Mixing, tensile and pasting properties of wheat flour mixed with raw and enzyme treated rice bran

Yuefei Teng · Chunying Liu · Jing Bai · Jianfen Liang

Revised: 25 March 2014 / Accepted: 10 April 2014 / Published online: 25 April 2014
© Association of Food Scientists & Technologists (India) 2014

Abstract Rice bran is a potential fiber and minerals source for nutrients enhancement of cereals food. For evaluation of rice bran applied in bread making, mixing properties, tensile and pasting properties of wheat flour dough with raw (RB) or enzymes treated rice bran (ERB) were investigated. Farinogram with two peaks, which was observed in the dough with 40 % ERB, was reported. For mixing properties, addition of RB and ERB significantly decreased water absorption and stability of wheat dough. Dough development time of mixed flour with ERB was longer than that with RB. Water absorption, stability time of the dough and farinograph quality number is negatively correlated with addition of RB and ERB. The alveograph tests indicated that extensibility of dough decreased remarkably with increased RB or ERB addition and RB had more negative effects than that of the ERB. Results of pasting behaviors predicted that addition of RB or ERB, could slow down starch retrogradation and delay bread staling. In general, wheat flour mixed with 20 % RB or ERB was fit for bread making and the later expects better sensory and nutritional values.

Keywords Mixing property · Extensibility · Pasting behavior · Rice bran · Enzyme treatment

Introduction

Rice bran (RB) is a by-product of rice milling and the production is over 10 million tons per year in China. RB usually goes to animal feeds or is thrown away as agricultural residue, though it is a good source of protein, minerals, fatty acids and dietary fiber (McCaskill and Zhang 1999). Bread acts as popular staple food all over the world. Except for the basic ingredients of wheat flour, water, yeast (or other leavening agents) and salt, other ingredients were added in bread for improved processing techniques, or specialty and novelty breads which have an increased nutritional values (Dewettinck et al. 2008). Fiber is an important ingredients used, which also plays an important role in human nutrition. Fiber is associated with prolonged gastric emptying, and slower transit time through the small intestine, modifying the trend and the extent of starch digestion (Angioloni and Collar 2011). In addition, increased intake of dietary fiber had positive effects on prevention of chronic diseases, such as cardiovascular diseases, diverticulosis, diabetes and colon cancer (Abdul-Hamid and Yu 2000). Bread, as one of the biggest consumption in bakery production, is considered as the main source to increase the dietary fiber content, and the performance of low-calorie is also of major interest (Collar et al. 2007; Collar 2008). Mixing material of abundant fiber with wheat flour is a way to improve nutritional value of bread. Pacheco de Delahaye et al. (2005) had mixed flours of legumes, root, tubers and other cereals with wheat for fiber enriched bread preparation.

However, application of fiber in bread recipe would change mechanical properties of dough and cause negative effect on bread sensory quality, such as decreased loaf volume, dark crumb appearance, increased crumb firmness, bad texture and unsuitable taste and mouthfeel (Sanz Penella et al. 2008; Wang et al. 2002). When compared with the bread without any fiber addition, loaf volume reduced by 22.9 and 37.8 %,

Electronic supplementary material The online version of this article (doi:10.1007/s13197-014-1366-y) contains supplementary material, which is available to authorized users.

Y. Teng · C. Liu · J. Bai · J. Liang (✉)
College of Food Science and Nutritional Engineering, Beijing Key Laboratory of Functional Food from Plant Resources, China Agricultural University, P.O. Box 294, Tsinghua East Road, Beijing 100083, People's Republic of China
e-mail: liangjf@cau.edu.cn

and the firmness was almost twice and 5 times respectively when 5 and 10 % dietary fiber were added (Abdul-Hamid and Yu 2000). RB can provide dietary fiber, and high-quality protein and minerals for bread, but may bring out similar negative effects on final bread quality. Barley flour fractions were used as a source of fiber to substitute the standard bread flour at the levels of 5, 20 and 40 %. The results showed that, compared to the control, the loaf volumes decreased and the colour was darker (Knuckles et al. 1997). Application of RB may have similar negative effects on bread sensory quality. Furthermore, RB also has high concentrations of phytic acid, which will combine protein and minerals and decrease nutritional values. Treating RB with different enzymes could increase its nutritional values (Wang et al. 2008).

