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BUCKWHEAT – ENRICHED INSTANT PORRIDGE IMPROVES LIPID PROFILE AND INFLAMMATION IN PARTICIPANTS WITH MILD TO MODEST HYPERCHOLESTEROLEMIA

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Abstract

Buckwheat (BW) food is a good source of beneficial substances. Based on increased interest in product development approach to formulate new types of BW food products with health claims, three different instant porridges were developed: BW – enriched high-protein (A); corn-based high-protein (B); corn-based non-protein (C) and their effects were investigated on selected clinical markers. A randomized, crossover intervention study was performed among 34 participants with mild to modest hypercholesterolemia. Intake of porridge A significantly reduced serum levels of total cholesterol, LDL cholesterol, triacylglycerol, uric acid and significantly increased serum adiponectin levels, HDL cholesterol, and fat free mass. In conclusion, intake of porridge A as a functional food may improve lipid profile and may reduce inflammation. These findings may support that BW as a part of porridge consumption is an effective and convenient nutritional therapy for the improvement of metabolic parameters in participants with metabolic syndrome components.

Keywords: buckwheat, porridge, hypercholesterolemia, metabolic syndrome, inflammation, nutrition therapy
1. Introduction

In recent decade, buckwheat (BW) has gained increased attention of food processors and consumers due to its high nutritional value and numerous other beneficial health effects its consumption may provide. A large number of studies have inferred to remarkable nutritional quality of BW, high biological value of its components and their potential beneficial effects as reviewed in (Gimenez-Bastida & Zielinski, 2015; Zhu, 2016). Additionally, BW is suitable for celiac sufferers as it is free from toxic prolamins (De Francisch, Salgado, & da Costa, 1994).

BW has superior protein quality in comparison to cereals due to well-balanced amino acid composition in spite of their low digestibility (Krkoškova & Mrazova, 2005; Christa & Soral-Smietana, 2008). BW contains soluble carbohydrates, fagopyritols, which are a source of D-chiro-inositol (Janet, Horbowicz, & Obendorf, 2005), a component appearing to be beneficial in the treatment of polycystic ovarian syndrome and diabetes (Larner, Brautigan, & Thormer, 2010; Unfer & Porcaro, 2014). Due to presence of resistant starch, BW is suggested as an ingredient in design of low glycemic index (GI) food (Alvarez-Jubete, Arendt, & Gallagher, 2010). Fats in BW are mostly unsaturated with the predominance of oleic and essential linoleic acids (Christa & Soral-Smietana, 2008). Besides high-quality proteins, fat and favourable carbohydrate composition, BW is an abundant source of numerous other components with healing benefits: dietary fibres, flavonoids and flavones (rutin, quercetin, isovitexin), phytosterols (β-sitosterol), macro and microelements, B vitamins (B2, B6), etc. (Krkoškova & Mrazova, 2005; Christa & Soral-Smietana, 2008; Alvarez-Jubete, Arendt, & Gallagher, 2010).

Health effects and pharmacological activities of BW were mostly reported in animal studies and only scarce human data exist (Gimenez-Bastida & Zielinski, 2015; Zhu, 2016). In
humans, BW leaf tea was confirmed to have pharmacological action in the treatment of leg oedema (Lhme et al., 1996). Furthermore, it has been reported successful application of tartary BW in the treatment of gastritis and diabetic patients (Lin, Jia, & Ren, 1998). He (1998) reviewed the medical use of tartary BW in China and reported its use as a bactercidal agent in the treatment of wounds and ulcers, to control hyperlipidemia, diabetic hypertension and diabetic coronary disease (He, 1998). In addition, daily administration of BW supplement was proven to reduce triacylglycerols (TAG), total cholesterol, low density lipoprotein (LDL) cholesterol, blood pressure, body weight and increase high density lipoprotein (HDL) cholesterol in senile hyperlipemia patients (Xiping & Xianqiong, 1995). Moreover, a study involving human subjects reported the positive effect of consuming tartary BW cookies on the reduction of myeloperoxidase which is a biomarker of neutrophilic inflammation caused by lower airway inflammation (Wieslander et al., 2011). The same study inferred that consumption of cookies made from common and tartary BW may lower cholesterol levels and cardiovascular risks as well as improve lung vital capacity. These effects were ascribed to the presence of rutin and other flavonoids in BW (Wieslander et al., 2011). Recently, Nishimura et al. (2016) have shown that rutin-rich tartary BW was effective in lowering body weight, body mass index and body fat percentage of human subjects. The ability of tartary BW to change body composition was associated to its high antioxidant activity. Other beneficial health effects associated with regular daily intake of BW-enriched food were evidenced in recent human studies such as a fatigue reduction in healthy subjects after regular consumption of BW cookies providing an intake of 359.7 mg rutin equivalents per day (Wieslander et al., 2012) and an alleviation of renal dysfunction in type-2 diabetic patients (Qiu, Li, Qin, Yue, & Liu, 2016).

Considering all these powerful functional properties and beneficial health effects provided by BW, it is not odd that regular BW consumption has been associated with
preventive nutrition (Krkoškova & Mrazova, 2005; Zhang et al., 2012). So far, the preventive
health impact of BW has been related to radical scavenging effect of BW peptides as well as
high concentration of numerous other components with healing effects such as flavones,
flavonoids, phytosterols, D-chiro-inositol and myo-inositol (Zhang et al., 2012).
Consequently, BW has been regarded as an ingredient particularly suitable for use in a novel
class of food preparations known as FOSHU (Food for Specified Health Use) (Brunori et al.,
2009). BW is used for food in many different forms: as (un)roasted decorticated grains for
traditional dishes referred to as “kasha”, served as an alternative to rice or porridge or as an
addition to soups/stews or in the form of flour, combined with other cereal flours in bread,
noodles, cakes, pancakes, muffins, etc. Apart from health benefit, an important feature of food
is its convenience. Processing may offer the convenience of consumption to food product.
Following this trend, BW has been lately used as an ingredient in processed ready-to-eat food
such as puffed snacks (Wojtowicz, Kolas, & Moscicki, 2013) and ginger-nut biscuits
(Filipčev, Šimurina, & Bodroža-Solarov, 2015). Porridge is a popular healthy meal consumed
mostly as a breakfast and consists of various cereals or legumes cooked in water or milk to a
mushy consistency. A variant of porridge is instant porridge which preparation is simple as it
does not require cooking but pouring over with warm water. BW can be used as an ingredient
for instant porridges.

