

Research Article

Effects of Pentosans Isolated from Wheat Bran on Textural Properties of Some Starch-Based Foods

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Abstract: Water-Soluble Pentosans (WSP) and Water-Insoluble Pentosans (WIP) were extracted from wheat bran and added in concentrations of 0, 0.5, 1.0 and 1.5%, respectively to starch-based foods. The effects of these pentosans on the physical properties of the unfermented and fermented dough, uncooked wet noodles and cooked noodles, as well as the bread staling were investigated by using a Texture Profile Analysis and a Differential Scanning Calorimetry. The results showed that WSP and WIP increased the volume of the fermented dough, the strength and cohesiveness of the unfermented dough, the strength of the uncooked wet noodles, the firmness and extensibility of the cooked noodles and retarded bread staling and decreased the firmness of the unfermented dough. Cooking yield and loss of wet noodles were increased and decreased with the increasing addition of pentosans, respectively. These results provide an indication that WSP and WIP can improve the textural properties of starch-based foods.

Keywords: Pentosans, starch-based foods, textural properties, wheat bran

INTRODUCTION

Pentosans are the dietary fibers existing widely in the outer layer of cereals such as wheat, rye, barley, etc. One of the richest sources is wheat bran containing more than 20% pentosans (Denli and Ercan, 2001). Some literatures (Lzydorczyk and Biliaders, 1992; Lu *et al.*, 2000; Miyata *et al.*, 2010; Nguyen *et al.*, 1993) have demonstrated that pentosans possess many biological activities as anti-breast cancer, anti-mutation, anti-colon cancer, anti-coagulation, anti-atherosclerosis, reducing blood lipids, reducing osteonecrosis of femoral head, losing weight and moderating blood glucose, etc. Besides, pentosans are very important in determining dough-handling properties and bread-making quality due to its water-binding capacity, high viscosity, gelation property formed by oxidative cross-linking and emulsion stability (Brijs *et al.*, 2004; Revanappa *et al.*, 2010). Thus, pentosans are attracting more attention gradually in food industry due to its functional properties.

Pentosans consist mainly of arabinose and xylose. The important index of pentosans is the ratio of Arabinose to Xylose (A/X), that is, degree of substitution. Pentosans are classified into the Water-Soluble Pentosans (WSP) and Water-Insoluble Pentosans (WIP) (Rouau and Surget, 1994). Beaugran (2004) reported that the A/X of WIP in wheat is from 0.60 to 1.07 and the A/X of WSP is about 0.32. The structure of WSP is similar to that of WIP, but WSP

have the higher degree of branching leading to the difference between WSP and WIP functions (Lzydorczyk and Biliaderis, 1995). Arabinoxylans (AX) are the major constituent of pentosans in wheat. Ferulic Acid (FA) combined with AX is a key factor controlling the effect of WSP and WIP on bran yield and properties (Mohammadkhani, 2005). In recent years, wheat pentosans are becoming more and more important in view of the increased use of pentosans to the productions of wheat bakery and bran products (Buksa *et al.*, 2010; Maeda and Morita, 2003; Wang *et al.*, 2004). Research attention has focused mostly on the effects of pentosans obtained from wheat endosperm on the quality of bread, while few literatures have reported the impacts of pentosans isolated from wheat bran on starch-based food quality. So, we studied the effects of WIP and WSP isolated from wheat bran on the properties of starch-based foods such as the unfermented and fermented dough, uncooked wet noodles and cooked noodles, as well as the bread staling process by using a Texture Profile Analysis (TPA) and a Differential Scanning Calorimetry (DSC).

MATERIALS AND METHODS

Chemicals: Wheat bran powders (mesh number: 80) was supplied from Jiugui starch Co., Anhui, China. Dry yeast was purchased from Angel yeast Co., Ltd. (Hubei, China). Cellulase (80,000 U/g), α -amylase (100,000 U/g) and protease (100,000 U/g) were purchased from Sigma. Alcohol, sodium hydroxide and sulfuric acid

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were purchased from Nankai University Chemical Co. (Tianjin, China). All chemicals were analytical grade.

Isolation and purification of WSP and WIP: Wheat bran powders (100 g) were defatted with 200 mL 95% alcohol and then extracted with distilled water (1:10, W/V) using a mechanical stirrer under a constant rotating speed (100 rpm). During the extraction process, cellulase, α -amylase and protease were added to the extraction solution in turn and the solution was heated and held in a water bath at 37, 65 and 55°C, for 20 min, respectively. The additional contents of cellulase, α -amylase and protease were 0.25, 0.75 and 1.25%, respectively. The mixture was centrifuged (3000 rpm, 20 min) to obtain the supernatant and precipitation. Thereafter, 400 mL 95% ethanol was added to 100 mL supernatant using stirring. After standing overnight at 4°C, the precipitated material containing WSP was collected by centrifugation and then lyophilized. Besides, the precipitation obtained above were suspended in 100 mL of distilled water and adjusted to pH 5.0 with sodium hydroxide at 30°C for 30 min using stirring. The extraction solution was then centrifuged (3000 rpm, 20 min) to get the supernatant. Four hundred milliliter 95% ethanol was added to 100 mL supernatant using stirring as mentioned above. After standing overnight at 4°C, the precipitated material containing WIP was collected by centrifugation and washed by using ethanol to further remove small molecular weight fractions, then centrifuged and lyophilized.

Determination of the pentosans content: For the case of Total Pentosans (TP), 100 mg samples were weighed in a pyrex glass tube fitted with a screw cap. Two mol/L sulfuric acid (5 mL) was added to the sample and then the mixture was gently dispersed for 60 sec using a homogenizer. Fifty milliliter sample suspension was boiled for 15 min in a water bath (100°C) and cooled in water and then centrifuged for 5 min at 4000 rpm. An aliquot of the clear supernatant diluted 10 times was used to determine TP content by a gas chromatographic method (Folkes, 1998). In terms of WSP, 2 g samples were weighed into a centrifuge tube. Twenty milliliter distilled water was poured into the tube and then the sample was homogenized for 60 sec and shaken for 15 min at 30°C and centrifuged for 5 min at 4000 rpm. An aliquot of the supernatant was diluted 30 times and WSP was determined by the spectrophotometric method (Lzydorczyk *et al.*, 1991). WIP was calculated by subtracting the content of WSP from that of TP. The contents of WSP and WIP powder obtained in this experiment were determined to be 95.27 and 92.83%, respectively.

Wheat flour-WSP and wheat flour-WIP blends: The additional contents of WSP and WIP to wheat flour were 0, 0.5, 1.0 and 1.5%, respectively. Wheat flour-WSP or Wheat flour-WIP were mixed for 10 min to ensure uniform blending.