RB was proposed to use as one of ingredients for higher fiber and minerals contents of bread in this study. And in order to improve the utilization of nutrients in rice bran and weaken the negative effects on sensory quality and nutritional values of bread, RB was enzymatic treated with alcalase, cellulase and phytase (named as enzyme treated rice bran, ERB). For comparison, the paper systematically evaluated the addition of RB and ERB on mechanical properties, such as mixing properties, extensibility and pasting behaviors, of bread dough by using instruments of Farinograph, Alveograph and Mixolab station and revealed the possibility of using RB as nutrients supplement in bread making.

Materials

Rice bran (RB): According to rice milling procedure and colour of bran, rice mill separated RB as two parts of oily bran, which is composed of the most outlayer of brown rice kernel, dark brown and mainly used for oil production, and white bran, which is mainly composed of inner bran layer and aleurone layer, light grey, and mainly goes to animal feeds. In this study, white rice bran (Hunan Jinjian Cereals Industry Co., Ltd.) was collected and ground to pass through 80-mesh sieve.

Enzyme treated rice bran (ERB): Based on results of previous study, rice bran was mixed with deionized water by 1:5 (w/v), followed with addition of alcalase (Novozymes 10^5 U g⁻¹) at the level of 0.2 %, cellulase (Beijing Challenge Bio-technology Co., Ltd, 700 U g⁻¹) at the level of 1 %, and phytase (Beijing Style SCI & TECH Development Co., Ltd, 2.5 U g⁻¹). The mixture was reacted at 40 °C for 2 h followed with heating in boiling water for 15 min (Wang et al. 2008). Treated mixture was then cooled and vacuum freezing dried, followed with grinding and sieving by 80-mesh sieve.

Wheat flour (WF): Collected from Beijing Les Brands Moulins DE Co., Ltd. and stored at room temperature before use.

Mixed flour: RB and ERB were mixed with WF according to the levels of 10, 20, 30, 40 and 50 % (WF basis), respectively. WF was used as control.

Basic chemical compositions of RB, ERB and WF used in this study were presented in Table 1.

Determination of mixing properties

A Farinograph (Brabender, Germany) with a 50 g mixer was used to evaluate the farinograph properties of mixed flour. All dough was mixed in the Farinograph bowl to 500 Brabender Units (BU) reached. Parameters of water absorption (WA, percentage of water required to yield dough consistency of 500 BU), dough development time (DDT, time to reach maximum consistency, min), and stability time (ST, time during dough consistency is kept at 500 BU, min), and degree of softening (DS) and farinograph quality number (FQN) were measured.

Determination of extensibility

Extensibility of dough was performed with an Alveograph (Model Alveograph NG, Chopin, France). Deformation energy (W), resistance to extension or tenacity (P), extensibility (L) and configuration ratio (P/L ratio) of dough were investigated.

Pasting behaviors measurements

Mixing and pasting behaviors of dough were investigated using a Mixolab station (Chopin, Tripette et Renaud, France). The mixed flour was mixed in the bowl and the apparatus adds distilled water to achieve pre-fixed hydration. Total mass of mixed flour and distilled water in bowl was 75 g. The analyzer gave torque (Nm) produced by the passage of dough between two kneading arms. The detailed analysis procedures were as follows: 1) keeping tank temperature at 30 °C and mixing for 8 min; 2) increasing tank temperature till 90 °C by heating rate of 4 °C/min and keeping for 7 min; 3) cooling tank temperature to 50 °C by rate of 4 °C/min and keeping for 5 min. The whole analysis procedure totally took 45 min.

Bread-making procedure and evaluation on the sensory quality and nutrition

RB and ERB (20 %, on wheat flour basis) were mixed with wheat flour as flours for bread-making. The procedure is performed using the straight dough method used in inspection of grain and oil according to GB/T 14611–2008 (2009) with small modification. And for comparison, except for mixed flour, we used same ingredients (without modifiers) and procedures, which were briefly described as follows. Dough was prepared following the formulation of 1.8 % instant active dry yeast (Angel Yeast Co. Ltd.), 1.5 % salt, 6 % sucrose, 4 % skimmed milk powder, 3 % shortening (all ingredients w/w, mixed flour basis), and adequate water. Ingredients were mixed 15 min at 30±1 °C in a Kenwood

