Functional and physiological properties of total, soluble, and insoluble dietary fibres derived from defatted rice bran

Cheickna Daou · Hui Zhang

Revised: 27 December 2012 / Accepted: 10 January 2013 / Published online: 25 January 2013
© Association of Food Scientists & Technologists (India) 2013

Abstract Enzymatic- gravimetric method was used to obtain three fractions of dietary from defatted rice bran. The functional and physiological properties such as viscosity, cation exchange capacity (CEC), and glucose dialysis retardation index (GDRI), cholesterol and bile salt adsorption capacity of the resultant fractions were evaluated. Insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) when compared showed that SDF exhibited significantly ($p < 0.05$) higher viscosity (2.35 mPa.s), greater GDRI value (17.65 %) at 60 min and significantly lowered concentration of cholesterol at pH7 (29.90 %, $p < 0.05$). However IDF showed the highest CEC and its adsorption capacity of bile salt was higher than SDF (18.20 % vs. 13.76 %; $p < 0.05$), while CEC and cholesterol absorption capacity of TDF were similar to SDF. These properties indicate that rice bran soluble, insoluble and total fibres are functional ingredients which can be added to various food products and dietetic, low-calorie high-fiber foods to enhance their nutraceutical properties and health benefits.

Keywords Dietary fibre · Defatted rice bran · Functional properties · Hypoglycaemic effect · Cholesterol- lowering effect and health benefits

Introduction

Rice, a staple food of many countries, is usually consumed polished (Zha et al. 2009). Rice bran, made up of pericarp, seed coat, aleuronic layer, germ and small portion of starchy endosperm is derived from the outer layer of brown rice (Shibuya and Iwasaki 1984). It is a by-product resulting from the processing of brown rice and constituted 10 % of the entire weight of the rice (Li et al. 2008). At the present, a large amount of this by-product is discarded or used as animal feed (Harada et al. 2008). However, according its proximate composition (protein, oil, vitamin, mineral dietary fiber, etc.) the bran promotes high nutritional quality and physiological properties (Zigoneanu et al. 2008).

Rice bran has many food applications in prepared foods, nutraceuticals and functional foods. Some of applications are in snack foods, bakery, pasta, gluten free, beverages (Faccin et al. 2009) and meat products (Huang et al. 2005). It has been also used to stabilize a variety of food products (Mahua 2007). While, defatted rice bran, a by-product of rice bran (residue resulting from oil extraction from whole rice) is an excellent source of nutrients including, dietary fiber and other components (Abdul-Hamid and Luan 2000)

Dietary fiber is the edible portion of plants or analogous carbohydrates that are resistant to digestion and adsorption in the human small intestine with complete or partial fermentation in the large intestine (AACC 2001). It includes polysaccharides, oligosaccharides, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and blood cholesterol and glucose attenuation (AACC 2001). Some of these materials may in fact be partially digested in the lower gastrointestinal tract by the microbial flora of the colon. According to solubility, dietary fiber may be classified as soluble dietary fiber (SDF) or insoluble dietary fiber (IDF), and the soluble

C. Daou (✉) · H. Zhang
State Key Laboratory of the School of Food Science and Technology, Jiangnan University, 1800 Lihu Road, Wuxi 214122, People's Republic of China
e-mail: rimma504@yahoo.fr

C. Daou · H. Zhang
School of Food Science and Technology, Jiangnan University, 1800 Lihu Road, Wuxi 214122, People's Republic of China

C. Daou
Universite des Sciences des Techniques et des Technologies de Bamako, Bamako, Mali

and insoluble fractions together give total dietary fiber (TDF). Both types are known to be associated with specific metabolic and physiological functions in human (Roehrig 1988).

The role of dietary fiber in health and nutrition has stimulated a wide range of research activities. Accumulating evidence favors the view that increased intake of dietary fiber (DF) has beneficial effects against chronic diseases. Anderson et al. (2009) reported that increasing dietary fiber intake lowers blood pressure and serum cholesterol levels, improves glycaemia and insulin sensitivity in non-diabetic and diabetic individuals. Anderson further stated that, increasing consumption of DF significantly enhances weight loss in obese individuals as well as benefits gastro esophageal reflux disease, duodenal ulcer, diverticulitis, constipation and hemorrhoids and enhances immune function (prebiotic fibers :stimulating the production of beneficial bacteria in the colon). Champ and Guillon (2000) also concluded that dietary fiber has been accepted in the prevention and management of disease in western society; it exerts its direct physiological effect throughout the gastrointestinal tract in addition to affecting metabolic activities. These mechanisms of action are related to its physico-chemical properties and its fermentation in large intestine. Schneeman (1998) also reported about health benefits of dietary fibers. The recommended intake of dietary fiber is ranging from 30 to 45 g per day (Schweizer and Wursch 1991).