The objective of the current randomized, placebo-controlled, crossover intervention study
was to evaluate the effects of a porridge A on metabolic health parameters.
2. Methods

2.1 Study participants

39 Caucasian healthy male and female volunteers were recruited (age 46.6±8.2 y; BMI 25.7±4.2 kg/m²) according to the following inclusion criteria: non-smoking men and women, with a BMI between 20 and 35 kg/m², and serum concentration of total cholesterol and/or triacylglycerol above normal (total cholesterol >5.2 mmol/L or/and LDL cholesterol >3.3 mmol/L or/and TAG >1.7 mmol/L). Exclusion criteria included the presence of diabetes mellitus; cardiovascular, gastrointestinal, or liver disease; usage of antihypertensive or cholesterol-lowering medication; adherence to a prescribed diet; unstable weight in the past 3 months; vigorous physical activity; pregnancy or lactation. A physician confirmed the health conditions of the participants through a complete medical history and physical examination.

The study was approved by the National Ethics Committee of Slovenia. All the participants signed an informed consent. The metabolic studies were performed at the Faculty of Health Sciences of the Primorska University, Isola, Slovenia.

2.2 Intervention

The randomized, placebo-controlled, crossover intervention study was conducted between October 2015 and March 2016 (Fig. 1). After enrolment, subjects were randomly allocated into one of the 3 intervention groups by a staff member not involved in the study. All products were in bags that were identical in appearance and coded A, B, and C. Encoding was performed by a staff member not involved in the study. Encoding was broken after all data analysis had been performed. The study was organized in 3 subsequent phases to evaluate
metabolic effects of A, B and C. Each phase lasted five weeks. Phase 1 included a washout
period (7-days) during which the participants abstained from eating any BW products,
followed by an intervention period (35-days), during which subjects ate 1 bag of product A,
B, or C each day (instead of breakfast). Then, the phase 2 and phase 3 included a washout
period followed by A, B, or C intervention period as in phase 1. Flowchart of participants
through the study is presented in Fig. 2.

All A, B and C porridges used in the study came from the same batch. In order to
standardize the eating process, all participants received the same instructions. Before the
study, an expert dietitian assessed eating and physical activity habits of each participant. To
minimize potential confounding variables, derived from individual lifestyle, subjects followed
some simple rules throughout the study phases. These included exclusion of any food
containing BW (with the exception of the test products taken during the intervention periods),
maintenance of habitual levels of physical activity, maintenance of the usual eating pattern,
avoidance of foods particularly rich in polyphenols, vitamins, other nutrient supplements,
herbal products and medications. Food intake and physical activity were monitored weekly
throughout the study, by 3-day diet records (two weekdays and one weekend). An expert
dietitian carefully explained how to record everything they were eating and drinking and how
to record their physical activity. Dietary data was analysed using the Open Platform for
Clinical Nutrition (OPEN) that is accessible through the website http://opkp.si/. At the end of
each washout and intervention period body weight and composition were measured in the
fasting state, while food and exercise diaries were checked by a dietitian and discussed with
the subjects. At the same time-points, body composition indices were obtained using
bioelectrical impedance (Tanita MC-980MA (Maeno-cho, Japan) and dedicated software
(GMON Pro-Tanita)).
2.3 Products characteristics

The products included three types of porridges (A based on extruded BW, B and C based on extruded maize). Porridge was formulated to contain min 57% cereal-based ingredients (on as is basis). Porridge B contained min 47% cereal-based ingredients and was fortified with proteins (soy protein isolate + casein). Porridge A was defined as containing min 39% (pseudo)cereal-based ingredients and proteins (soy protein isolate + casein). All the ingredients (dried apples, oat flakes, cinnamon) except maize and BW extruded were present in equal amounts in the porridge formulations.

Proximate composition of porridges is displayed in Table 1. Composition of porridges was analysed using the methods of AOAC (2000), which included protein (Official Method No. 950.36), fat (Official Method No. 935.38), reducing sugar (Official Method No. 975.14), total dietary fibre (Official Method No. 958.29), ash (Official Method No. 930.22), starch (14.031), and moisture (Official Method No.926.5) determinations.

The descriptive profiles of porridges A, B and C were evaluated by a panel of 7 trained panellist aged between 30-50 years. During training, porridges were described with attributes by reaching a panel consensus. The panel used 22 descriptive terms grouped under odour, appearance, colour, oral consistency, taste, flavour and aftertaste (Table 2). Attributes were scored according to their intensities on a 9-point scale in which 0 denoted a not
perceived attribute and 9 denoted a strongly perceived attribute. The sensory evaluation was
carried out in a sensory laboratory with booths for each panellist, equipped according to ISO

Porridges were prepared by vigorous mixing of dry porridge blend with warm
water (50°C) at 1:2.5 proportion (w/w), after which it was allowed to swell for 10 minutes.
The porridges were served in randomized order, in portions of approximately 100 ml placed
in glass containers on a white plate. The samples were evaluated using stainless steel
teaspoons. The sensory evaluation was carried out in duplicate.

Back-extrusion method was used to instrumentally determine porridge firmness
and cohesiveness on a Texture Analyser (TA-XTplus, SMS, Godalming, UK). The test
settings were the following: test speed 1.0 mm/s, trigger force 10 g and travel distance 30 mm.
The maximum force registered during penetration of the probe into the sample was used as an
indicator of firmness. On probe return, sample resisted the flow off the disc and the registered
peak force was taken as an indicator of cohesiveness.

General Atwater conversion factors were used to calculate the energy content of all
three porridges. The contribution of soluble fibres to the energy content was also taken into
account (2 kcal/g) as well as the contribution of sweetener. When calculating the energy value
of porridges, carbohydrate content was determined by calculation: available carbohydrates =
100 – (protein + fat + water + ash + alcohol + total fibre) according to FAO/WHO guidelines
that are accessible through the website http://www.fao.org/docrep/006/y5022e/y5022e03.htm.