Table 1 Basic chemical composition of materials (Dry basis, mean±SD)

	Moisture %	Protein %	Lipid %	Crude Fiber %	Phytic acid mg g ⁻¹	Minerals mg kg ⁻¹		
						Ca	Fe	Zn
RB	9.8±0.0	15.7±0.1	14.6±0.0	3.6±0.0	57.8±0.9	571.4±46.4	96.67±7.9	37.2±4.6
ERB	4.9±0.0	14.8±0.1	13.1±0.0	0.2±0.0	49.5±0.6	588.1±47.2	117.8±7.2	39.2±2.4
WF	14±0.1	15.3±0.1	1.2±0.0	0.6±0.0	6.8±0.0	136.4±1.5	17.6±0.6	12.9±0.3

760 mixer. The resulting dough was divided to the pieces of 100 g. The dough was then put in fermentation bowls after being rolled and followed with fermentation at 85 % (rh, relative humidity) at 30±1 °C for 90 min with two intermediate sheeting (break down big bubbles) at 55 min and at 80 min with roller distance of 6 mm. The fermented dough was sheeted with distances of 7 mm and 5 mm roller and put into a bread mould, upper size 130 mm×73 mm, bottom size 115 mm×57 mm, and depth 58 mm. Molded dough was then proofed 45 min at 30±1 °C 85–90 % (rh) in fermentation cabinet. After proofing, the dough was baked at 215 °C for 20 min in electric oven. Specific volume of bread was determined 5 min after baking. Hardness and contents of protein, fat and fiber were determined 1 h after baking. Hardness was determined with a texture analyzer (TA-XT2i) described by Steffolani et al. (2012). Sensory quality, such as colour, lightness, was evaluated by scoring after training. Sensory scores of bread with RB or ERB are not shown.

Statistics analysis

All measurements were in triplicates. Significance and correlation analysis were conducted by using SPSS version 12.0 statistics software package. T test was derived with Microsoft Office Excel 2003.

Results and discussion

Mixing properties of mixed flour

Mixing properties of mixed flour were evaluated by farinograph. Farinographs parameters registered and the correlations to amount of RB and ERB were given in Table 2.

Data in Table 2 indicated that RB and ERB significantly affected the mixing properties of mixed flour. WA, ST and FQN decreased, while DS increased. WA, ST, FQN and DS significantly correlated with contents of RB or ERB. RB and ERB showed different effects on DDT, which is RB shortened DDT, while ERB prolonged, and no significant correlation was observed.

Mixing properties of mixed flour affected by RB and ERB could be explained by composition of dough. Presence of gluten protein is the main reason for mixing of flour-water dough, WA and formation of gluten network (Zhu 2001; Abang Zaidel et al. 2008). WA, which is expressed as the quantity of water needed to reach the defined dough consistency, is mainly reflected the contents of gluten protein in wheat flour and can be evaluated in Farinograph test (Sanz Penella et al. 2008; Wang et al. 2004). In mixed flour, WA will reflect not only the amount of water absorbed by gluten, but also that by coarse bran in RB which typically binds water when it is added (Noort et al. 2010). However, capacity of WA of fiber is much lower than that of gluten protein. At the same

Table 2 Addition of RB and ERB on farinograph properties of dough

Addition %		WA %	DDT min	ST min	DS BU	FQN
RB	0	64.1	7.5	25	29	158
	20	63.0	5.2	11.0	45	131
	30	62.1	6.1	9.7	66	123
	40	62.7	5.8	7.3	118	92
	50	62.3	6.3	3.4	146	86
	Correlation	−0.931*	−0.479	−0.961**	0.941*	−0.981**
ERB	20	62.6	8.3	6.6	72	128
	30	61.4	8.0	4.6	111	110
	40	61.1	8.1	3.2	155	106
	50	59.2	8.1	2.3	183	97
	Correlation	−0.989**	0.359	−0.903*	0.989**	−0.982**

*, ** significant correlation at levels of $p < 0.05$ and $p < 0.01$, respectively