The health benefit and physiological properties of dietary fiber are difficult to predict on the basis of their structures alone, however, they are predictable on the basis of physico-chemical properties such as water holding capacity, swelling, oil or fat binding capacity, viscosity, cation exchange capacity, bile acid binding, particle size etc. Thus physiological effects of fiber are dependent on a complex mixture of structural, chemical and physical properties (Blackwood et al. 2000)

The purpose of this study was to develop a comparative study of functional and physiological properties of soluble, insoluble and total dietary fiber derived from defatted rice bran.

Materials and methods

Defatted rice bran was obtained from Xuzhou oil Company (Xuzhou, Jiangsu Province, China).

Proximate Composition of defatted rice bran and its TDF

The moisture, ash, protein, and fat contents were determined according to methods established by the AOAC. Total

insoluble and soluble dietary fiber in the defatted rice bran was determined according to the enzymatic-gravimetric method of Prosky et al. (1988) Cellulose, hemicellulose and lignin content were determined according biochemical method (Maynard 1970)

Extraction of dietary fibers

Insoluble, soluble and total dietary fibers were extracted according to the method described by Mirko et al. 2003 with minimal modifications. The defatted rice bran was cooked with Termamyl TM 75 $\mu\text{L/g}$ v/w (heat stable α -amylase 20.000 U/g -Novozymes Biological Engineering – Beijing – China) at 100 °C for 1 h to give gelatinization, hydrolysis and depolymerization of starch followed by digestion with alcalase 35 $\mu\text{L/g}$ v/w (Alcalase 2.4 L (2.4 AU/g) Novozymes Biological Engineering Beijing-China) at 60 °C for 1 h to solubilise and depolymerized proteins. Enzymatic treatment was completed with incubation with amyloglucosidase 30 $\mu\text{L/g}$ v/w (100.000 U/g Novozymes Biological Engineering Beijing – China) at 60 °C for 1 h to hydrolyze starch fragments into glucose.

Following the above treatment of the samples four volumes of 80 % (v/v) ethanol (preheated at 60 °C) were added to precipitate total dietary fiber (TDF) as well as to remove depolymerized protein and glucose. The precipitation was allowed to occur at room temperature for 60 min, followed by centrifugation (4000 rpm for 15 min), and washing of the residual mass twice with 78 % and 95 % (volume/volume) of ethanol respectively and then with acetone. The washed residual mass was then dried overnight in a vacuum oven at 60 °C.

For IDF and SDF the suspension was centrifuged (4000 rpm for 20 min) and the resultant supernatant was used for isolation of SDF while the residue was washed twice with hot water (70 °C), 95 % (v/v) ethanol and acetone and finally dried overnight in vacuum oven at 60 °C to give IDF.

Combined solution of the supernatant and water washings is precipitated with four volumes of 80 % (v/v) ethanol (60 °C) for SDF determination. After centrifugation, the residue was washed twice with 78 % and 95 % (v/v) ethanol and acetone respectively, and was dried in a vacuum oven at 60 °C.

TDF, IDF and SDF were corrected for residual protein and ash content (one duplicate is analyzed for protein and the other is incubated at 525 °C to determine ash. The TDF, IDF and SDF are the weight of filtered and dried residue less the weight of the protein and ash).

Viscosity

Viscosities of dietary fiber fractions were measured using the method of Frost et al. (1984) with some modifications.

Two different concentrations of sample slurry, namely 1 % and 3 % (weight/volume) were prepared by slowly adding an appropriate amount of dietary fiber fractions to distilled water and mixing at high speed in a warring blender for 1 min. The solutions were allowed to sit at room temperature for 24 h to come to equilibrium and entrapped air to escape before viscosity measurements were made using a Rheometer AR-1000 (TA. Instruments) with Steel cone 2°, 60 mm under following conditions Shear stress (Pa): 1–50; Shear rate (S^{-1}): 0–50; Gap (μm): 1000 at room temperature

The glucose dialysis retardation index (GDRI) the GDRI was measured according to the procedure reported by Adiotomre et al. (1990). The effect of fiber on jejunal nutrient absorption was indicated by the GDRI, which is calculated as:

$$GDRI = 100 - \left(\frac{\text{Total glucose diffused from sac containing fibre}}{\text{Total glucose diffused from sac with no fibre present}} \right) \times 100$$