>> INSERT TABLE 2

2.4 Metabolic assessment
Venous blood samples were collected in vacuum test tubes between 7 A.M. and 9 A.M to obtain serum which was treated according to the analytical protocols and stored at -80°C, until measurements. Serum concentrations of glucose, TAG, total cholesterol, LDL cholesterol and HDL cholesterol were measured using Olympus reagents and performed on an AU 680 analyser (Beckman Coulter). In addition, serum levels of uric acid, bilirubin and adiponectin were also measured. Total bilirubin and uric acid were measured with the cobas c111 analyser (Roche). Serum adiponectin concentrations were measured using enzyme-linked immunosorbent assay by means of commercially available kits. Assay sensitivity was 10 pg/mL. Assays interassay and intraassay CVs were typically <10%.

2.5 Statistics

Data are expressed as mean ± SEM or mean ± SD. In order to evaluate protein effects and BW × protein interactions (A and B), we have used repeated measured ANOVA or ANCOVA (washout values as covariates), where appropriate. When the results of BW × protein interactions were significant (p ≤ 0.05), the changes induced by the products, evaluated as the difference between the values obtained at the end of the intervention and the washout periods, were assessed through paired T-test. Values were logarithmically transformed when appropriate. P-values <0.05 were considered statistically significant. Statistical analysis was performed using SPSS software (version 21; SPSS, Inc., Chicago, IL).
3. RESULTS

3.1 Study population

39 apparently healthy subjects were randomly allocated at the start of the study. The mean age, BMI, SBP, and DBP were 46.6±8.2 years old, 25.7±4.2 kg/m², 136±28 mmHg, 72±19 mmHg, respectively. The mean glucose was 5.16±0.51 mmol/L, most of the subjects were hyperlipidemic, and the mean total, LDL and HDL cholesterol, and TAG were, 6.79±1.02 mmol/L, 4.54±0.82 mmol/L, 1.35±0.35 mmol/L, and 1.86±0.84 mmol/L, respectively. The mean energy intake was 8744.6±2278.1 kJ/day (2092±545 kcal/day).

This randomized, placebo-control, crossover intervention study was organized in 3 subsequent phases (each phase lasted five weeks with a washout period during 7-days) to evaluate the effects of porridges A, B and C on lipid profile (Fig. 1). Of the 39 subjects (17 men, 21 women) who started the study, 34 completed all interventions (Fig. 2). Three subjects dropped out because of illness and two subjects did not withdraw the consent.

3.2 Descriptive profile of porridges, including firmness and cohesiveness

The tested porridges exhibited significant (p < 0.05) differences regarding the majority of descriptive attributes and textural properties (Table 3). The porridge A was firmer and more viscous in relation to the others. It had similar cohesiveness to the non-protein maize porridge C. There was similar trend between instrumentally measured texture and orally
perceived viscosity. Increase in texture and consistency for C and A porridge appears to be related to higher fibre content. It is likely that fibre swelling contributed to the formation of stronger extensive networks. Although gelatinized starch is a main contributor to viscosity of porridges, fibres (especially insoluble ones) have an ability to form stronger rigid structures. The surface of porridge A was significantly less glossy but smoother than C and B, with marked greyish nuance. It had intensive odour, flavour and aftertaste on BW and slightly bitter taste which partially masked the cinnamon/apple aroma. Intensive aroma and perceived bitterness might be attributed to the presence of phenolic compounds in BW. Beany and milky flavour was lightly perceived in B porridge due to presence of soy protein isolate and casein.

Although A porridge also contained the same protein sources in the same amounts, beany and milky flavour as well as beany aftertaste was masked by strong BW aroma. At the same time, the highest sweetness could be attributed to this porridge formulation A.

>> INSERT TABLE 3

3.3 Daily intake of bioactive compounds

Analysis of phenolic compounds was performed according to the method of Mišan et al. (2011). As expected, the porridge A contributed to significantly higher intake of rutin and quercetin due to being based on BW. BW is known as a good source of rutin, quercetin, and flavonoids with healing effect. Porridge A was also high in gallic acid and catechin whereas the porridges B and C were dominated by protocatechuic acid (Table 4).

>> INSERT TABLE 4
3.4 Food intake

Food intake and physical activity were monitored weekly throughout the study, by 3-day diet records. The calculation of energy values of porridges was performed and is as follows: for A 365.92 kcal/100g, for C 366.28 kcal/100g, and for B 374.87 kcal/100g. During intervention, instead of breakfast, participants consumed 80 g of porridge, approximately 300 kcal (Table 5; data for participant A01). Overall, there were no statistically significant differences in daily energy intakes between three groups at baseline (1985 kcal; 2019 kcal; 1997 kcal; p > 0.05) and after the 5-week intervention period of all three phases of the study (p > 0.05) (data not shown).

3.5 Effects of porridges A, B and C on body composition and metabolic profile

The effects of porridges A, B and C on body composition and anthropometric data were also evaluated (Table 6). Weight, fat mass (FM), fat free mass (FFM), metabolic age, and total body water (TBW) of all participants before and in the end of each phase of the study were measured. Table 8 shows that the interaction of BW and protein did not give significantly differences when studying body weight, FM, metabolic age and TBW. However, FFM significantly increased at week 5 in the group who consumed porridge A, confirming the significant BW x protein effect on FFM (0.70±2.1 kg, p=0.037).

The effects of porridges A, B and C on serum glucose levels, lipid profile, inflammatory marker CRP, anti-inflammatory adiponectin, and on serum bilirubin and uric acid levels were also analysed (Table 6). Serum glucose level did not significantly differ
between the groups, nor did inflammatory marker CRP and serum bilirubin levels. However, BW x protein interaction gave marginally significant difference to serum bilirubin levels, a potent endogenous antioxidant (p=0.051). In addition, there was a significant BW x protein effect on serum total cholesterol, LDL cholesterol, HDL cholesterol, and TAG levels. The ingestion of porridge A significantly decreased total cholesterol (-0.69±0.19 mmol/L, p=0.002), LDL cholesterol (-0.63±0.16 mmol/L, p=0.001), TAG (-0.27±0.15 mmol/L, p=0.028); on the other hand, significant increase in HDL cholesterol was observed (0.14±0.07 mmol/L, p=0.003). Moreover, there was also a significant protein effects on total cholesterol (-0.25±0.18 mmol/L, p=0.034). Furthermore, there was also a significant BW x protein effect on serum adiponectin and uric acid levels. Anti-inflammatory adiponectin significantly increased in the group which consumed porridge A compared to the group which consumed porridge B and C (4.6±2.8 µg/mL, p=0.021); whereas, endogenous antioxidant uric acid decreased from baseline to week 5 in the group which consumed porridge A (-17.6±15.9 µmol/L, p=0.024). In addition, significant correlation between reduction in LDL cholesterol and production of anti-inflammatory adiponectin was observed at week 5 in the group which consumed porridge A (R²=0.764; p < 0.01).