WA water absorption, DDT dough development time, ST stability time, DS degree of softening, BU Brabender units, FQN farinograph quality number

time, RB and ERB will dilute gluten protein in WF since they did not have any gluten proteins, and the more RB or ERB added, the lower ratios of gluten protein in mixed flour. And we also can see that degradation of fiber also led lower water absorption (WA of mixture with RB was higher than that of ERB). Dough ST is influenced mainly by gluten quality and its resistance to kneading forces (Dabčević et al. 2009). It's easily found in Table 2 that addition of RB or ERB would significantly shorten ST, and shorter ST of mixture with ERB than that of RB at same addition. According the experience criteria in America and Canada, ST of bread flour should be longer than 7 min (Wang et al. 1997). So, considering ST, addition of RB or ERB should less than 40 % or 20 %, respectively. Lower strength and stability of mixed flour is mainly deduced by interaction of fiber fraction from RB and ERB with the gluten physically or chemically, which negatively influence gluten aggregation (Noort et al. 2010). It has been reported that effects of fiber on DS differed with addition. When less than 4 % of lentinus edodes fibers in wheat flour, DS increased with addition of fiber, while when addition is in the range of 4–15 %, DS kept at relatively unchanged levels, and DS decreased with addition when more than 20 % of fiber was added (Zhou 2000). Two aspects of reason led the differences of Zhou's from our results. The one is pre-treatment, we use cellulase treated rice bran, which may degrade fiber; while Zhou used untreated materials. And the other one is composition, we used rice bran, except for fiber which also contained big quantities of starch and protein, while Zhou used fiber extracted from lentinus edode. Furthermore, increase of DS affected by RB and ERB was in accordance with ST reduction trend.

DDT of mixed flours changed maybe the result of different water absorption ability of gluten and fiber in RB or ERB. Which means gluten wouldn't start to absorb water until fiber from RB or ERB had absorbed water fully (Hu et al. 2002). Many previous studies reported that the DDT prolonged when insoluble RB dietary fiber, and more addition would lead longer DDT (Qian and Ding 1996; Ozboy 1997; Sudha et al. 2007). Our results are different from those studies. This may be caused by the material of RB. We used white RB, which has much lower insoluble fiber than normal RB, and ERB, which contains even lower fiber than WF.

FQN, farinograph quality number, is used for flour quality evaluation since 1990's and it was applied in ISO standard of "wheat flour—physical characteristics of dough—Part 1: Determination of water absorption and rheological properties using a farinograph" (ISO 2013). Further study indicated that FNQ well correlated with evaluation value, ST and DS. It can be used for reflection to flour strength and mixing-resistance of strong and medium gluten (Jiang et al. 2004). It is clear that addition of RB or ERB lowered FQN, and the more RB or ERB, the lower FQN. It was reported that when over 10 % of bagasse dietary fiber added to flour, FQN decreased (Zheng et al. 1996). Fiber-gluten interactions are the main reasons for

lowered FQN, like increased DS and decreased ST. FQN indicated that mixed flour with 20–30 % RB or ERB would be still fit for bread.

Farinographs gave direct patterns of mixing properties of mixed flour. As representatives, farinographs of mixed flour with 20 % RB (a), 20 % ERB (b), 40 % RB (c), 40 % ERB (d) and the control (e) were illustrated in Fig. 1.

Form Fig. 1, it is observed that addition of RB by 20 % (a) and 40 % (c) had similar mixing properties to the control (e), which differed from the mixed flour with ERB at the same levels (b, d). Two peaks in the curve of mixed flour with 40 % ERB (d) were observed. And no similar results had been reported. By observation of phenomena during mixing test and analysis of composition of ERB, it was found that when high level (e.g. 40 %) of ERB added, some components, such as fiber, would absorbed water firstly (Hu et al. 2002), which may lead the occurrence of first peak as the reflection of resistance strength. And then, with mixing going, water combined with ERB began to release, which caused a short-time decreased resistance, and hydrogen bonds of gluten protein and water molecule started. With agitation going on, dough would gradually form and dough strength would increase, which would cause the second peak. The other possible reason for the two peaks was denaturalization of protein of ERB by boiling process for inactivation of enzymes. High contents of denaturalized proteins may lead double peaks in the curve. The hypothesis needs further confirmation.

Tensile properties of dough with RB and ERB

Tensile properties of dough with addition of RB or ERB using a Chopin Alveograph, were reported in Table 3.