The preparation of unfermented and fermented dough: The required amount (50%, w/w) of water was added to the dry blends (Wheat flour-WSP or Wheat flour-WIP) with different ratios at ambient temperature. The unfermented dough was prepared at a constant speed of 100 rpm using a NH-1 experimental kneading machine (Nantong First Machinery Co., Ltd, China). The fermented dough was obtained by the following process: 50% of warm water and 0.3% active dry yeast were added to the dry blends (Wheat flour-WSP or Wheat flour-WIP) with different ratios. The preparation of fermented dough was similar to that of the unfermented dough and fermentation was carried out in a pre-heated proving cabinet set at 35±1°C and at a relative humidity of 80% for 6 h.

The preparation of uncooked wet noodles and cooked noodles: A process for the production of noodles by machines, which comprises the following steps:

- Preparing a noodle dough with 50% of water added to the dry blends (Wheat flour-WSP or Wheat flour-WIP) with different ratios
- Forming the noodle dough into a noodle sheet
- Maturing the noodle sheet at a temperature of 30 to 35°C and a relative humidity of 80% for 30 min
- Rolling a matured noodle sheet followed by cutting into strands of noodles
- Stretching the strands at a stretching ratio of 2 times into desired strands of uncooked wet noodles
- Cooking the wet noodles in boiled water for 5 min to obtain cooked noodles

The volume of the fermented dough: The volume of the fermented dough was obtained according to Approved Method 10-05 (AACC, 2000). Data were determined as the mean of three measurements, which were performed on three fermented dough from different experiments.

Texture properties of the unfermented dough stickiness: A Texture Analyzer TA-XTplus (Stable Micro Systems, UK) was used to measure the force-time curve. Before using the cell, rotate the internal screw to move the piston and increase the sample chamber to its maximum capacity. Place a small quantity of prepared dough into the chamber and remove the excess dough with a spatula so that it is flush with the top of the chamber. Screw on the extruder lid. Rotate the internal screw a little way to extrude a small amount of dough through the holes and remove this first extrusion from the lid surface using a spatula. Rotate the screw once again to extrude a 1 mm high dough sample. Place the perspex cap over the exposed sample surface to minimize moisture loss, whilst allowing the prepared dough surface to rest for 30 sec to release the stress produced by extrusion. After this time remove the cover and place the cell directly

under the 25 mm cylinder probe attached to the load cell. The dough can then be removed from the lid surface and extruded again to repeat the test, using the above procedure. The TA setting parameters were as follows: Probe type was SMS/Chen-Hoseney Dough Stickiness Cell (A/DSC); Pre-Test Speed was 0.5 mm/sec; Test Speed was 0.5 mm/sec; Post-Test Speed was 10.0 mm/sec; Force was 40 g; Time was 0.1 sec; Distance was 4 mm; Trigger Type was Auto-5 g; Tare Mode was Auto; Data Acquisition Rate was 500 pps. Experimental data obtained by using the Texture Analyzer with accompanying computer Software (SAS). Every value was measured three times and then averaged. Registered parameters were firmness, strength and cohesiveness.

Cooking properties and texture analysis of the uncooked wet noodles:

The strength of the uncooked wet noodles: The uncooked wet noodles were tested individually by placing one end into the lower rig arm slot and winding the loosened arm sufficiently, in order to anchor the noodle end (away from the slot) by at least two revolutions of the arm. The arm is tightened and the same procedure is performed to anchor the other noodle end to the upper arm. The TA setting parameters were as follows: Probe type was Spaghetti tensile grips (A/SPR) using 5 kg load cell; Mode was measure force in tension; Option was return to start; Pre-Test Speed was 1.0 mm/sec; Test Speed was 3.0 mm/sec; Post-Test Speed was 10.0 mm/sec; Distance was 100 mm; Trigger Type was Auto-5 g; Tare Mode was Auto; Data Acquisition Rate was 200 pps. Experimental data obtained by using the Texture Analyzer with accompanying computer Software (SAS). Every value was measured three times and then averaged.

Cooking properties of the uncooked wet noodles:

The optimum cooking time and the cooking loss of noodles were determined according to approved method 66-50 (AACC, 2000). Cooking time was performed using 20 g of wet noodles that were cooked in 500 mL of boiling water and following the 2-min time point, a sample was removed from the water and squeezed between two pieces of glass. The optimum cooking time was the time recorded when the white core in the strand was appeared. The process was duplicated to obtain the mean values of cooking time for each replicate. Cooking yield and cooking loss were determined on 20 g of wet noodles cooked in 500 mL of boiling water to the optimum cooking times determined as described above. The cooked noodles were rinsed in cold water for 20 sec and drained for 5 min before weighting. Cooking yield was calculated from the wet weight of cooked noodles divided by the dry weigh to the raw noodles and expressed as a percentage. The cooking water in an oven was evaporated at 105°C to constant weight. The residue

was weighed and reported as percent cooking loss based on the dry weigh to the uncooked noodles. Three replicates of cooked noodles at each level of pentosans content were prepared. Three determinations for each replicate were performed to obtain the mean values.

Texture properties of the chewiness of the cooked noodles:

The firmness and fracturability values, indicators of noodle chewiness, were determined by using the Texture Analyzer TA-XTplus (Stable Micro Systems, UK) with 5 kg load cell. The flat cutting blade (Light Knife Blade, A/LKB) was used to cut the cooked noodles. The texture parameters were set as pretest speed = 0.5 mm/sec; test speed = 0.2 mm/sec; post test speed = 10 mm/sec; and distance = 4.5 mm; data acquisition rate was 400 pps. Five strands of cooked noodles were placed parallel on a flat plastic plate and were cut by the noodles blade to a distance of 4.5 mm. Noodle samples were evaluated within 5 min after cooking. Experimental data obtained by using the Texture Analyzer with accompanying computer Software (SAS). Every value was measured three times and then averaged.

The Tgs of the bread staling process during storage:

The glass transition temperatures (Tgs) of the breads containing WIP or WSP were determined using a PerkinElmer DSC8000 Thermal Lab System. The measurements were carried out under a nitrogen purge gas at a flow rate of 50 mL/min. The instrument was calibrated for temperature and heat flow using indium and zinc as standards at a heating rate of 10°C/min. A baseline for an empty pan was established for each corresponding heating rate. An empty aluminum pan was used as a reference. Triplicate samples (5.0±0.1 mg, dry basis) were sealed in aluminum pans. The samples were scanned between -50 and 100°C, followed by cooling as rapidly as possible in the calorimeter (about 150°C/min) and immediate heating at 20°C/min. The immediate reheat and the rapid scanning rate minimize the danger of ageing artifacts, due to physical ageing appearing in the second heating trace from which the Tg is taken. After the first-run heating, the gelatinized samples were kept at 4°C for 0, 5, 10, 15, 20 and 25 days, respectively. The stored samples were rescanned from -50 and 100°C at a heating rate of 20°C/min to study the effects of WIP and WSP on the bread staling process during storage. Three replicates of each treatment were evaluated.