>> INSERT TABLE 6
4. DISCUSSION

In recent years, there is renewed interest in the utilization of BW due to the “re-discovered” nutritional benefits (Izydorczyk et al., 2014; Zhu, 2016). Based on increased potential to produce a new generation of food products that can deliver specific health benefits, the porridge A was developed and a randomized controlled study was performed.

Porridge A was observed to show lipid lowering and anti-inflammatory effects in healthy participants with mild to modest hypercholesterolemia during a randomized controlled trial. A number of animal studies have shown that bioactive compounds of BW could positively impact on the metabolic outcomes (Tomotake et al., 2007; Yao et al., 2008; Merendino et al., 2014), whereas proteins, dietary fibres, and flavonoids were the effective components of BW (Izydorczyk et al., 2014). These compounds have been shown to improve hypercholesterolemia (Tomotake et al., 2007; Yang et al., 2014), hyperlipidemia (Wang, Liu, Gao, Parry, & Wei, 2009), hyperglycemia and oxidative stress (Yao et al., 2008; Gong, Li, Zhang, Li, & Zhang, 2012) in rodent models. Furthermore, numerous studies on BW confirmed that this plant has beneficial metabolic effect and plays an antioxidant, anti-inflammatory and anti-hypertensive role also in humans (Weislander et al., 2011; Weislander et al., 2012; Nishimura et al., 2016; Qiu, Li, Qin, Yue, & Liu, 2016).

The foods used in this study were based on commercially available ingredients and recipes and were well accepted by the participants. BW is not quite common in industrially produced food; therefore, the daily intake of nutrients and phytochemicals from these products is limited (Guo et al., 2012; Qin, Wu, Yao, & Ren, 2013). The porridge A from the present study retained most of the beneficial nutrients, while keeping acceptable sensory characteristics for consumption. To mask the bitterness of BW, dried apples, sweetener and cinnamon were used. Compared with C and B, porridge A contains more insoluble fibres,
more rutin, quercetin, gallic acid, and less sugar. The choice has been determined by the aim of evaluating the metabolic effects of porridge A on lipid profile, inflammation, and oxidative stress, while at the same time preserving the most appreciated porridge properties, such as taste, odour, appearance, oral consistency, flavour, and minimizing undesirable consequences. Indeed, during the whole intervention periods neither side effects, allergic reactions, gastrointestinal discomforts nor any other manifestation were noticed in any of the subjects.

Anthropometrical and biochemical analysis were performed before and at the end of each intervention periods. The combined nutrient and phytochemical composition of porridge A likely exerted synergistic effects beneficial on human health. Although the number of studies investigating the cholesterol-lowering activity of BW in humans is small (Weislander et al., 2011; Gimenez-Bastida & Zielinski, 2015), our results indicated strong association between porridge A intake and improved lipid profile, as shown by lower total cholesterol, LDL-cholesterol, and TAG. Indeed, TAG, total cholesterol and LDL-cholesterol were significantly reduced by the porridge A dietary intervention, as significant differences were observed in the changes from baseline to week 5. The dietary intake showed that after 5-weeks of intervention, the energy intake was not affected. Therefore, porridge A intervention showed a significant decrease in lipids with a relatively stable energy intake and stable weight during the test period. Proteins extracted from BW have low digestibility and are known to suppress hypercholesterolemia by increasing faecal excretion of sterol in mice (Tomotake et al., 2006) and rats (Tomotake et al., 2007) and down-regulation of intestinal NPC1L1 and ACAT2 (Yang et al., 2014). In addition to BW proteins, previous studies showed that also dietary fibre, phytosterols and polyphenols can lower the cholesterol level in animal models (Park et al., 2002; Yang et al., 2014). However, in the present study it is difficult to dissect whether these effects are due to the beneficial effects of one bioactive compound or because of the synergistic effects of different chemical compounds, including added proteins in porridge A.
Indeed, significant reduction in total cholesterol has been observed due to dietary intervention with both, BW and protein – enriched porridges. Recently, by performing meta-analysis, it has been shown that soy protein supplementation reduces clinical indices in type 2 diabetes and metabolic syndrome (Zhang, Zhang, & Chi, 2016).

Moreover, the ingestion of the porridge A, significantly increased FFM at week 5, probably, due to synergistic effects of different chemical compounds and added proteins in the porridge A. Recently, Nishimura et al. (2016) revealed that rutin-rich Tartary BW showed potential effects on decreasing body weight and body fat percentage. Furthermore, Egawa et al. (2012) reported that the ingestion of 110 mg quercetin for 12 weeks decreased visceral fat area in subjects with BMI between 25 kg/m² and 30 kg/m². However, little is known about the beneficial effects of BW on FFM until now. It is well known that high-protein diets exert beneficial effects on appetite, anthropometry, and body composition; indeed, in the present study casein and soy protein isolate have influence on FFM, which is in agreement with previous report (Tahavorgar, Vafa, Shidfar, Gohari, & Heydari, 2014), although, the influence was not statistically significant.

There are inconsistent data about antidiabetic effect of the BW in in vitro and in vivo studies (Zeng, Pu, Du, Yang, & Jia, 2012; Su-Que et al., 2013; Qiu, Li, Qin, Yue, & Liu, 2016). BW, for example, is used as a dietary use in China in order to prevent diabetes (Zeng, Pu, Du, Yang, & Jia, 2012). In addition, consumption of BW bread or BW groats compared to white wheat bread showed a decrease in the postprandial plasma glucose in both type 2 diabetic subjects and healthy subjects (Su-Que et al., 2013). It has been shown, that quercetin, isoquercetin, rutin, and D-chiro-inositol, extracted from BW are effective in lowering glucose level (Yao et al., 2008). This is consistent with the in vitro and in vivo studies that BW extract and polyphenols showed inhibitory activities against starch digestive enzymes, thereby lowering blood glucose level (Qin, Wu, Yao, & Ren, 2013; Zhu, 2015). Moreover, Lee et al.
demonstrated that rutin and quercetin extracted from BW improved hyperglycemia and hyperinsulinemia in C57BL6 mice (Lee, Hsu, Shen, Cheng, & Wu, 2012). However, in the present study intervention with A did not show an improvement in serum glucose level. But, it has to be stress out, that participants in the present study were normoglycemic.

