Effect of pentosans addition on pasting properties of flours of eight hard white spring wheat cultivars

Saqib Arif · Tahira Mohsin Ali · Qurat ul Afzal ·
Mubarik Ahmed · Asim Jamal Siddiqui · Abid Hasnain

Revised: 18 January 2012 / Accepted: 24 January 2012 / Published online: 3 February 2012
© Association of Food Scientists & Technologists (India) 2012

Abstract The effects of water extractable pentosans (WEP) and water unextractable pentosans (WUP) on pasting properties in flours of eight different hard white spring wheat (HWSW) cultivars was studied. WEP and WUP isolated from a hard wheat flour were added to each of the cultivars at 1% and 2% level. The results indicated that WEP exhibited a pronounced effect on pasting properties as compared to WUP and variety. Univariate analysis of variance (ANOVA) was used to evaluate sources of variation. The variety significantly ($P<0.001$) influenced all the pasting parameters. WUP caused significant ($P<0.001$) variation in paste viscosities (except breakdown). WEP influenced more pronouncedly the hot paste, cold paste, breakdown and setback viscosities with F values—221.802, 214.286, 98.073 and 120.159, respectively. Variety-by-WEP interaction exhibited significant ($P<0.01$) influence on pasting time, peak, hot paste and cold paste viscosities. Whereas, variety-by-WUP interaction only significantly ($P<0.001$) influenced the pasting- time and -temperature. Duncan's test was used to analyze the significant difference ($P<0.05$) within the variety. The results revealed that WUP did not

induce significant ($P<0.05$) influence on all the pasting parameters, whereas, WEP influenced significantly ($P<0.05$) the paste viscosities of some of the varieties. It was also found that the addition of WEP remarkably reduced the setback, hot paste, cold paste viscosities and increased the breakdown viscosity in all cultivar flours. The effect of WEP was greater at higher level of supplementation on paste viscosities.

Keywords Pentosans · Pasting properties · Hard white spring wheat flours

Introduction

Starch is the most abundant component of food. It is the major component of wheat kernel and therefore its behavior during wheat processing is an area of interest for researchers and bakers. A lot of work has been undertaken on the role of wheat starch and its pasting properties in bread making and storage (Toshiki and Paula 1992; Ozkoc et al. 2009; Martin and Hoseney 1991; Zeleznak and Hoseney 1986). Also, starches from other sources such as rye (Buksa et al. 2010; Ragaei and Abdel-Aal 2006), water chestnut (Lutfi and Hasnain 2009; Murty et al. 1962) and sweet potato (Lee et al. 2002) have been studied. In addition to starch, the pasting properties of wheat flours are related to protein, particles size distribution, α -amylase activity and damaged starch (Nagao 1995) and also influenced by presence of other ingredients such as sugar and salt (Wootton and Bamunuarachchi 1980).

Wheat pasting properties would be useful to predict performance of wheat flour during processing and phenomenon of bread staling (Collar 2003). Bakers are often interested to assess as well as control the bread staling.

S. Arif (✉) · Q. ul Afzal · M. Ahmed
Grain Quality Testing Laboratory, SARC, PARC,
Karachi University Campus,
Karachi, Pakistan 75270
e-mail: saqiawan@yahoo.com

T. M. Ali · A. Hasnain
Department of Food Science & Technology, University of Karachi,
Karachi, Pakistan 75270
e-mail: abidhasnain@hotmail.com

A. J. Siddiqui
Department of Statistics, University of Karachi,
Karachi, Pakistan
e-mail: asimjs2000@yahoo.com

Table 1 Analysis of variance of pasting parameters of flours of different HWSW varieties

Source	Pasting temperature(°C)	Time to reach peak viscosity (min)	Viscosity (BU)				
			Peak	Hot paste	Cold paste	Breakdown	Setback
R^2	0.45	0.48	0.70	0.90	0.90	0.81	0.84
Corrected Model F value	2.526***	2.831***	7.009***	28.083***	26.643***	13.073***	16.503***
Variety (V) F value	4.067***	4.700***	9.379***	8.677***	12.966***	9.668***	4.856***
WUP F value	0.541 ns	0.360 ns	9.761***	21.029***	13.775***	1.185 ns	13.609***
WEP F value	1.445 ns	3.620*	16.399***	221.802***	214.286***	98.073***	120.159***
$V \times WUP$ F value	3.439***	3.300***	1.662 ns	1.108 ns	1.039 ns	1.607 ns	1.303 ns
$V \times WEP$ F value	1.785*	2.364**	2.914**	3.691***	2.710**	1.721 ns	1.114 ns