RESULTS AND DISCUSSION

The volume of the fermented dough: Changes in maximum volume (V_{max}) of the fermented dough as a function of pentosans are reported in Table 1. Enrichment with WSP (0.5-1.5%) led to greater

Table 1: Effects of pentosans addition on maximum volume (V_{max}) of the fermented dough

Addition (%)	V_{max} (cm ³)	
	WSP	WIP
0.0	352±0.02	352±0.03
0.5	387±0.01	371±0.02
1.0	446±0.04	394±0.03
1.5	481±0.02	405±0.01

Data are expressed as means±standard deviations (n = 3)

changes in dough expansion properties than WIP (0.5-1.0%). Dough expansion gradually increased with increasing levels of WSP and WIP. Compared with the control sample, the addition of 1.5% WSP and 1.0% WIP made dough volumes increased by 36.65 and 11.93%, respectively. This may be because the high viscosity of pentosans increases the strength and extensibility of bran and starch film to enhance anti-thermal fracture ability of protein foam and gas-holding capacity of dough. This makes the rate of diffusion of carbon dioxide produced during fermentation decreases and the texture of dough become smoother and uniform, which increases the volume of dough (Wang *et al.*, 2004). Besides, pentosans can interact with gluten by Folic acid, which affects dough volumes (Koehler and Wieser, 2013).

Texture properties of the unfermented dough

stickiness: The effects of WSP and WIP on the unfermented dough stickiness were analyzed by using a texture analyzer. The texture drawings are shown in Fig. 1-2. The maximum force reading, i.e., highest peak, the positive area and the distance between the anchors set (1-2), are all indicators of the stickiness of the dough. Three parameters, such as firmness, strength and cohesiveness, were used to describe texture characteristics of dough stickiness. The 'peak' or maximum force is taken as a measurement of firmness. The higher the value is, the firmer of the sample is. The positive area is taken as an indication of the cohesiveness of the sample. The larger the positive area is, the higher cohesiveness of the sample is. The distance between the anchors set (1-2) is referred to as the strength of the sample. The higher value implies the stronger dough. Figure 1-2 show the effect of different WSP or WIP contents on the unfermented dough stickiness. From Fig. 1-2, it is observed that the maximum force is decreased and the positive area and the distance between the anchors set (1-2) are increased with increasing WSP or WIP contents. It suggests that WSP and WIP affect the stickiness of unfermented dough compared with control. The contents of WSP or

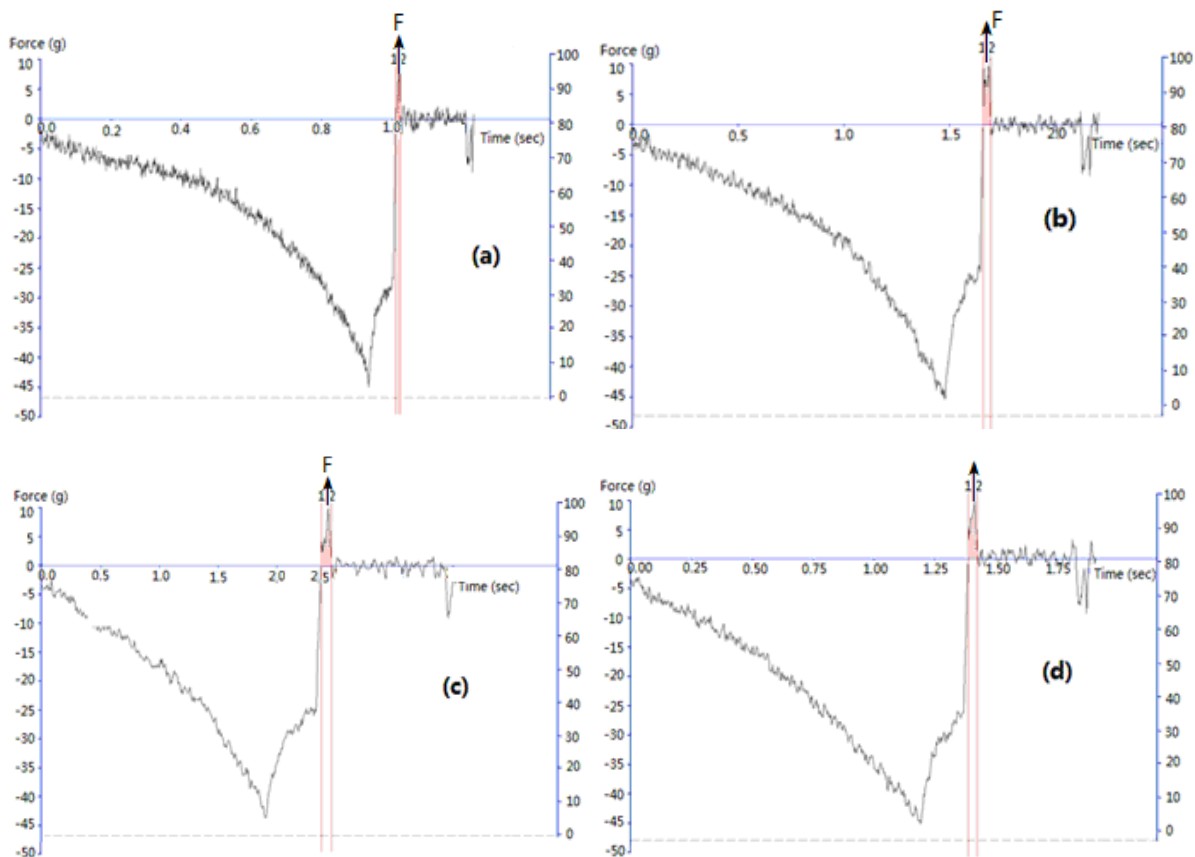


Fig. 1: The effect of different WSP contents on the unfermented dough stickiness; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%