Adiponectin, a 244-amino acid peptide secreted from adipocytes, protects against metabolic and cardiovascular diseases (Turer & Scherer, 2016); while low serum levels of adiponectin is common in obesity (Petelin et al., 2014). In the present study, serum adiponectin levels were higher when the diet was enriched with BW, but they declined when BW was absent, which was all the more remarkable because weight and FM was similar between interventional periods in all three dietary interventions. Previously, it has been shown that rutin has the potential to inhibit the expression of leptin and up-regulate the expression of adiponectin at the protein level in 3T3-L1 adipocytes (Hsu, Wu, Huang, & Yen, 2009). BW, especially rutin has therefore the potential to stimulate adiponectin secretion from adipose tissue and improve adipokine imbalance. In addition, it has been recently shown that tartary BW extract and rutin inhibited the nuclear factor kappa B activation in LPS-stimulated macrophages (Karki, Park, & Kim, 2013), confirming the positive effects of BW on reducing the inflammation.

Increasing appreciation of functional properties of BW has also encouraged some researchers about its beneficial effects through its antioxidant properties. Zhou et al. have recently reported that BW honey showed protective effects on hydroxyl radical-induced DNA damage (Zhou et al., 2012). The high antioxidant capacity of BW is mainly due to its polyphenol content, especially rutin (Kreft, Fabjan, & Yasumoto, 2006). Indeed, it has been suggested that rutin may be involved in activation and upregulation of endogenous anti-oxidative enzymes (Yeh, Yang, Yang, Li, & Kuan, 2014); one proposed mechanism was through the activation of heme oxygenase (HO-1). In the present study, increase in serum
bilirubin levels, the potent endogenous antioxidant, was detected, confirming the expression
of HO-1. In addition to increasing serum bilirubin levels, heme oxygenase-1 system is
involved also in enhancing adiponectin synthesis and release (Nicolai et al., 2009). 
Overexpression of HO-1 resulted in a marked increase in adiponectin with a corresponding
decrease of inflammatory cytokines in animal models of obesity (Li et al., 2008). Therefore,
BW, especially rutin, may be linked to improved metabolic factors through an anti-
inflammatory and anti-oxidative related mechanism. However, further studies investigating
the anti-inflammatory and anti-oxidative effects of the BW are required to draw conclusions
due to the low number of studies performing so far.

Uric acid is another potent water-soluble antioxidant and an increase in its serum
levels could be associated with the lipid disorders in subjects with metabolic syndrome.
However, several observational studies indicate that high levels of uric acid increase the risk
of cardiovascular events by metabolism-related inflammation (Kushiyama et al., 2016). In
agreement with previous studies on high fat-fed rats (Amin, Kamel, & Eltawab, 2011; Joanna,
Henryk, Jadwiga, & Renata, 2013), enrichment of the diet with BW resulted in decrease of
serum uric acid levels. The elevated serum uric acid levels in the present study may
compensate the oxidative stress related to metabolic syndrome related disorders. It is therefore
possible that the 5-weeks of dietary intervention with A resulted in lower oxidative stress and
consequently, decreased serum uric acid levels were detected.

We have to stress out that the present study has several limitations. First of all, the
duration of the present study was only 5 weeks, which might be insufficient to detect
considerable changes in glucose levels. Second, the present study allowed participants to
remain in “free-living” environments; therefore, the results are based on participant’s
motivation and compliance. Because of the length of the study, we had concerns about
compliance; participants in “free-living” environments might add instead of substituting foods
to their usual diet, leading to higher overall energy intake. Third, we did not use any biomarkers related to BW.

However, overall, these findings may support that BW as a part of porridge consumption is an effective and convenient nutritional therapy for the improvement of lipid profile, inflammation, and oxidative stress in participants with metabolic syndrome components.
Acknowledgments

The authors would like to thank all the subjects for volunteering in this study and nurses of the Faculty of Health Sciences for taking the blood samples. The authors would also like to thank Vanja Pahor and the Izola General Hospital biochemical laboratory staff and Slavica Karanović from EuroTim, Novi Sad, who helped them formulate and produce the porridges.

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Conflict of interest

The authors have no conflicts of interest to report.
REFERENCES


Joanna, C., Henryk, B., Jadwiga, K., & Renata, F. (2013). The Effect of Buckwheat (Fagopyrum
esculentum Moench) Groats Addition to the Lard Diet on Antioxidant Parameters of Plasma
1
2 and Selected Tissues in Wistar Rats. *International Journal of Biological, Biomolecular,*
3
4 *Agricultural, Food and Biotechnological Engineering*, 7, 2013.
5
7
8 oxidation
9
10 and inhibits pro-inflammatory mediators in lipopolysaccharide-stimulated macrophages
11 (RAW264.7). *Journal of Integrative Medicine, 11*, 246-252.
12
15
16
18
20
21 Kushiyama, A., Nakatsu, Y., Matsunaga, Y., Yamamotoya, T., Mori, K., Ueda, K., ... Asano, T. (2016). Role of Uric Acid Metabolism-Related Inflammation in the Pathogenesis of
22 Metabolic Syndrome Components Such as Atherosclerosis and Nonalcoholic Steatohepatitis.
23 *Mediators of Inflammation, 2016*, 8603164.
24
26 signaling and insulin resistance. *Molecular Medicine, 16*, 543-552.