Ten-centimeter lengths of dialysis bags (12000–14000 molecular weight cut off (MWCO), Dialysis Tubing Visking, Medicell International Ltd, London, UK) were soaked in 1 g sodium azide/l. the bag was filled with 6 ml of 1 g sodium azide/L and 36 mg glucose alone (control) or with the addition of 0.2 g of fiber. Fiber had been hydrated in an aqueous solution of 1 g sodium azide/L for 14 h before dialysis. The bag tied and suspended in 100 ml of 1 g sodium azide/L and placed in stirred bath at 37 °C for 60 min. at 30 and 60 min, 2 ml of the dialysate was analyzed for glucose by the glucose oxidase- peroxidase method.

Determination of cation- exchange capacity (CEC)

The CEC of fiber was determined as described by Gorecka et al. (2000) with some modifications: the samples were immersed in 0.1 mol/L HCl. After 48 h excess acid was removed using distilled water and 10 % $AgNO_3$ solution respectively, until chloride ions were not identified (when the opaque white precipitate becomes of $AgCl$ colorless) and the samples then freeze- dried.

0.205 g of freeze dried sample was accurately weighed, dispersed in 100 ml of 5 % NaCl solution and magnetically stirred and slowly titrated with 0.1 mol/L NaOH until end point and the pH value recorded. .

Determination of cholesterol and sodium cholate absorption capacity

Cholesterol absorption capacity of dietary fiber was determined according to the method of Gao et al. (2007). Fresh egg yolk was diluted with distilled water 9 times its weight and whipped to fully emulsion. 2.0 g of DF was put in 250 ml volumetric flask and added 50 g of

diluted egg yolk, the pH were then adjusted to 2.0 and 7.0 respectively. The flasks were then incubated at 37°C for 2 h with continuous oscillation and then centrifuged at 2000 rpm for 15 min. 1 ml of supernatant was then diluted 5 times with 90 % volume/volume acetic acid, and added 0.1 ml O-phthalaldehyde as color reagent and the cholesterol level was determined using colorimetric assay at 550 nm. The cholesterol content in each mixture after the incubation period was estimated based on a standard curve.

For the determination of sodium cholate absorption capacity, the methods of Gao et al. (2007) and Hu (2001) have been used. The TDF (1 g) was mixed with NaCl solution (100 ml, 0.15 M, pH7.0) and sodium cholate (0.2 g) in 250 ml conical flask. The mixture was kept on the shaker at 37 °C for 1, 2, and 3 h, it was then centrifuged (4000 rpm) for 20 min. After that 1 ml of supernatant was taken to determine the content of sodium salt at 620 nm using spectrophotometer. The absorption capacity was determined by the difference of the concentration before and after reaction. At the same time the blank was determined.

IDF and SDF (1 g) were mixed with the NaCl solution (100 ml, 0.15 M, pH6.0) and sodium salt (0.2 g) in 250 ml conical flasks. The mixtures were kept at 37 °C for 1, 2 and 3 h. The absorption capacities were determined using spectrophotometer at 620 nm

Sodium cholate standard curve with equation $Y = 2.4358X - 0.0447$ and $R^2 = 0.9929$, was used to estimate the amount of sodium cholate absorbed by each fiber fraction in the mixtures. One milliliter, (every standard of different concentrations) was sampled 15 ml tube, added 6 ml of 45 % volume/volume sulphuric acid and 1 ml of 0.3 % volume/volume of furfural, mixed and incubated for 30 min at 65 °C in water bath, cool them at room temperature. Absorbances were measured at 620 nm.

Statistical Analysis

All experiments were carried out in triplicate. For statistical analysis, Statistical Package for the Social Science (SPSS, version 17.0) was used. The results were subjected to analysis of variance (ANOVA), followed by Duncan's multiple-range test for mean comparison at the level of 0.05.