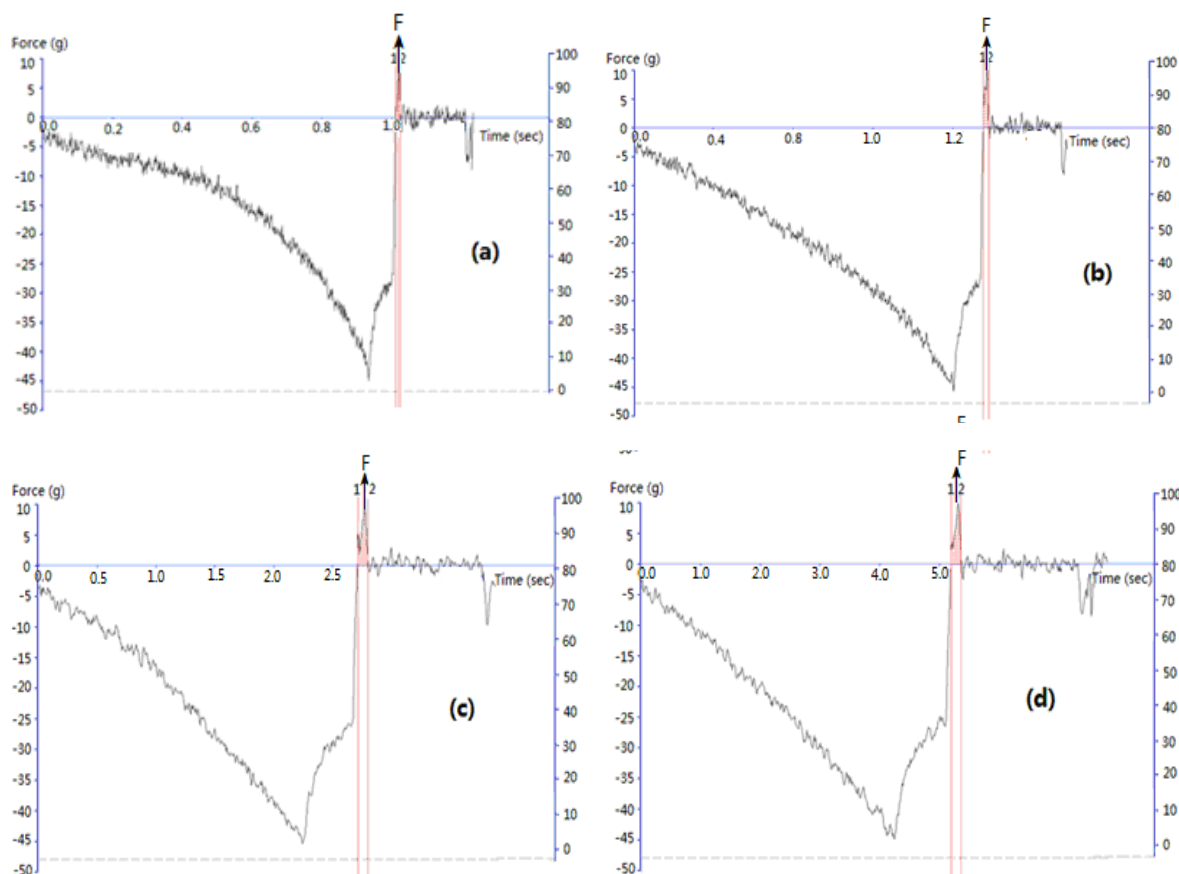


Fig. 2: The effect of different WIP contents on the unfermented dough stickiness; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%

Table 2: Effects of pentosans on the unfermented dough stickiness

	Firmness (g)	Cohesiveness (gsec)	Strength (sec)
Control	9.346±0.001	0.140±0.001	0.241±0.002
0.5%WSP	9.065±0.001	0.161±0.001	0.283±0.003
1.0%WSP	8.784±0.003	0.207±0.002	0.292±0.003
1.5%WSP	8.714±0.001	0.219±0.001	0.308±0.001
0.5%WIP	9.002±0.002	0.151±0.003	0.248±0.004
1.0%WIP	8.995±0.002	0.167±0.004	0.262±0.001
1.5%WIP	8.292±0.001	0.168±0.001	0.278±0.002

Data are expressed as means±standard deviations (n = 3)

WIP have great effects on the stickiness of unfermented dough when they increase from 0.5 to 1.5%. The corresponding parameters are shown in Table 2. Compared with the control sample, for 0.5% pentosans the effect on the stickiness of unfermented dough is not significant. For 1.5% pentosans the effect is clearly evident as seen in Table 2. Both cohesiveness and strength increased with the addition of pentosans, which implies that pentosans have the ability to immobilise water and to form viscous network by covalent cross-linking. The resistance to small deformations of the dough also increased as the pentosans content increased. The water holding capacity of pentosans probably affects the distribution of moisture among dough constituents and therefore leads to an increased the cohesiveness and strength of dough (Labat *et al.*,

2002). Conversely, the firmness of the unfermented dough was decreased with increasing WSP or WIP contents.

Cooking properties and the strength of the uncooked wet noodles: The texture drawings of the strength of the uncooked wet noodles are shown in Fig. 3-4. The maximum force is taken as an indication of the maximum force needed by breaking the noodles. The higher the value is, the more strength the sample is. From Fig. 3-4, it is seen that the maximum force was increased with increasing WSP or WIP contents. It suggests that WSP and WIP can improve the poor strength of wheat flour to enhance the texture properties of wheat products.

Cooking characteristics such as cooking time, cooking loss and cooking yield of wet noodles with different WSP or WIP contents are listed in Table 3. The cooking time of noodles containing pentosans was longer than that of the control. The cooking time of noodles also increased as the pentosans content increased. In general, high cooking yield and low cooking loss are considered to be connected to high cooking quality of noodles. Cooking yield and loss were affected by pentosans. Compared with the control, cooking yield of wet noodles containing WSP or WIP

Table 3: Cooking properties of the uncooked wet noodles

	Cooking time (min)	Cooking yield (%)	Cooking loss (%)
Control	6.0	84.03±0.01	6.23±0.02
0.5%WSP	6.5	87.95±0.01	4.87±0.01
1.0%WSP	7.0	93.87±0.02	4.32±0.02
1.5%WSP	9.0	98.06±0.01	3.74±0.01
0.5%WIP	7.0	86.65±0.02	5.12±0.03
1.0%WIP	7.0	90.32±0.01	4.79±0.01
1.5%WIP	8.5	95.21±0.01	4.16±0.03

Data are expressed as means±standard deviations (n = 3)

was higher, whereas cooking loss was lower. Both cooking yield and loss of wet noodles containing different pentosans were increased and decreased with the increasing addition of pentosans, respectively. Cooking yield was increased by 16.70% and cooking loss was decreased by 39.70% when WSP was added at a level of 1.5% to wet noodles. This may be because the high viscosity of pentosans makes starch embedded in the cross-linked protein network, which leads to