Merendino, N., Molinari, R., Costantini, L., Mazzucato, A., Pucci, A., Bonafaccia F,…


Table 1

Proximate composition of the tested porridges A, B and C.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Porridge</th>
<th>A</th>
<th>C</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(g/100 g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch content</td>
<td></td>
<td>26.79±0.32</td>
<td>41.08±0.54</td>
<td>36.18±0.46</td>
</tr>
<tr>
<td>Total sugar content</td>
<td></td>
<td>9.77±0.13</td>
<td>17.17±0.27</td>
<td>14.77±0.21</td>
</tr>
<tr>
<td>Saccharose</td>
<td></td>
<td>2.29±0.07</td>
<td>1.98±0.01</td>
<td>1.69±0.02</td>
</tr>
<tr>
<td>Fructose</td>
<td></td>
<td>5.26±0.08</td>
<td>12.70±0.14</td>
<td>11.07±0.10</td>
</tr>
<tr>
<td>Glucose</td>
<td></td>
<td>2.22±0.01</td>
<td>2.49±0.02</td>
<td>2.02±0.01</td>
</tr>
<tr>
<td>Protein content</td>
<td></td>
<td>17.33±0.12</td>
<td>7.66±0.10</td>
<td>17.50±0.15</td>
</tr>
<tr>
<td>Total fibre content</td>
<td></td>
<td>8.74±0.90</td>
<td>7.60±0.18</td>
<td>6.71±0.50</td>
</tr>
<tr>
<td>Insoluble</td>
<td></td>
<td>7.19±0.62</td>
<td>4.80±0.06</td>
<td>3.23±0.08</td>
</tr>
<tr>
<td>Soluble</td>
<td></td>
<td>1.65±0.10</td>
<td>3.08±0.08</td>
<td>3.38±0.18</td>
</tr>
<tr>
<td>Moisture content</td>
<td></td>
<td>8.11±0.21</td>
<td>7.51±0.10</td>
<td>7.37±0.17</td>
</tr>
<tr>
<td>Fat content</td>
<td></td>
<td>4.68±0.15</td>
<td>5.48±0.11</td>
<td>6.57±0.17</td>
</tr>
<tr>
<td>Ash content</td>
<td></td>
<td>2.55±0.06</td>
<td>1.71±0.08</td>
<td>2.11±0.01</td>
</tr>
<tr>
<td>Available carbohydrates (by calculation)</td>
<td></td>
<td>58.61</td>
<td>70.94</td>
<td>58.85</td>
</tr>
<tr>
<td>(mg/100 g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>299.10±0.10</td>
<td>10.83±0.03</td>
<td>239.27±0.06</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>407.93±4.93</td>
<td>319.77±5.95</td>
<td>256.5±1.82</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>39.44±0.04</td>
<td>18.56±0.04</td>
<td>16.48±0.02</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>10.08±0.10</td>
<td>53.35±0.12</td>
<td>34.53±0.05</td>
</tr>
<tr>
<td>Fe</td>
<td></td>
<td>10.68±0.06</td>
<td>8.33±0.04</td>
<td>7.44±0.08</td>
</tr>
<tr>
<td>Zn</td>
<td>5.58±0.05</td>
<td>3.10±0.03</td>
<td>3.20±0.02</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as means ± standard deviation.

1 calculated according FAO/WHO Guidelines retrieved from [http://www.fao.org/docrep/006/y5022e/y5022e03.htm](http://www.fao.org/docrep/006/y5022e/y5022e03.htm), available carbs=100-

(prot+fat+water+ash+alcohol+total fibre)
<table>
<thead>
<tr>
<th>Property</th>
<th>Descriptive profile</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour</td>
<td>Odour intensity</td>
<td>The overall odour intensity of the porridge</td>
</tr>
<tr>
<td></td>
<td>Maize porridge odour</td>
<td>Intensity of odour associated with cooked maize porridge</td>
</tr>
<tr>
<td></td>
<td>Buckwheat odour</td>
<td>Intensity of odour associated with cooked buckwheat</td>
</tr>
<tr>
<td></td>
<td>Cinnamon/apple odour</td>
<td>Intensity of odour associated with cinnamon and apple</td>
</tr>
<tr>
<td>Appearance</td>
<td>Glossiness</td>
<td>The amount of shine or gloss perceived on the surface when the cup is bent in the direction of light</td>
</tr>
<tr>
<td></td>
<td>Smoothness</td>
<td>Evenness of porridge associated with presence of lumps or clumps</td>
</tr>
<tr>
<td>Colour</td>
<td>Yellow</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Ochre</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Grey</td>
<td>-</td>
</tr>
<tr>
<td>Oral</td>
<td>Coarseness</td>
<td>The degree to which grittiness of porridge due to presence of small particles could be perceived</td>
</tr>
<tr>
<td></td>
<td>Viscosity</td>
<td>Amount of force required to draw a paste from spoon over the tongue</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Creaminess</strong></td>
<td>Intensity of mouthfeel associated with fatty product such as dairy cream</td>
<td></td>
</tr>
<tr>
<td><strong>Taste</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taste intensity</td>
<td>The overall taste intensity of the porridge</td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td>Basic sweet taste associated with saccharose</td>
<td></td>
</tr>
<tr>
<td>Bitter</td>
<td>Basic bitter taste associated with quinine</td>
<td></td>
</tr>
<tr>
<td><strong>Flavour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinnamon/apple</td>
<td>Intensity of flavour associated with combination of cinnamon and apple</td>
<td></td>
</tr>
<tr>
<td>Maize porridge</td>
<td>Intensity of flavour associated with cooked maize porridge</td>
<td></td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Intensity of flavour associated with cooked buckwheat</td>
<td></td>
</tr>
<tr>
<td>Beany</td>
<td>Intensity of flavour associated with undercooked soy</td>
<td></td>
</tr>
<tr>
<td>Milky</td>
<td>Intensity of flavour associated with dairy products, butter</td>
<td></td>
</tr>
<tr>
<td><strong>Aftertaste</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beany</td>
<td>Intensity of flavour associated with undercooked soy perceived after swallowing the porridge</td>
<td></td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Intensity of flavour associated with cooked buckwheat perceived after swallowing the porridge</td>
<td></td>
</tr>
</tbody>
</table>
Table 3

Descriptive profile of porridges A, B and C, including firmness and cohesiveness measured instrumentally on TA-XTplus Texture Analyser.