Results and discussion

Proximate composition of defatted rice bran and its dietary fiber

The Table 1 shows proximate composition of defatted rice bran and its dietary fiber. Defatted rice bran dietary fiber (TDF) content is 32.98 % (w/w) and IDF represents the

Table 1 Chemical composition of defatted rice bran (DRB) and its dietary fibers

Proximate composition of DRB (% of dry weight of DRB)	
Moisture	8.7±0.03
Protein	16.2±0.2
Fat	2.8±0.05
Ash	10.7±0.01
TDF	32.9±0.3
IDF	30.2±0.4
SDF	2.7±0.15
Composition of TDF (% of dry weight TDF)	
IDF	93.8±0.59
Cellulose	33.4±0.15
Hemicellulose	54.5±0.20
lignin	5.8±0.14
SDF	6.1±0.08

Values are means ± standard deviation (SD) of 3 replicates ($n=3$) *TDF* total dietary fibre, *IDF* insoluble dietary fiber, *SDF* soluble dietary fiber

major component (93.84 %) while SDF content is only 6.16 % (w/w) of rice bran dietary fiber. These values of TDF and IDF contents were higher than those found by Abdul-Hamid while the values of SDF content were similar (Abdul-Hamid and Luan 2000). The higher IDF content means the increase of fecal bulk and decrease intestinal transit time thus, prevent against constipation and colon cancer (Wardlaw and Kessel 2002). IDF present also higher water holding capacity thus their technological benefits (Sangnark and Noomhorm 2004). While, the low SDF content means that the DRB fiber will less affected delay gastric emptying, glucose absorption and blood cholesterol (Wardlaw and Kessel 2002). Composition of dietary fiber can be help to understand their physiological and functional properties.

Viscosity

Viscosity (η), resistance to flow, is defined as the ratio of shear stress (τ) to shear rate ($\dot{\gamma}$). Most polysaccharide solutions exhibit non-Newtonian flow and an increased shear rate can increase or decrease viscosity (Sanderson 1981). Water soluble fibers are the major component that would increase the viscosity of a solution. They form viscous solution, and increase viscosity in the intestine (Anderson and Chen 1986) of TDF, IDF and SDF at different concentration can be seen in the Fig. 1. SDF at 3 % (w/v) showed higher viscosity (2.37 mPa.s) than TDF and IDF (2.14 mPa.s and 0.84 mPa.s respectively). The viscosity of SDF and TDF are relatively higher than those reported by Abdul-Hamid and Luan (2000). Viscosity of all fraction fibers was low but increases with an increased fiber concentration (Fig. 1).

Fig. 1 Viscosity of total dietary fibre (TDF), insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) of 1 and 3 % concentration of fibre solutions. Each value calculated represents the mean of 3 replicates ($n=3$) ± standard deviation (SD). Columns of the same concentration of fibre solutions superscripted by different letters are significantly different according to Duncan's multiple range test ($p<0.05$)

Table 2 showed the variation in viscosity of fiber fractions based on shear rate. The viscosity of all fiber fractions increases with an increased of shear rate (Table 2) thus, these fiber solution cannot exhibit pseudoplastic behavior ($n<1$, n the flow behavior index), where apparent viscosity or consistency decreases instantaneously with an increase in shear rate, as described by the power-law model ($\tau=K \dot{\gamma}^n$) also known as the Ostwald–de Waele power law is a mathematical relationship between shear stress (τ) and shear rate ($\dot{\gamma}$) (Elleuch et al. 2008). Power law is useful because of its simplicity, but only approximately describes the behavior of a real non-Newtonian fluid. When $n=1$ the shear stress is directly proportional to shear rate and these fluids have a

Table 2 Variation in the viscosity of TDF IDF and SDF based on shear rate

Shear rate (1/s)	Viscosity (mPa.s)		
	TDF	IDF	SDF
190	1.87±0.035f	0.73±0.018ef	2.15±0.025f
195	1.97±0.02e	0.74±0.02e	2.20±0.015e
200	2.04±0.03d	0.78±0.03d	2.27±0.01cd
205	2.08±0.03c	0.80±0.02bc	2.29±0.01bc
210	2.12±0.015ab	0.81±0.01b	2.32±0.025b
215	2.14±0.01a	0.84±0.04a	2.37±0.011a

Values represent the means of 3 replicates ($n=3$) ± standard deviation. Values in the same column with different letters are significantly different according to Duncan's multiple range tests ($p<0.05$). *TDF* total dietary fibre, *IDF* insoluble dietary fibre and *SDF* soluble dietary fibre

constant viscosity at all shear rate (Newtonian fluids) and when $n > 1$ the apparent viscosity increased at higher shear rates (Dilatant or shear-thickening fluids) (www.rheology-school.com). In this case the viscosity of the fiber solutions increased with an increasing of shear rates thus, they have a dilatant fluids property.

Viscosity a physicochemical property which is the main cause of increasing viscosity in the intestine slows intestinal transit, delays gastric emptying (Anderson and Chen 1986), and slows glucose and sterol absorption by the intestine (Kahlon and Chow 1997) and lower serum cholesterol, postprandial blood glucose, and insulin levels. These health benefits are related to viscous fibers or soluble fibers (SDF).