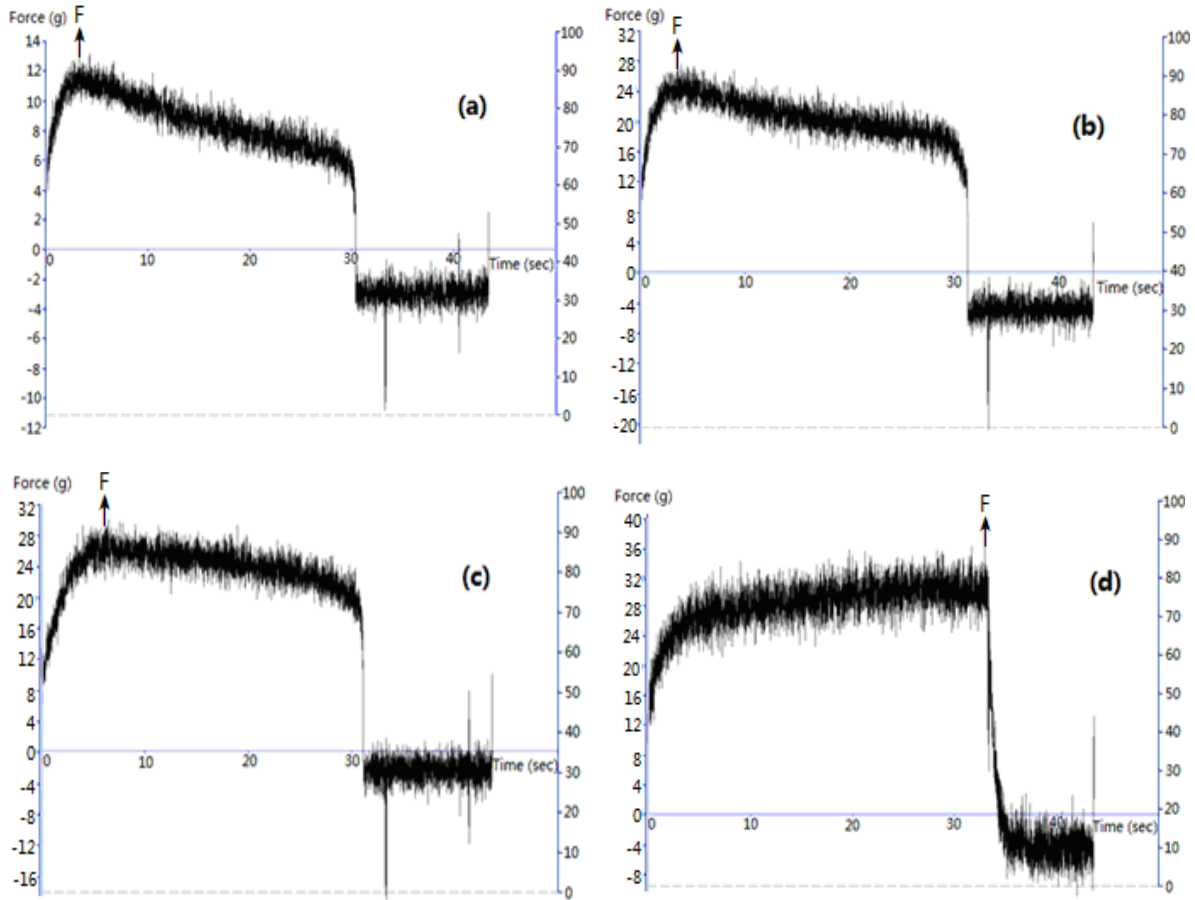
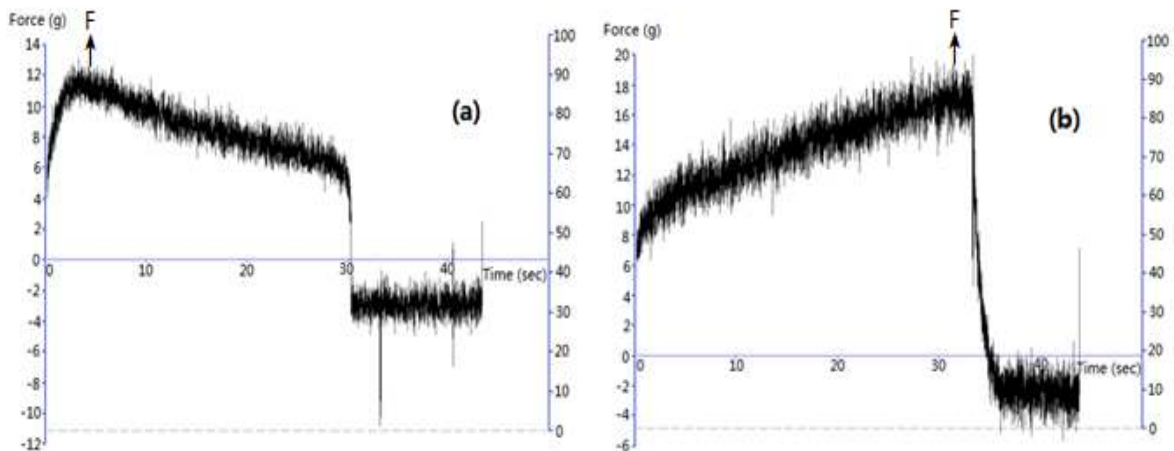


Fig. 3: The effect of different WSP contents on the strength of the uncooked wet noodles; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%



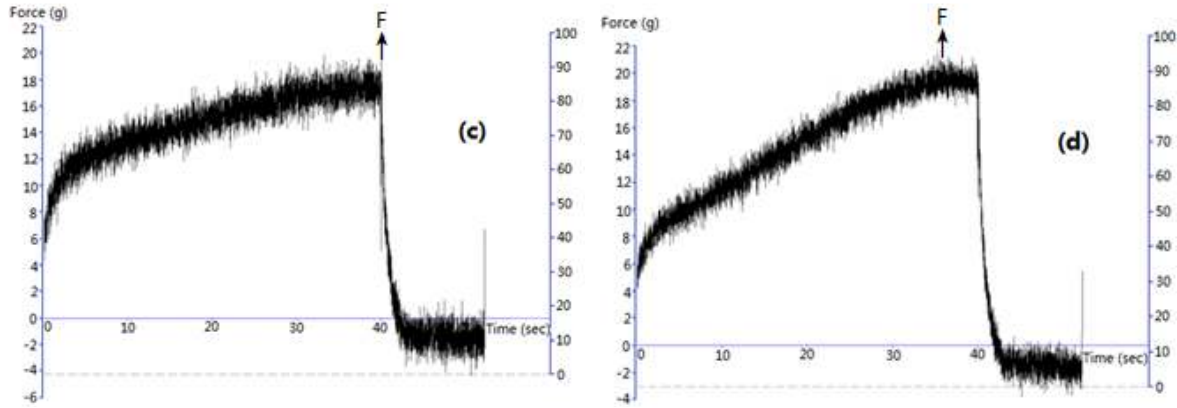


Fig. 4: The effect of different WIP contents on the strength of the uncooked wet noodles; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%