<table>
<thead>
<tr>
<th>Property</th>
<th>Descriptive profile</th>
<th>Porridge</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odour</td>
<td>Odour intensity</td>
<td>A 7.71±0.45</td>
<td>4.57±0.51</td>
</tr>
<tr>
<td></td>
<td>Maize porridge odour</td>
<td>0.43±0.38</td>
<td>2.67±0.50</td>
</tr>
<tr>
<td></td>
<td>Buckwheat odour</td>
<td>8.83±0.44</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td></td>
<td>Cinnamon/apple odour</td>
<td>2.00±1.18</td>
<td>4.57±0.96</td>
</tr>
<tr>
<td>Appearance</td>
<td>Glossiness</td>
<td>1.29±0.52</td>
<td>8.43±0.73</td>
</tr>
<tr>
<td></td>
<td>Smoothness</td>
<td>4.14±0.63</td>
<td>3.71±0.76</td>
</tr>
<tr>
<td>Colour</td>
<td>Yellow</td>
<td>0.71±0.71</td>
<td>4.29±0.75</td>
</tr>
<tr>
<td></td>
<td>Ochre</td>
<td>0.86±0.64</td>
<td>7.17±0.87</td>
</tr>
<tr>
<td></td>
<td>Grey</td>
<td>8.29±0.79</td>
<td>1.57±0.74</td>
</tr>
<tr>
<td>Oral consistency</td>
<td>Coarseness</td>
<td>7.13±0.87</td>
<td>5.71±0.72</td>
</tr>
<tr>
<td>Taste</td>
<td>Taste intensity</td>
<td>8.71±0.49</td>
<td>5.43±0.53</td>
</tr>
<tr>
<td></td>
<td>Sweet</td>
<td>5.62±0.82</td>
<td>4.29±0.49</td>
</tr>
<tr>
<td></td>
<td>Bitter</td>
<td>3.86±0.74</td>
<td>0.14±0.38</td>
</tr>
<tr>
<td>Flavour</td>
<td>Cinnamon/apple</td>
<td>2.13±0.61</td>
<td>3.86±0.72</td>
</tr>
<tr>
<td></td>
<td>Maize porridge</td>
<td>0.14±0.38</td>
<td>6.86±0.83</td>
</tr>
<tr>
<td></td>
<td>Buckwheat</td>
<td>8.86±0.58</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td></td>
<td>Beany</td>
<td>0.00±0.00</td>
<td>1.43±0.85</td>
</tr>
<tr>
<td></td>
<td>Milky</td>
<td>1.86±1.07</td>
<td>0.14±0.12</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>Buckwheat</td>
<td>5.86±0.69</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td></td>
<td>Beany</td>
<td>0.57±0.53</td>
<td>2.14±0.66</td>
</tr>
<tr>
<td>Instrumental</td>
<td>Firmness (g)</td>
<td>126.28±3.01</td>
<td>40.77±2.37</td>
</tr>
<tr>
<td>texture</td>
<td>Cohesiveness (g)</td>
<td>117.47±18.86</td>
<td>37.91±4.10</td>
</tr>
</tbody>
</table>

*p-values (ANOVA). Attributes highlighted in bold have significant effect in the ANOVA model. P value greater than 0.05 is considered non-significant.
Table 4
Daily intake of bioactive (polyphenolic) compounds of porridges A, B and C (if 80 g of porridges A, B and C was consumed daily).

<table>
<thead>
<tr>
<th>Bioactive compounds</th>
<th>Porridges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Gallic acid</td>
<td>3.184±0.262</td>
</tr>
<tr>
<td>Protocatechuic acid</td>
<td>2.165±0.019</td>
</tr>
<tr>
<td>p-Hydroxybenzoic acid</td>
<td>0.000±0.000</td>
</tr>
<tr>
<td>Catechin</td>
<td>2.355±0.126</td>
</tr>
<tr>
<td>Caffeic acid</td>
<td>1.735±0.017</td>
</tr>
<tr>
<td>Epicatechin</td>
<td>0.720±0.009</td>
</tr>
<tr>
<td>Ferulic acid</td>
<td>0.527±0.058</td>
</tr>
<tr>
<td>Rutin</td>
<td>2.139±0.106</td>
</tr>
<tr>
<td>Cinnamic acid</td>
<td>0.310±0.009</td>
</tr>
<tr>
<td>Quercetin</td>
<td>3.124±0.169</td>
</tr>
</tbody>
</table>
Table 5
Daily menu, before and during the intervention, for participant A01.

<table>
<thead>
<tr>
<th>Daily Menu, before</th>
<th>Food (g)</th>
<th>Energy (kcal)</th>
<th>Daily Menu, during</th>
<th>Food (g)</th>
<th>Energy (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td></td>
<td>383.96</td>
<td>Breakfast</td>
<td></td>
<td>366.73</td>
</tr>
<tr>
<td>Coffee with milk</td>
<td>200</td>
<td>73.99</td>
<td>Coffee with milk</td>
<td>200</td>
<td>73.99</td>
</tr>
<tr>
<td>Cornflakes</td>
<td>40</td>
<td>151.82</td>
<td>Porridge A</td>
<td>80</td>
<td>292.74</td>
</tr>
<tr>
<td>Buttermilk</td>
<td>220</td>
<td>66.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Grapes</td>
<td>120</td>
<td>91.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
<td>800.40</td>
<td>Lunch</td>
<td></td>
<td>783.22</td>
</tr>
<tr>
<td>Bolognese sauce</td>
<td>300</td>
<td>284.06</td>
<td>Gorgonzola sauce</td>
<td>150</td>
<td>268.28</td>
</tr>
<tr>
<td>Cooked Pasta</td>
<td>200</td>
<td>262.00</td>
<td>Cooked Pasta</td>
<td>250</td>
<td>327.50</td>
</tr>
<tr>
<td>Parmesan</td>
<td>25</td>
<td>97.35</td>
<td>Cabbage</td>
<td>100</td>
<td>25.05</td>
</tr>
<tr>
<td>Red wine</td>
<td>100</td>
<td>83.00</td>
<td>Vegetable oil</td>
<td>10</td>
<td>88.40</td>
</tr>
<tr>
<td>Coffee with milk</td>
<td>200</td>
<td>73.99</td>
<td>Coffee with milk</td>
<td>200</td>
<td>73.99</td>
</tr>
<tr>
<td>Afternoon snack</td>
<td></td>
<td>292.47</td>
<td>Afternoon snack</td>
<td></td>
<td>398.44</td>
</tr>
<tr>
<td>Ice cream</td>
<td>126</td>
<td>292.47</td>
<td>Cheesecake</td>
<td>100</td>
<td>286.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Milk 1.4%</td>
<td>244</td>
<td>112.44</td>
</tr>
<tr>
<td>Dinner</td>
<td></td>
<td>378.31</td>
<td>Dinner</td>
<td></td>
<td>349.11</td>
</tr>
<tr>
<td>Cabbage with</td>
<td>100</td>
<td>25.05</td>
<td>Chicory with</td>
<td>79</td>
<td>23.92</td>
</tr>
<tr>
<td>Beans and</td>
<td>50</td>
<td>47.99</td>
<td>Beans and</td>
<td>144</td>
<td>138.20</td>
</tr>
<tr>
<td>Tuna</td>
<td>50</td>
<td>199.15</td>
<td>Sweet corn</td>
<td>78</td>
<td>63.18</td>
</tr>
<tr>
<td>Olive oil</td>
<td>12</td>
<td>106.12</td>
<td>Olive oil</td>
<td>14</td>
<td>123.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1855.14</td>
<td></td>
<td></td>
<td>1904.76</td>
</tr>
</tbody>
</table>
### Table 6