Glucose dialysis retardation index (GDRI)

The glucose dialysis retardation index (GDRI) is a useful in vitro method for the prediction of the effect of fiber on the delay in glucose adsorption in the gastrointestinal tract (Adiotomre et al. 1990). GDRI is shown in Fig. 2. The GDRI was greater after 30 min than 60 min in TDF, IDF and SDF. After 30 min the GDRI were 22.08 %, 21.60 % and 19.24 % respectively for TDF, IDF and SDF. After 60 min the GDRI of TDF and IDF significantly ($p < 0.05$) decreased (14.33 % and 12.08 % respectively) while GDRI of SDF did not change significantly (17.65 %). As the time increased from 30 min to 60 min the concentration in the all fiber fractions dialysate also increased from 1.15 mmol/l to 1.66 mmol/l; 1.25 mmol/l to 1.71 mmol/l and 1.28 mmol/l to 1.59 mmol/l for TDF, IDF and SDF respectively, whereas the concentration of glucose in the control dialysate ranged

from 1.58 mmol/l to 1.94 mmol/l. The higher GDRI of TDF and IDF after 30 min due to the lower glucose diffusion rate across the dialysis membrane might be explained by the glucose adsorption ability and entrapment of glucose with the network of these fibers which related with their higher WHC and lower density (Cheickna and Hui 2011). These fiber fractions initially hindered the diffusion of the glucose and then increased GDRI. After 60 min the rate of glucose diffusion across the dialysis membrane increased faster for these fibers than SDF and their GDRI were lower because the insoluble fibers with lower viscosity (2.11 mPa.s at 3 %) did not contribute toward the increase in viscosity. Moreover, due to their complete imbibitions and saturation, further retention of glucose could not occur Gupta and Premavalli (2011) causing the diffusion rate to increase resulting in rising levels of glucose in the dialysate.

Low GRDI of SDF (19.24 %) after the first 30 min might be due to its low WHC (Cheickna and Hui 2011); however its relatively higher viscosity (2.35 mPa.s at 3 %), SDF slowed the rate of the glucose diffusion across the dialysis membrane. Thus the concentration of glucose in the dialysate of SDF (1.59 mmol/l) was the lowest followed by the TDF (1.66 mmol/l) and IDF (1.71 mmol/l) after 60 min.

Thus, SDF significantly ($P < 0.05$) decreased the levels of diffusible glucose from dialysis tubing throughout the time course of the experiment and can be described as a hypoglycemic agent. Moreover, the studies (In vitro and In vivo) have shown that the delay in glucose adsorption in the gastrointestinal tract is determined mainly by viscosity of soluble polysaccharides Adiotomre et al. (1990).

This mechanistic action increases the viscosity of nutrients in the stomach and small intestine, delays absorption of glucose and reduces accessibility of serum amylase to substrate as a result of increased viscosity of the gut (Leclerc et al. 1994). SDF, IDF and TDF also reduced postprandial rise in blood glucose concentration. IDF decreases intestinal transit time, simultaneously increases intestinal bulk and decreases the excretion of the glucose in urine, and plasma glucose concentration (Fleury and Lahaye 1991).

Cation exchange capacity

Cation-exchange is an important physical property of dietary fiber. It is the ability of fiber to bind metal ions on its surface in much the same way that clay minerals are able to hold cations in soil so the reduced mineral availability and electrolyte adsorption are undoubtedly due to the binding of minerals and electrolytes (Mongeau and Brooks 2003). The number of free carboxyl groups on the sugar residues and the uronic acid content of polysaccharides appear to be related to the cation exchange properties of fibers. Thus

Fig. 2 Glucose dialysis retardation index of insoluble dietary fibre (IDF), soluble dietary fibre (SDF) and total dietary fibre (TDF) after 30 and 60 min of dialysis. Each value calculated represents the mean of 3 replicates ($n=3$) $\pm$ significantly (SD). Columns of the same time of dialysis superscripted by different letters are significantly different according to Duncan's multiple range test ($p < 0.05$)