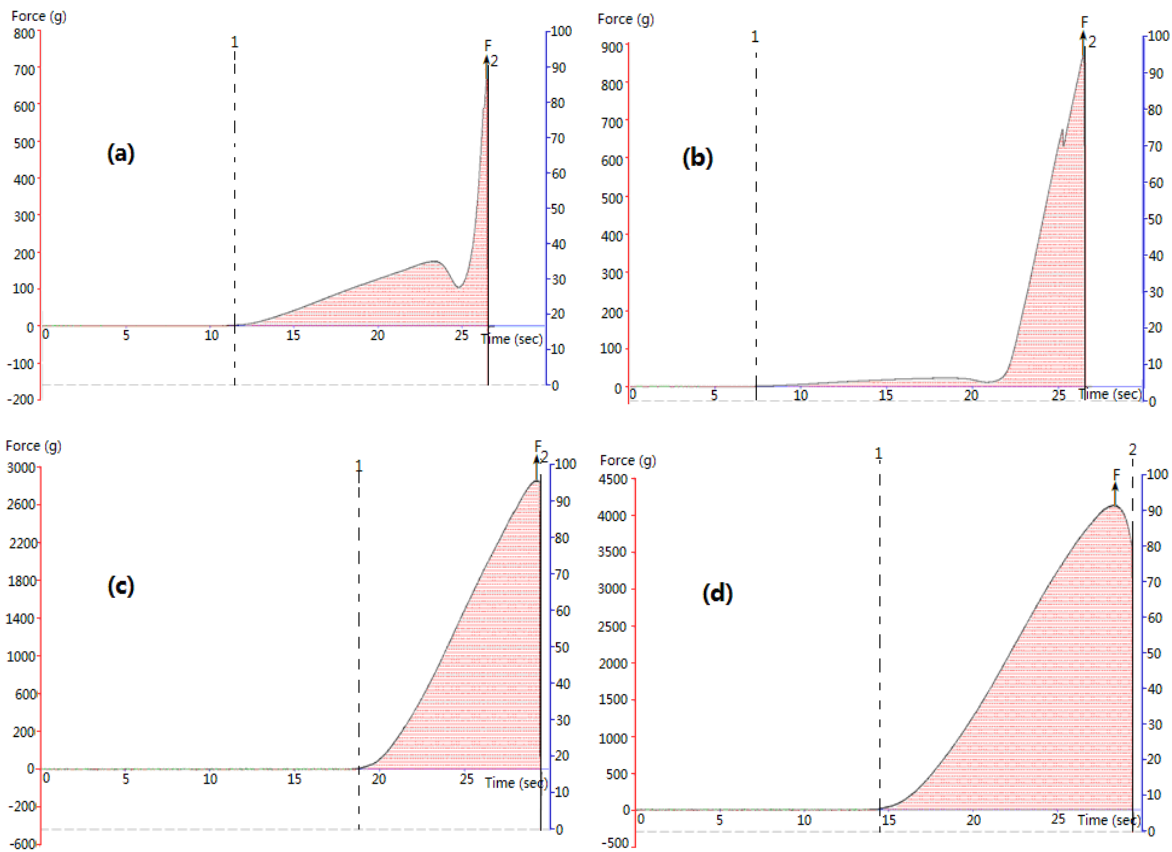


Fig. 5: The effect of different WSP contents on the chewiness of the cooked noodles; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%

decrease starch loss as reflected by a reduction of cooking loss (Devesa and Martínez-Anaya, 2003).

Texture properties of the chewiness of the cooked noodles: Two parameters as firmness and extensibility were used to describe the chewiness of the cooked noodles. The maximum force is taken as a measurement of firmness. The higher the value is, the firmer of the sample is. The positive area between the anchors set (1-2) is referred to as the extensibility of the sample. Figure 5-6 show the effect of different WSP or WIP

contents on the chewiness of the cooked noodles. From Fig. 5-6, it is seen that the maximum force is increased and the positive area between the anchors set (1-2) are increased with increasing WSP or WIP contents. It suggests that WSP and WIP affect the chewiness of the cooked noodles compared with control, especially WSP.

The Tgs of the bread staling process during storage: The effects of pentosans on the Tgs of the bread staling process during storage were determined by using DSC

shown in Fig. 7-8. Obviously, the changes in the Tgs of the breads containing WIP or WSP are listed during reheating after storage at 4°C for 0, 5, 10, 15, 20 and 25 days, respectively in Fig. 7-8. The results demonstrate that Tgs of the breads decreases with increasing pentosans contents and increases with increasing storage time. Compared with the Tg (-8.52°C) of the

control, the Tgs decreased to -21.03 and -23.01°C for the breads containing 1.5% WSP or 1.5% WIP, respectively, after 25 days of storage. These results indicate that pentosans can reduce obviously re-crystallization of the breads so to significantly retard the staling of breads. From these results, the WSP and WIP improved bread qualities distinctly. WIP had more

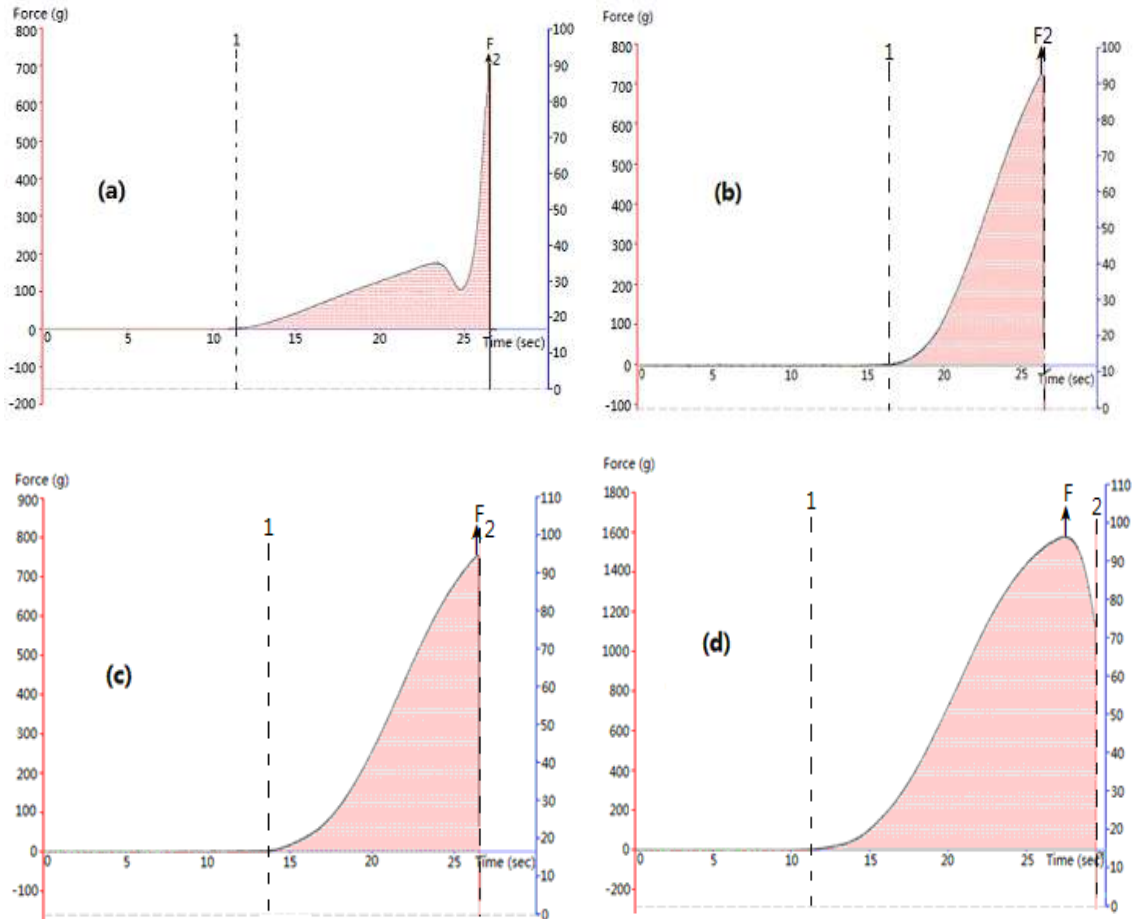
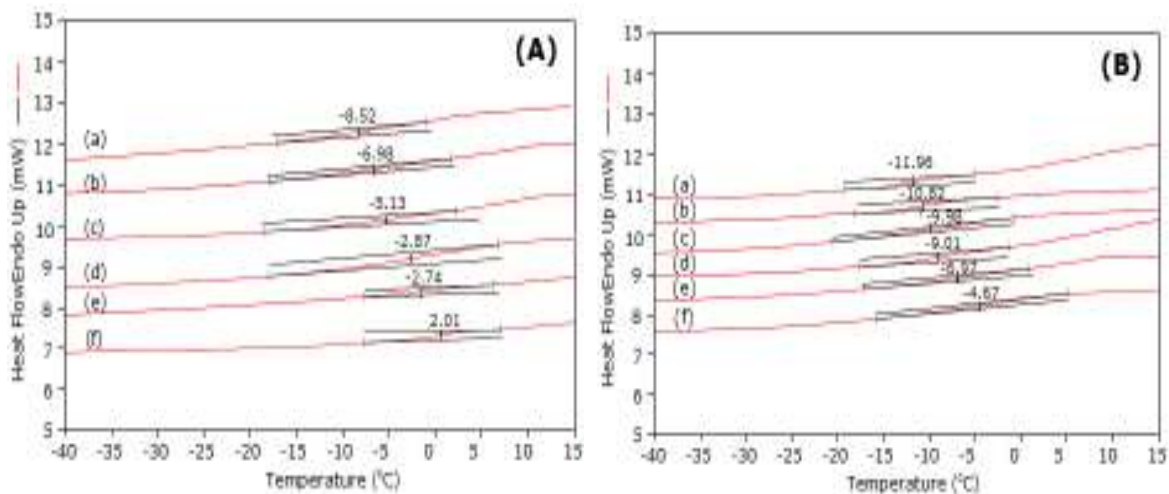