Effect of porridges A, B and C on body composition, anthropometric data, and metabolic profile.

<table>
<thead>
<tr>
<th></th>
<th>Study Phase 1</th>
<th>Study Phase 2</th>
<th>Study Phase 3</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Washout</td>
<td>Washout</td>
<td>Washout</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.7±2.8</td>
<td>76.2±2.9</td>
<td>76.1±2.7</td>
<td>75.3±2.8</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>55.2±2.1</td>
<td>55.9±2.2</td>
<td>55.7±2.1</td>
<td>56.1±2.2</td>
</tr>
<tr>
<td>FM (kg)</td>
<td>20.5±1.2</td>
<td>20.3±1.4</td>
<td>20.4±1.3</td>
<td>20.4±1.2</td>
</tr>
<tr>
<td>Metabolic age (yr)</td>
<td>44.5±2.0</td>
<td>44.0±1.8</td>
<td>44.2±2.0</td>
<td>43.9±1.9</td>
</tr>
<tr>
<td>TBW (%)</td>
<td>51.9±0.9</td>
<td>52.2±0.9</td>
<td>52.0±1.0</td>
<td>52.1±0.9</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>5.25±0.07</td>
<td>5.21±0.09</td>
<td>5.12±0.12</td>
<td>5.11±0.10</td>
</tr>
</tbody>
</table>

### Lipid metabolism

<table>
<thead>
<tr>
<th></th>
<th>Study Phase 1</th>
<th>Study Phase 2</th>
<th>Study Phase 3</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol (mmol/L)</td>
<td>6.82±0.19</td>
<td>6.13±0.17</td>
<td>6.72±0.17</td>
<td>6.47±0.18</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/L)</td>
<td>4.55±0.16</td>
<td>3.92±0.15</td>
<td>4.49±0.16</td>
<td>4.28±0.15</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/L)</td>
<td>1.37±0.06</td>
<td>1.51±0.07</td>
<td>1.32±0.07</td>
<td>1.39±0.08</td>
</tr>
<tr>
<td>(mmol/L)</td>
<td>1.89±0.14</td>
<td>1.62±0.15</td>
<td>1.90±0.14</td>
<td>1.76±0.16</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>Inflammatory/anti-inflammatory mediators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRP (mg/L)</td>
<td>2.9±0.8</td>
<td>2.6±0.6</td>
<td>2.4±0.7</td>
<td>2.3±0.7</td>
</tr>
<tr>
<td>Adiponectin (μg/mL)</td>
<td>15.9±2.2</td>
<td>20.5±2.8</td>
<td>14.8±2.1</td>
<td>15.3±2.3</td>
</tr>
<tr>
<td><strong>Antioxidants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilirubin (μmol/L)</td>
<td>9.37±1.21</td>
<td>11.25±1.61</td>
<td>9.10±1.11</td>
<td>9.34±1.31</td>
</tr>
<tr>
<td>Uric acid (μmol/L)</td>
<td>332.6±15.9</td>
<td>315.0±15.0</td>
<td>335.4±15.7</td>
<td>333.9±16.0</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SEM. Repeated measurements ANOVA or ANCOVA (washout values as covariates) were used where appropriate.

P value greater than 0.05 is considered non-significant. BW, buckwheat; CRP, C-reactive protein; FFM, fat free mass; FM, fat mass; HDL, high density lipoprotein; LDL, low density lipoprotein; TAG, triacylglycerols; TBW, total body water.
Highlights:

- A new type of buckwheat food product with health benefits was developed
- A new buckwheat-enriched porridge is effective in improving lipid profile
- A new buckwheat-enriched porridge is effective in reducing inflammation
- Buckwheat-enriched porridge is a convenient food product for nutritional therapy
Figure 1. Design of the experimental study.

Figure 2. Participant flow diagram. The diagram depicts number of recruited volunteer and actual number of participant included in data analysis.
Enrollment:

42 Invited to screening

39 Randomly assigned and started study

3 Excluded
2 cholesterol lowering drug did not meet criteria

Phase 1

13 Started A intervention
Allocation 1
Follow-Up 1
Analysis 1
0 Lost to follow-up
13 Analyzed

13 Started C intervention
Allocation 1
Follow-Up 1
Analysis 1
1 Lost to follow-up (illness)
12 Analyzed

13 Started B intervention
Allocation 1
Follow-Up 1
Analysis 1
2 Lost to follow-up (illness)
11 Analyzed

Phase 2

13 Started C intervention
Allocation 2
Follow-Up 2
Analysis 2
1 Lost to follow-up (withdrew consent)
12 Analyzed

12 Started B intervention
Allocation 2
Follow-Up 2
Analysis 2
1 Lost to follow-up (withdrew consent)
11 Analyzed

11 Started A intervention
Allocation 2
Follow-Up 2
Analysis 2
0 Lost to follow-up
11 Analyzed

Phase 3

12 Started B intervention
Allocation 3
Follow-Up 3
Analysis 3
0 Lost to follow-up
12 Analyzed

11 Started A intervention
Allocation 3
Follow-Up 3
Analysis 3
0 Lost to follow-up
11 Analyzed

11 Started C intervention
Allocation 3
Follow-Up 3
Analysis 3
0 Lost to follow-up
11 Analyzed