the CEC of fiber depends on the presence of several functional groups which are responsible for exchange ability. This property depends primarily on the presence of phenol group of the lignin fraction and carboxyl groups from weak uronic acid of the pectin and hemicellulose fraction, glucuronoxylan (Gorecka et al. 2000). Figure 3 shows the Cation-exchange capacity of the IDF, TDF and SDF. IDF has a high exchange capacity followed by TDF and SDF respectively. This high CEC of IDF may be due to its chemical composition such its lignin, cellulose and hemicellulose content 5.85 %, 33.45 % and 54.54 % w/w respectively (Table 1). Cation exchange capacity of TDF depends mainly at its IDF content (93.84 % w/w vs. 6.16 % w/w for SDF) (Table 1). According to Van Soest et al. (1991) the exchange serves as a bank where K^+ , Ca^{++} , Na^+ , and Mg^{++} are exchanged for H^+ when pH drops and recharged when new cations become available when saliva and ingesta are mixed. As well as CEC is ability of fiber to bind minerals so it can lead to increase a fecal secretion of minerals and electrolytes. However the higher CEC of fibers may help in binding heavy metal (McDougall et al. 1996). Moreover all fiber fraction exhibited the cation exchange capacity property thus, the defatted rice bran fiber could effectively detoxify human body to ingested heavy toxic cation metal such Hg, Pb and Cd (Zhang et al. 2011) and enhance the excretion of cholesterol and bile acids or salts. This capacity to bind

Fig. 3 Cation exchange capacity (as measured by changes in pH as a function of concentration of NaOH solution) of total dietary fibre (TDF), insoluble dietary fibre (IDF) and soluble dietary fibre (SDF). Each value calculated represented the mean of 5 replicates ($n=5$) $\pm$ standard deviation (SD)

heavy metal ions confer them high antioxidant activity (metal chelating activity) (Cheickna and Hui 2011).

Determination of cholesterol and sodium cholate absorption capacity

According the result of our study (Fig. 4a) soluble dietary fiber significantly lowered concentration of cholesterol more than Insoluble at pH2 and pH7 which correspond to stomach digestion and duodenum, upper small intestine and mouth digestion condition respectively. The reduction were 19.89 % vs.5.28 % at pH2 and 29.9 % vs. 7.55 % at pH7 ($p<0.05$) for SDF and IDF respectively. However, the IDF absorption capacity of sodium cholate (bile salt) was significantly higher

Fig. 4 Cholesterol absorption capacity at pH2 & pH7 and sodium cholate absorption capacity after 1 & 3 h incubation at 37 °C of total dietary fibre (TDF), insoluble dietary fibre (IDF) and soluble dietary fibre (SDF). Each value represents the mean of 3 replicates ($n=3$) $\pm$ standard deviation (SD). Columns of same pH (a) or time (b) superscripted by different letters are significantly different according to Duncan's multiple range tests ($p<0.05$)

than SDF (Fig. 4b) 18.20 % vs. 13.76 % respectively ($p < 0.05$).

There are numerous reports on dietary fiber potential lowering of blood cholesterol (Anderson et al. 2009; Estruch et al. 2009). The cholesterol reducing effect of SDF is based on different mechanisms. The binding of water in the chyme and resulting increase viscosity is regarded as main effect. This leads to a reduced diffusion rate of bile acids (bile salts) which cannot be reabsorbed by the body and thus excreted (Anttila et al. 2004). Other study has indicated direct binding forces between SDF and Bile Acids (bile salts) (Kritchevsky 1995)

The cholesterol lowering effect of IDF is low compared to SDF and is mainly based on direct binding of bile acid or salt. In the small intestine bile acid bound with IDF and excreted from the enterohepatic circulation together with the undigested DF which results in lowering of blood cholesterol levels (Chau et al. 2004). On the other hand, Lairon (2001) reported that fibers derived from wheat bran, oat and other cereals also increase the fecal excretion of lipid and sterol. Hsu et al. (2006) also suggested that the hypolipidaemic and hypocholesterolemic action of carrot IDF can be attributed to its ability to enhance the excretion of cholesterol, lipid and bile acids through the faeces. Thus IDF with higher CEC could entrap, destabilize and disintegrate the lipid emulsion by forming fiber micelle complexes which act as barriers to the diffusion or absorption of micelles (emulsion of lipid), consequently decreasing the diffusion and absorption of lipid and cholesterol in small intestine (Furda 1990).

The high lowering effect of SDF may also be explained by production of short chain fatty acid (SCFA) during its fermentation in small intestine. SCFA transport to the liver may suppress cholesterol synthesis and then reduce blood level of LDL cholesterol and triglycerides (McDougall et al. 1996).