Fig. 6: The effect of different WIP contents on the chewiness of the cooked noodles; (a): 0%; (b): 0.5%; (c): 1.0%; (d): 1.5%



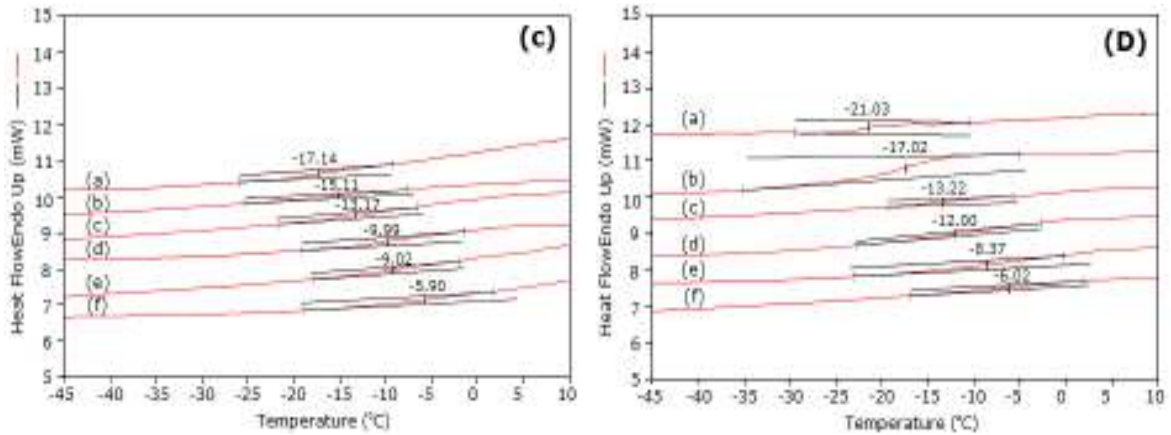


Fig. 7: The effect of different WSP contents on the Tgs of the bread staling process during storage; (A): 0%; (B): 0.5%; (C): 1.0%; (D): 1.5%
(a): 0 day; (b): 5 days; (c): 10 days; (d): 15 days; (e): 20 days; (f): 25 days