The alveograph P (dough resistance to deformation or tenacity) is used for prediction of gas retaining ability (Rosell et al. 2001). As was given in the Table 3, P increased slightly with increasing addition of RB and ERB, but no significant correlation was observed. Conversely, alveograph L, which indicates the handling characteristics of the dough (Rosell et al. 2001), decreased significantly with increase of RB and ERB, and as well as alveograph W, which indicates the deformation energy. L and W significantly negatively correlated with addition of RB and ERB. Furthermore, dough with RB had worse extensibility and strength than that of ERB.

P/L, the curve configuration, is an index to gluten behavior or performance and provides information of elastic resistance and extensibility balance of dough (Agyare et al. 2005; Rosell et al. 2001). It had been reported that the optimum range of P/L for bread was 0.8–1.4, and when it was in 1.6–5.0, the elasticity is fit while the extensibility is not sufficient (Qi 1998). From Table 3, we could see that the more RB or ERB, the higher P/L, which means the better elasticity and worse extensibility would occur. Our results were similar to

Fig. 1 Farinograms of wheat flour and mixed flours with RB or ERB. **a, b, c, d** and **e** are farinograph curves for mixed flour with 20 % RB, 20 % ERB, 40 % RB, 40 % ERB and the control, respectively. Curves **a, c** and **e** had similar shape, and two peaks appeared on curve (**d**)

the dough with carob fiber, insulin and pea fiber (Wang et al. 2002). And the findings of cereal fiber (wheat, rice, oat and

Table 3 Effects of RB and ERB on alveograph characteristics of the mixed flour and the correlation

Addition %	P (mm)	L (mm)	P/L	W($10^{-4} \times J$)
RB 0	91	162	0.56	428
20	106	49	2.15	205
30	110	34	3.25	158
40	116	24	4.74	124
50	103	23	4.53	103
correlation	0.673	-0.898*	0.973**	-0.946*
ERB 20	92	90	1.03	264
30	88	75	1.17	202
40	115	38	3.00	161
50	103	32	3.25	139
correlation	0.626	-0.982**	0.907*	-0.975**

*, ** Indicates correlation is significant at $P < 0.05$ and $P < 0.01$ levels, respectively

P maximum over pressure, *L* average abscissa at rupture, *P/L* curve configuration ratio; *W* deformation energy of dough

barley) would reduce the extensibility of dough and had higher *P/L* (Sudha et al. 2007) were also well in agreement with our results. Presence of fiber or polysaccharides, and denaturalized protein in RB or ERB may break down the continuity of protein network by gluten protein and result in changing of alveographic properties of dough, like elasticity and extensibility (Gómez et al. 2011). When flour had WF and RB was mixed, high fiber from RB would interact and cross-link with gluten proteins, resulting in increased dough elasticity and decreased extensibility. Addition of ERB less than 30 % would not affect the elasticity (Alveograph *P*) remarkably and crude fiber in ERB was much lower than that in RB and WF (Table 1) maybe the main reason. The decreased extensibility (Alveograph *L*) of mixed powder was mainly due to the fiber-gluten interactions. Tesile properties of mixed flour indicated that when addition of ERB by 20 and 30 %, the dough was still fit for bread making.

Mixing and pasting (thermomechanical) behavior of mixed flour dough

Mixing curves of mixed flour were carried out at 30 °C following the protocol previously described. For better

Fig. 2 Typical thermomechanical curve from Mixolab analysis of wheat dough. There are three curves in this figure. The temperature of the mixing bowl, the temperature of dough and the torque measured by the sensor of Mixolab station

understanding of the results obtained, a typical Mixolab curve is presented in Fig. 2. As reported by Huang et al., according to the temperature of mixing bowl and mixing force, the procedure is divided into five stages summarized as follows. 1) the first stage (①), hydration of the compounds occurred during the initial mixing (0–8 min, 30 °C), and a three-dimensional visco-elastic structure formed accompanied by increase in the torque; 2) the second and the third stage (②,③), mixing during 8–23 min, the temperature of bowl increases up to 90 °C at the rate of 4 °C per min, the torque of dough decreases because the proteins begin to destabilize and unfold, and the contribution of the proteins to the torque is masked by the starch changes in the third stage (③); 3) the fourth stage (④), the temperature of bowl is constant at 90 °C for 7 min, and the swelling and gelatinization of the starch granules occur until the physical breakdown of the granules; 4) the fifth stage (⑤), the torque of dough increases further when the temperature decreased at the same rate, associating with the recrystallization of the starch. In this figure, C1 is the maximum torque of the first mixing stage and C2 to C5 are the end points of the corresponding mixing stages. Figure 2 shows three slopes (α , β , γ). Slope α represents the protein reduction rate; slope β represents the starch gelatinization rate; slope γ

represents starch recrystallization during paste cooling (Huang et al. 2010).