Conclusion

Defatted rice bran dietary fiber fractions showed important physiological properties. IDF showed significantly ($p < 0.05$) high cation exchange and bile salt adsorption capacity compared to soluble fiber. GDRI and cholesterol lowering capacity of SDF were significantly ($p < 0.05$) higher than IDF. These properties are influenced by their functional and physico-chemical properties. Therefore, defatted rice bran dietary fibers could be incorporated as low-caloric bulk ingredients in higher-fiber foods to reduce calorie level, to lower blood cholesterol, help to control blood glucose concentration and to enhance elimination of heavy toxic cations. Thus they exhibited physiological and health benefits. However, further investigation on In-vivo are needed to

confirm the hypoglycemic, hypocholesterolemic effects and other physiological functions of these fiber fractions of defatted rice bran using animal feeding experiments.

References

- AACC (2001) The definition of dietary fiber. *Cereal Food World* 46:112–126
- Abdul-Hamid A, Luan YS (2000) Functional properties of dietary fiber from defatted rice bran. *Food Chem* 68:15–19
- Adiotomre J, Eastwood MA, Edwards CA, Brydon WG (1990) Dietary fiber: in-vitro methods that anticipate nutrition and metabolism in humans. *Am J Clin Nutr* 52:128–134
- Anderson JW, Chen W-JL (1986) Cholesterol-lowering properties of oat products Pages 309–333 In: *Oats Chemistry and Technology*. F. H. Webster, ed. Am. Assoc. Cereal Chem.: St. Paul, MN
- Anderson JW, Baird P, Davis RH Jr, Ferreri S, Knudtson M, Koryam A et al (2009) Health benefits of dietary fiber. *Nutr Rev* 67(4):188–205
- Anttila H, Sontag-Strohm T, Salovaara H (2004) Viscosity of beta-glucan in oat products. *Agr Food Sci* 13:80–87
- Blackwood AD, Salter J, Dettmar PW, Chaplin MF (2000) Dietary fiber, physicochemical properties and their relationship to health. *JRS* 120:242–247
- Champ M, Guillon F (2000) Structural and physical properties of dietary fibers, and consequences of processing on human physiology. *Food Res Int* 33:233–245
- Chau CF, Huang YL, Lin CY (2004) Investigation of the cholesterol-lowering action of insoluble fiber derived from the peel of *Citrus sinensis* L. cv. Liucheng. *Food Chem* 87(3):361–366
- Cheickna D, Hui Z (2011) Physico-chemical Properties and Antioxidant Activities of Dietary Fiber Derived from Defatted Rice Bran Adv. *J Food Sci Technol* 3(5):339–347
- Elleuch M, Bedigian D, Roiseux O, Besbes S, Blecker C, Attia H (2008) Dietary fiber and fiber-rich by-products of food processing: characterization, technological functionality and commercial applications: a review. *Food Chem* 124:411–421
- Estruch R, Martínez-González MA, Corella D, Basora-Gallissá J, Ruiz-Gutiérrez V, Covas MI et al (2009) Effects of dietary fiber intake on risk factors for cardiovascular disease in subjects at high risk. *J Epidemiol Commun H* 63:582–588
- Faccin GL, do Nascimento Vieira L, Miotto LA, Pedro LM B, Amante ER (2009) Chemical, sensorial and rheological properties of new organic rice bran beverage. *Rice Sci* 16:226–234
- Fleury N, Lahaye M (1991) Chemical and physicochemical characteristics of fibers from *Laminaria digitata* (Kombu Breton): a physiological approach. *J Sci Food Agric* 55:389–400
- Frost J, Hegedus EF, Glicksman M (1984) Objective characterization of hydrocolloid organoleptic properties. *Food Technol* 38(1):118–122
- Furda I (1990) Interaction of dietary fiber with lipid mechanistic theories and their limitations. In: Furda I, Brine CJ (eds) *New developments in dietary fiber*. Plenum Press, New York, pp 67–82
- Gao Y-Y, Chao H-J, Ding H-X, Xia D-H, Zhang Y (2007) Study on Preparation and Properties of Special Moso Bamboo Leaves Dietary Fiber (SDFMBL). *J Food Sci Technol* 28(12):200–204
- Gorecka D, Lampart-Szczapa E, Janitz W, Sokolowska B (2000) Composition of fractional and functional properties of dietary fiber of lupines (*L. luteus* and *L. albus*). *Nahrung* 44(4):229–232
- Gupta P, Premavalli KS (2011) In-vitro studies on functional properties of selected natural dietary fibers. *Int J Food Prop* 14:397–410