F values used type III mean squares; ns, non-significant; *, $P<0.05$; **, $P<0.01$; and ***, $P<0.001$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

Hydrocolloids or gums are known to influence pasting properties of wheat starch and flour (Rosell et al. 2001) and widely used as antistaling agent in bread making (Davidou et al. 1996; Armero and Collar 1998). Many hydrocolloids like Xanthan gum, guar gum, CMC, gum acacia and locust bean gum have been investigated to exploit their effects on bread staling (Dickinson 2003; Juszczak et al. 2004; Gavilighi et al. 2006; Azizi and Rao 2004). But only few researchers have included pentosans in their studies even though pentosans compete well for water with other constituents of flour and subsequently affect the pasting properties of flour.

Pentosans and hemicelluloses are the major component of cell walls of cereal grains and varies between 4% and 8% in wheat (Hong et al. 1989; Saulnier et al. 1995). Pentosans positively affect shelf life of breads either by directly interacting with starch (Benamrouche et al. 2002; Devesa and Martinez-Anaya 2003) or by curtailing the availability of water during retrogradation (Biliaderis et al. 1995). Water soluble pentosans had detrimental effects on starch gelation

(Santos et al. 2002). Some researchers have found the increasing effect of pentosans on peak viscosity, and the effect was greater by adding water extractable pentosans than water unextractable pentosans (El-Wakeil et al. 1976). Others have found no effects of pentosans on pasting properties of wheat flour (Kim and D'Appolonia 1977b). The discrepancies in results could be due to the different sources from which pentosans were isolated. Tao and Pomeranz (1967) reported that durum pentosan decreases peak viscosity, whereas, pentosans from other flour varieties (including hard red winter, hard red spring, soft red winter and club wheats) either increased or had no effects on peak viscosity. Other factors could be difference in isolation procedures of pentosans; level of supplementation and the quality of base flours.

The pasting properties of wheat are largely related to cultivar (Bhattacharya et al. 1997; Singh et al. 2011; Massaux et al. 2008), irrigation practices and sowing time (Singh et al. 2010). Despite the significance of flour pasting properties and role of pentosans, no extensive study had

Table 2 Pasting temperature (°C) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	57.2±0.1A	57.8±1.8A	61.6±5.4A ^a	59.1±0.4A	58.8±0.6A
Imdad	57.5±1.2A	58.5±1.0AB	57.4±0.6A	58.4±1.3A	57.8±0.2A
Mehran	57.6±1.1A	62.1±3.4B ^a	57.4±2.4A	58.5±0.1A	58.2±1.8A
Abadgar	59.9±4.1A	58.0±0.5A	57.5±0.6A	58.1±0.1A	56.7±0.7A
Moomal	56.8±0.2A	56.8±0.8A	56.8±0.6A	56.9±0.2A	58.3±0.9A
Anmol	57.3±0.1A	57.7±0.1A	57.9±1.5A	58.4±0.9A	58.6±0.4A
SKD-1	59.5±1.3A	58.8±0.1AB	57.9±0.2A	58.3±1.2A	58.5±1.8A
TJ-83	58.5±0.1A	58.0±1.8A	60.1±0.5A	62.0±8.2A	58.7±1.4A

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

been undertaken on Pakistani wheat cultivars. The present study had therefore been emphasized to study the effects of pentosans on pasting properties of HWSW flours.

Materials & methods

Eight hard white spring wheat cultivars namely TJ-83, Abadgar, Anmol, TD-1, Moomal, Imdad, SKD-1 and Mehran were grown at two locations Hyderabad and Nawabshah-Sindh in Pakistan. Both the locations have almost identical agro-ecology and are about 120 km distance to each other. Hyderabad lies 25.36° latitude and 68.36° longitude whereas Nawabshah lies 26.25 and 68.41° latitude and longitude, respectively. The environmental factors including maximum temperature, minimum temperature and precipitation for the crop period (about 15Nov to 15May, 2008) was found to be 30.0 °C, 15.8 °C and 1.3 mm for Hyderabad and 31.9 °C, 10.4 °C and 0.12 mm for Nawabshah respectively. Both the areas are irrigated and canal-fed and are rich and known for wheat cultivation. On harvest, the wheat representing different genotypes were randomly sampled, mixed and divided to form representative laboratory samples.

In laboratory, samples were mixed thoroughly using precision electronic divider and thereafter cleaned manually using appropriate sieves. Wheat grain was milled into flour with the help of Brabender Quadramat Junior Mill, in accordance to the procedure of AACC 26–50 (2000). Wheat was conditioned to 15% moisture for 18 h before milling. The feeding rate was kept at about 100 g/min.