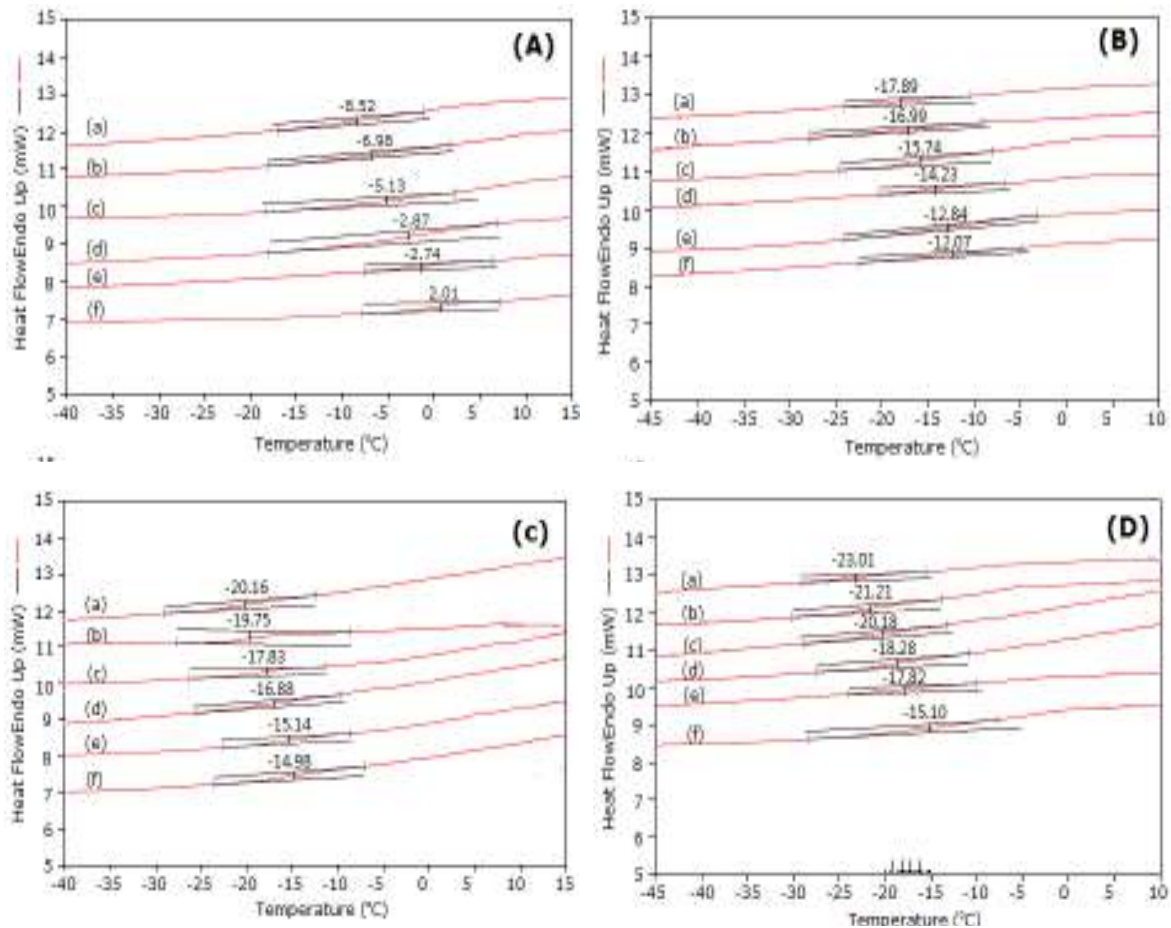


Fig. 8: The effect of different WIP contents on the Tgs of the bread staling process during storage; (A): 0%; (B): 0.5%; (C): 1.0%; (D): 1.5%
(a): 0 day; (b): 5 days; (c): 10 days; (d): 15 days; (e): 20 days; (f): 25 days

satisfactory effects on the decrease of Tg and retardation of staling of bread than WSP did. As a result, a relatively larger amount of WSP than WIP is needed to obtain good bread-baking quality.

CONCLUSION

The present study investigated the relationships between textural properties of some starch-based foods

and pentosans using TPA and DSC. It is concluded that the addition of pentosans to the unfermented and fermented dough, uncooked wet noodles and cooked noodles, as well as the bread staling can modify the textural properties of these starch-based foods. Pentosans have significant effects on the volume increase of the fermented dough, the strength and cohesiveness increase of the unfermented dough, the strength increase of the uncooked wet noodles, the firmness and extensibility increase of the cooked noodles and the retardation of bread staling. WSP and WIP can decrease the firmness of the unfermented dough. Besides, pentosans can increase and decrease cooking yield and loss of wet noodles, respectively. These findings indicate that pentosans have significant effects on the texture and cooking quality of starch-based foods, which deserves to be considered when different kinds of starch-based foods are produced.

ACKNOWLEDGMENT

This research has been supported by National Natural Science Foundation of China (Grant No. 31371735 and 31171655).

REFERENCES

- AACC, 2000. Approved Methods of the American Association of Cereal Chemists. 10th Edn., American Association of Cereal Chemists Press, St. Paul, MN.
- Beaugran, J., 2004. Arabinoxylan and hydroxycinnamate content of wheat bran in relation to endoxylanase susceptibility. *J. Cereal Sci.*, 40: 223-230.
- Brijs, K., J.A. Inglebrecht, C.M. Courtin, L. Schlichting, B.A. Marchylo and J.A. Delcour, 2004. Combined effects of endoxylanases and reduced water levels in pasta production. *Cereal Chem.*, 81: 361-368.
- Buksa, K., A. Nowotna, W. Praznik, H. Gambuś, R. Ziobro and J. Krawontka, 2010. The role of pentosans and starch in baking of wholemeal rye bread. *Food Res. Int.*, 43: 2045-2051.
- Denli, E. and R. Ercan, 2001. Effect of added pentosans isolated from wheat and rye grain on some properties of bread. *Europ. Food Res. Technol.*, 212: 374-376.
- Devesa, A. and M.A. Martínez-Anaya, 2003. Influence of pentosans on texture of starch gels during storage and effects after enzyme treatment. *Europ. Food Res. Technol.*, 216: 323-330.
- Folkes, D.J., 1980. A gas chromatographic method for the determination of pentosans. *J. Sci. Food Agric.*, 31: 1011-1016.
- Koehler, P. and H. Wieser, 2013. Chemistry of Cereal Grains. In: Marco, G. and G. Michael (Eds.), *Handbook on Sourdough Biotechnology*. Springer, New York, ISBN: 1461454255, pp: 298.
- Labat, E., X. Rouau and M.H. Morel, 2002. Effect of flour water-extractable pentosans on molecular associations in bran during mixing. *LWT- Food Sci. Technol.*, 35: 185-189.
- Lu, Z.X., K.Z. Walker, J.G. Muir, T. Mascara and O.D. Kerin, 2000. Arabinoxylan fiber, a byproduct of wheat flour processing, reduces the postprandial glucose response in normoglycemic subjects. *Am. J. Clin. Nutr.*, 71: 1123-1126.
- Lzydorczyk, M.S. and C.G. Biliaders, 1992. Influence of structure on the physicochemical properties of wheat arabinoxylan. *Carbohydr. Polym.*, 17: 237-247.
- Lzydorczyk, M.S. and C.G. Biliaderis, 1995. Cereal arabinoxylans advances in structure and physicochemical properties. *Carbohydr. Polym.*, 28: 33-48.
- Lzydorczyk, M.S., C.G. Biliaders and W. Bushuk, 1991. Physical properties of water-soluble pentosans from different wheat varieties. *Cereal Chem.*, 68: 145-150.
- Maeda, T. and N. Morita, 2003. Flour quality and pentosan prepared by polishing wheat grain on breadmaking. *Food Res. Int.*, 36: 603-610.
- Miyata, N., K. Kumagai, M. Osaki, M. Murata, M. Tomita *et al.*, 2010. Pentosan reduces osteonecrosis of femoral head in SHRSP. *Clin. Exp. Hypert.*, 32: 511-516.
- Mohammadkhani, A., 2005. Study of pentosans (Non Starch Polysaccharides), in durum wheat and its relation to the quality of protein and grain Hardness Index (H.I.). *Pak. J. Nutr.*, 4: 208-209.
- Nguyen, N.M., J.E. Lehr and K.J. Pienta, 1993. Pentosan inhibits angiogenesis in vitro and suppresses prostate tumor growth in vivo. *Anti. Res.*, 13: 2143-2147.
- Revanappa, S.B., C.D. Nandini and P.V. Salimath, 2010. Structural characterisation of pentosans from hemicellulose B of wheat varieties with varying chapati-making quality. *Food Chem.*, 119: 27-33.
- Rouau, X. and A. Surget, 1994. A rapid semi-automated method for the determination of total and water-extractable pentosans in wheat flours. *Carbohydr. Polym.*, 24: 123-132.
- Wang, M.W., T.V. Vliet and R.J. Hamer, 2004. How bran properties are affected by pentosans. *J. Cereal Sci.*, 39: 395-402.