Mixing and pasting behavior of mixed flour dough is presented in Table 4.

Results of WA by Mixolab station were similar to that of farinogram, though they had different values.

C2 values of mixed flour decreased significantly with addition of RB and ERB, which indicated that protein strength weakened severely with RB and ERB. Values of C2 are affected by both the mechanical shear stress and the high temperature. Mixed flour with 20 % RB got the most similar protein reduction rate (slope α) to that of the control.

C3 is the maximum torque during the heating stage (8–23 min), and slope β (slope of curve between C2 and C3) is the starch gelatinization rate in this stage. Addition of RB or ERB would decrease the C3 values, and more addition brought about more decrease. This may due to lower starch content in RB than that of WF, which could explain that dough with 20 % ERB got lower C3 than that with 40 % RB for there was lower starch in ERB after treatment with by enzymes. β value of dough with 20 % RB is 22.6 % larger than the control dough, which means addition of 20 % RB will shorten bread baking time.

Table 4 Mixing and pasting properties of mixed flour and dough

Addition (%)		WA %	ST min	C1 Nm	C2 Nm	C3 Nm	C4 Nm	C5 Nm	C5-C4 Nm	α	s	γ
RB	0	64.0	9.40	1.08	0.47	1.51	1.65	2.72	0.61	−0.114	0.292	0.024
	20	60.5	10.37	1.08	0.35	1.38	1.26	1.99	0.73	−0.108	0.358	−0.002
	30	59.6	9.43	1.08	0.29	1.24	1.10	1.65	0.79	−0.080	0.262	−0.020
	40	60.1	8.03	1.08	0.24	1.07	0.94	1.39	0.84	−0.074	0.282	−0.006
ERB	20	58.9	8.37	1.07	0.31	0.64	1.31	2.12	0.76	−0.078	0.088	0.016
	30	57.8	5.08	1.09	0.26	0.49	1.17	1.82	0.83	−0.072	0.052	0.012
	40	55.1	3.97	1.07	0.24	0.31	1.00	1.67	0.83	−0.066	0.018	0.036

C4 is the minimum torque during latter stages (constant temperature stage and cooling stage), slope γ (slope between curve of C3 and C4) is the degradation rate of starch by amylase, and C5 is the maximum torque of cooling stage which reflects starch gelatinization. As shown in Table 5, adding RB did not make any change on amylase activity, while addition of ERB had higher amylase reduction rate. This may because ERB was treated at high temperature after the treatment with enzymes. Difference value of C5 and C4 (expressed as C5-C4) decreased with more addition of RB or ERB. Changes in the viscometric behavior of starch during heating and cooling cycles have been correlated to bread staling (Collar et al. 2007). When the temperature is lower than 50 °C, starch retrogradation would happen and bread would be staling slowly. Addition of RB and ERB would bring about slower starch retrogradation, and slower bread staling, as well.

Specific Volume, hardness and nutrition of RB and ERB bread

It is widely accepted that the main quality parameters of mould bread are a high specific volume and a soft and uniform crumb structure (Steffolani et al. 2012). The simplest formulation of bread was used in this study. Specific volume and hardness of bread prepared in this study is presented in Table 5. Though specific volumes of all bread were higher than 3.0 ml g⁻¹, which is the lowest for acceptance, addition of RB and ERB by 20 % had been lowered specific volumes by 42.3 % and 27.0 % compared with pure wheat flour. Hardness of bread with ERB is two thirds of bread with RB, which was 3 times of the control. Further analysis indicated that specific volume and hardness of crumb of bread with ERB was significantly better than that of with RB, though they were significantly worse than that of bread from pure wheat flour ($p<0.05$). The results verified the results of alveograph properties of dough with RB and ERB, and treatment with enzymes could decrease the negative effect of RB the formation of gluten network. Better gluten network would lead better gas holding capacity and softer crumb structure.

Application of RB and ERB in bread led changes of nutrients as well. Contents of fiber, protein and fat in bread with RB and ERB (Table 6) were determined.