- Harada KM, Tanak K, Fukuda Y, Hashimoto W (2008) *Paenibacillus* sp. Strain HCl- xylanases responsible for degradation of rice bran hemicelluloses. *Microbiol Res* 163:293–298
- Hsu PK, Chen PJ, Chen CH, Chau CF (2006) Carrot insoluble fiber-rich fraction lowers lipid and cholesterol absorption in hamsters. *Leben Wiss Technol* 39:337–342
- Hu G (2001) Cereals bran dietary fiber on the adsorption of sodium cholate. *J Chin Food Addit* 2:10–12
- Huang SC, Shiau CY, Liu TE, Chu CI, Hwang DF (2005) Effects of rice bran on sensory and Physico-chemical properties of emulsified pork meatballs. *Meat Sci* 70:613–619
- Kahlon TS, Chow FI (1997) Hypocholesterolemic effects of oat, rice, and barley dietary fibers and fractions. *Cereal Food World* 42:86–92
- Kritchevsky D (1995) In vitro binding properties of dietary fiber. *Eur J Clin Nutr* 49(3):113–115
- Lairon D (2001) Dietary fiber and dietary lipids. In: McCleary BV, Prosky L (eds) *advanced dietary fiber technology*. Blackwell Science, Oxford, pp 177–185
- Leclerc CL, Champ M, Boillot J, Guille G, Lecannu G, Molis C et al (1994) Role of viscous guar gums in lowering the glycemic response after a solid meal. *Am J Clin Nutr* 59:914–921
- Li KY, Lai P, Lu S, Fang YT, Chen HH (2008) Optimization of acid hydrolysis conditions for feruloylated Oligosaccharides from rice bran through response surface methodology. *J Agric Food Chem* 56:8975–8978
- Mahua G (2007) Review on recent trends in rice bran oil processing. *J Amer Oil Chem Soc* 84:315–324
- Maynard AJ (1970) *Methods in food analysis*. Academic, New York, p 176
- McDougall GJ, Morrison IM, Stewart D, Hillman JR (1996) Plant cell walls as dietary fiber: Range, Structure, Processing and Function. *J Sci Food Agric* 70:133–150
- Mirko B, Ralph J, Kim H, Fachuang L, Sally A, Ralph JM, Marita RD, Hatfield HS (2003) Sinapate dehydrimers and sinapate-ferulate heterodimers in cereal dietary fibre. *J Agric Food Chem* 51:1427–1434
- Mongeau R, Brooks PJ (2003) Properties, sources and determination. In *Encyclopedia of Food Science and Nutrition*, Vol. 3, 2nd ed.; Caballero, B; Turgo, L.Z.; Finglas, P.M.; eds. Academic Press, 2003; 1813–1832
- Prosky L, Asp NG, Schweizer TF, De Vries JW, Furda L (1988) Determination of insoluble, soluble and total dietary fiber in foods and food products: collaboration study. *J Assoc O Anal Chem* 43:759–766
- Roehrig KL (1988) The physiological effects of dietary fiber—a review. *Food Hydrocoll* 2:1–18
- Sanderson GR (1981) Polysaccharides in foods. *Food Technol* 35(1):50–57
- Sangnark A, Noomhorm A (2004) Chemical and baking properties of dietary fiber prepared from rice straw. *Food Res Int* 37:66–74
- Schneeman BO (1998) Dietary fiber and gastrointestinal function. *Nutr Res* 18:625–632
- Schweizer TF, Wursch P (1991) The physiological and nutritional importance of dietary fiber. *Experientia* 47:181–186
- Shibuya N, Iwasaki T (1984) Structural features of rice bran hemicelluloses. *Phytochemistry* 24:285–289
- Van Soest PJ, Robertson JB, Lewis BA (1991) Methods for Dietary Fiber, Neutral Detergent Fiber and Nonstarch Polysaccharides in Relation to Animal Nutrition. *J Dairy Sci* 74:3583–3597
- Wardlaw GM, Kessel M (2002) *Perspectives in nutrition*. Mc Graw-Hill, New York
- Zha X, Wang J, Yang X, Liang H, Zhao L, Bao S, Luo J (2009) Antioxidant properties of polysaccharide fractions with different molecular mass extracted with hot-water from rice bran. *Carbohydr Polym* 78:570–575
- Zhang N, Huang C, Shiyi O (2011) In vitro binding capacities of three dietary fibers and their mixture four toxic elements, cholesterol, and bile acid. *J Hazard Mater* 186(2011):236–239
- Zigoneanu IG, Williams L, Xu Z, Sabliov CM (2008) Determination of antioxidant components in rice bran oil extracted by microwave-assisted method. *Bioresour Technol* 99:4910–4918, www.rheologyschool.com/power_law_model.html