group.

^a Significant difference (*p* < 0.005) within the rice bran group across time using Wilcoxon's rank sum test.

^b Significant difference (*p* < 0.005) within the rice bran + plant sterols group across time using Wilcoxon's rank sum test.

Changes in Blood Pressure, Glucose, Hormones, C-Reactive Protein, and F₂-Isoprostane at Baseline and after 8 Weeks of Energy-Restricted Diet¹

Table 5

	Rice Bran		Rice Bran + Plant Sterols	
	Baseline (n = 12)	Week 8 (n = 12)	Baseline (n = 12)	Week 8 (n = 12)
Systolic blood pressure (mmHg)	123.8 ± 16.9 ^a	116.7 ± 13.3 ^a	129.2 ± 13.8 ^b	119.9 ± 8.5 ^b
Diastolic blood pressure (mmHg)	75.7 ± 10.8	72.3 ± 9.0	81.8 ± 11.4	76 ± 7.3
Serum insulin (U/mL)	17.1 ± 10.6	18.9 ± 6.4	21.6 ± 14.2	19.3 ± 12.0
Serum glucose (mg/dl)	97.9 ± 7.4	100 ± 8.6	94.6 ± 9.7	96.4 ± 4.4
Serum leptin (ng/ml)	33.5 ± 12.6 ^a	22.2 ± 8.2 ^a	27.1 ± 11.9 ^b	19.3 ± 12.9 ^b
C-reactive protein (mg/L)	2.76 ± 2.30	2.33 ± 3.76	5.16 ± 3.52	6.0 ± 4.41
F ₂ -isoprostane (ng/mg)	38.1 ± 17.0 ^a	25.8 ± 11.7 ^a	37.2 ± 15.4 ^b	21.3 ± 10.2 ^b

¹ Values are means ± standard deviation (SD). Difference between groups using linear regression after adjusting for baseline measurement.² *p* Value of comparison across time within rice bran group.³ *p* Value of comparison across time within rice bran + plant sterol group.^a Significant difference (*p* < 0.005) within the rice bran group across time using Wilcoxon's rank sum test.^b Significant difference (*p* < 0.005) within the rice bran + plant sterols group across time using Wilcoxon's rank sum test.