From the table we could clearly see that addition of RB and ERB significantly increase contents of fiber in bread

Table 5 Specific volume and crumb hardness of bread (mean $\pm$ SD, %)

	Specific volume ml g ⁻¹	Hardness g
WF (Control)	5.2 $\pm$ 0.1 a	408 $\pm$ 2 c
RB	3.0 $\pm$ 0.1 c	1252 $\pm$ 8 a
ERB	3.8 $\pm$ 0.2 b	856 $\pm$ 4 b

Different letters means significant differences at levels of $p<0.05$

Table 6 Contents of fiber, protein and fat of bread (Dry basis, mean $\pm$ SD, %)

	Fiber	Fat	Protein
WF (Control)	0.3 $\pm$ 0.0 a	2.5 $\pm$ 0.0 a	14.8 $\pm$ 0.1 a
RB	3.8 $\pm$ 0.1 b	3.5 $\pm$ 0.0 b	14.5 $\pm$ 0.2 a
ERB	1.9 $\pm$ 0.0 c	4.1 $\pm$ 0.0 b	14.8 $\pm$ 0.0 a

Different letters means significant differences at levels of $p<0.05$

($p<0.05$), and improvement of RB was as 2 times as that of ERB. RB and ERB also significantly improve the content of fat, though they did not have significant effects on contents of protein. Sensory evaluation indicated that bread with RB had the smallest volume, darkest colour and the lowest sensory score and the lowest acceptance among samples in the research. However, ERB had acceptable sensory quality, including volume, colour, hardness and texture of crumb, and improved fiber contents and minerals nutrition. ERB was a potential way for high levels of RB used in bread for improved nutritional values.

Conclusions

It could be concluded that addition of RB or ERB increased contents of fiber and minerals of bread, and negatively affected mechanical properties of farinograph, alveograph, and starch pasting behaviour, as well. Elasticity, extensibility and FQN of dough with ERB was better than that of with RB at the same addition level. RB and ERB had no significant differences on protein contents of bread. However, the rate of starch retrogradation in the dough with RB was slowest, which predicted that addition of RB could inhibit the bread staling. Considered the overall results, mixed flour with 20 % RB or ERB was fit for bread making, and addition of ERB would have better nutritional values of minerals than that of RB. Further research is needed for better sensory quality of bread with RB and ERB with modifiers.

Acknowledgments The research was supported by Program for New Century Excellent Talents in University (NO. NCET-10-0781), from Ministry of Education, P. R. China. We gratefully acknowledge the assistance by Hui Sun and Weili Jiang (Academy of State Administration of Grain) for mechanical properties analysis.

References

- Agyare KK, Addo K, Xiong YL, Akoh CC (2005) Effect of structured lipid on alveograph characteristics, baking and textural qualities of soft wheat flour. *J Cereal Sci* 42:309–316. doi:10.1016/j.jcs.2005.03.008
- Abang Zaidel DN, Chin NL, Abdul Rahman R, Karim R (2008) Rheological characterisation of gluten from extensibility measurement. *J Food Eng* 86:549–556

- Abdul-Hamid A, Yu SL (2000) Functional properties of dietary fibre prepared from defatted rice barn. *Food Chem* 68:15–19
- Angioloni A, Collar C (2011) Physicochemical and nutritional properties of reduced-caloric density high-fibre breads. *LWT –Food Sci Technol* 44:747–758
- Collar C, Santos E, Rosell CM (2007) Assessment of the rheological profile of fibre-enriched bread doughs by response surface methodology. *J Food Eng* 28:820–826
- Collar C (2008) Novel high fiber and whole grain breads. In: Hamaker B (ed) Chapter 9, technology of functional cereal products. Woodhead Publishing Limited Abington Hall, Cambridge, pp 184–214
- Dabčević T, Hadnadev M, Pojić M (2009) Evaluation of the possibility to replace conventional rheological wheat flour quality control instruments with the new measurement tool—mixolab. *Agric Consepctus Sci* 74:169–174
- Dewettinck K, Van Bockstaele F, Kühne B, Van de Walle D, Courtens TM, Gellynck X (2008) Nutritional value of bread: influence of processing, food interaction and consumer perception. *J Cereal Sci* 48:243–257
- GB/T 14611–2008 (National standard) General administration of quality supervision, inspection and quarantine of the People's Republic of China, Standardization administration of People's Republic of China (2009) Inspection of grain and oils—Bread-baking test of wheat flour—Straight dough method
- Gómez M, Jiménez S, Ruiz E, Oliete B (2011) Effect of extruded wheat bran on dough rheology and bread quality. *LWT—Food Sci Technol* 44:2231–2237
- Hu GH, Zhai RW, Huang SH (2002) The affection of the farinographical and baking properties for the flour by replacement of the rice bran non-soluble dietary fiber (in Chinese). *China Food Addit* 3:27–30
- Huang W, Li L, Wang F, Wan J, Tilley M, Ren C, Wu S (2010) Effects of transglutaminase on the rheological and Mixolab thermomechanical characteristics of oat dough. *Food Chem* 121:934–939
- ISO Standard Number 5530–1 (2013) Wheat flour—physical characteristics of dough—Part 1: Determination of water absorption and rheological properties using a farinograph
- Jiang W, Sun H, Ling J (2004) Applicability of FQN in evaluation of wheat flour quality (in Chinese). *J Chin Cereals Oils Assoc* 19:42–48
- Knuckles BE, Hudson CA, Chiu MM, Sayre RN (1997) Effect of β -glucan barley fractions in high fibre bread and pasta. *Cereal Food World* 42:94–100
- Steffolani ME, Ribotta PD, Pérez GT, León A (2012) Combination of glucose oxidase, α -amylase and xylanase affect dough properties and bread quality. *Int J Food Sci Technol* 47:525–534
- McCaskill D, Zhang F (1999) Use of rice bran oil in foods. *Food Technol* 53:50–51
- Noort MW, van Haaster D, Hemery Y, Schols HA, Hamer RJ (2010) The effect of particle size of wheat bran fractions on bread quality—evidence fibre-protein interactions. *J Cereal Sci* 52:59–64
- Ozboy KH (1997) Unexpected strengthening effects of a coarse wheat bran on dough rheological properties and baking quality. *J Cereal Sci* 25:77–82
- Pacheco de Delahaye E, Jiménez P, Pérez E (2005) Effect of enrichment with high content dietary fiber stabilized rice bran flour on chemical and functional properties of storage frozen pizzas. *J Food Eng* 68:1–7
- Qi SY (1998) The introduction of Alveograph (in Chinese). *Heilongjiang Food Sci* 6:47–48
- Qian JY, Ding XL (1996) Effect of soy fibre on the rheological properties of Dough (in Chinese). *J Wuxi Univ Light Ind* 3:199–204
- Rosell CM, Rojas JA, Benedito de Barber C (2001) Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocoll* 15:75–81
- Sanz Penella JM, Collar C, Haros M (2008) Effect of wheat bran and enzyme addition on dough functional performance and phytic acid levels in bread. *J Cereal Sci* 48:715–721
- Sudha ML, Vetrmani R, Leelavathi K (2007) Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. *Food Chem* 100:1365–1370
- Wang G, Zhou G, Wang R (1997) The correlations between baking quality and dough development time and stability time (in Chinese). *J Chin Cereals Oils Assoc* 12:1–6
- Wang J, Rosell CM, Benedito de Barber C (2002) Effect of the addition of different fibres on wheat dough performance and bread quality. *Food Chem* 79:221–226
- Wang X, Choi SG, Kerr WL (2004) Water dynamics in white bread and starch gels as affected by water and gluten content. *Lebensm-Wiss Technol* 37:377–384
- Wang Y, Cheng Y, Ou K, Lin L, Liang J (2008) In vitro solubility of calcium, iron and zinc in rice bran treated with phytase, cellulase and protease. *J Agric Food Chem* 56:11868–11874
- Zheng JX, Geng LP, Gao KR (1996) Studies on extrusion modification of bagasse dietary fibre(II)—mechanism of extrusion degradation and effects on fibre physico-chemistry properties (in Chinese). *Food Sci* 17:11–14
- Zhou JY (2000) Influences of dietary fiber in lentinus edodes upon the rheology properties of wheat dough (in Chinese). *J Wuxi Univ Light Ind* 3:209–212
- Zhu ZP (2001) Function of water in fermentative dough products (in Chinese). *Cuisine J Yangzhou Univ* 3:53–56