Isolation of WUP and WEP

The WEP and WUP fractions of pentosans were isolated from a commercially available hard wheat variety “Inqlab”. Water-unextractable pentosans were isolated following the procedure of Wang et al. (2003) with slight modifications. The resultant starch slurry was passed twice through a muslin cloth before sieving through a 32 µm mesh size standard sieve. Further steps of isolation and purification of WUP including incubation for 16 h at 30 °C after adding α -amylase, freeze drying and grinding were adapted as described by Wang et al. (2003). For the extraction of WEP, procedure given by Cleemput et al. (1995) was followed.

Pasting properties

Both the isolated materials (WUP and WEP) were substituted at the rate of 1% and 2% to HWSW flours separately. The samples including control and pentosan substituted were analyzed for pasting properties using Brabender Microviscoamylograph (Model # 803201, Brabender, Germany), equipped with 300 control moment gyroscope (cmg) sensitivity cartridge. Sample

Fig. 1 The magnitude of increase or decrease (in percentage) in pasting parameters of HWSW (hard white spring wheat) flours due to addition of water-extractable pentosan. ($n=4$)

slurry (15%) w/v was subjected to heating cycle from 40 to 95 °C at a heating rate of 3 °C/min. The slurry was held at this temperature for 10 min and was subsequently cooled back to 50 °C/min at a cooling rate of 3 °C/min. The slurry was held at this temperature for 10 min. The speed of rotation of bowl was fixed at 75 rpm. Peak viscosity (PV), pasting temperature (PT), time to reach peak viscosity (TTP), hot paste viscosity (HPV), cold paste viscosity (CPV), breakdown (BD) and setback (SB) viscosities were recorded from resulting amylograph.

Statistical analysis

All the analytical tests were replicated four times for the randomized samples collected from the experimental locations. A 3-way ANOVA for a factorial design (the factors were variety at 8 levels and WEP or WUP at 3 levels each including control) was performed to analyze the sources of variation in pasting properties of HWSW flours. Duncan's test (at $P<0.05$) was used to separate varieties within treatments (control, 1% and 2%) and also to calculate significant differences of pentosan substituted flours from control. All the statistical analysis was undertaken using SPSS software (SPSS version 17, Inc., USA).

Results and discussion

Table 1 depicts the ANOVA analysis to determine the effects of varietal differences, WEP and WUP on pasting properties of HWSW flours. It is evident that 70–90% of total variation in peak, hot paste, cold paste, breakdown and setback viscosities are a result of varietal differences, WEP and WUP influence. For pasting- temperature and -time the model explained the variation to a lesser degree. The results for individual parameters are discussed as under.

Pasting temperature

Pasting temperature (PT) is the temperature at which the first rise in viscosity is recorded on a viscoamylograph. The results have indicated that neither WEP nor WUP had significant effect on PT of HWSW flours (Table 1). However, the significant variation in PT was caused by the varietal differences, variety-by-WEP and variety-by-WUP interaction. The HWSW flours, investigated in this study, had comparable PT values (Table 2). The lowest (56.8 °C) and highest (59.9 °C) values were found in varieties Moomal and Abadgar, respectively. In all the varieties except Abadgar and SKD-1, the WEP was found to have marginally increased (0.2–6%) the PT as shown in figure 1(a). Both these varieties exhibited decrease in PT for WEP and WUP substituted flours that is unexplainable and suggests further investigation to reach any meaningful conclusion. Such marginal decrease in PT had also been reported by Rao et al. (2007) who used rice and ragi origin WEP for addition in wheat flour.

The effect of WUP on PT in different varieties did not exhibit any uniform pattern and may be an indirect reflection of varietal composition or supplementation level or any other reason.

Peak viscosity

Peak viscosity (PV) is the equilibrium point between swelling and rupture of starch granules (Newport Scientific 1995). It was found that PV of different HWSW flours ranged between 962BU and 1252BU with the highest and lowest values exhibited by the varieties TJ-83 and Mehran respectively (Table 3).

Varietal differences, WEP, WUP and variety-by-WEP interaction contributed significantly in the variation of PV of HWSW flours (Table 1). Lin and Czuchajowska (1997) also found the significant effect of variety on peak viscosity. The

Table 3 Peak viscosity (BU) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	1054±77AB	1101±43AB	1044±40A	1001±95A	962±31AB
Imdad	1104±10ABC	1233±28B	1132±26A	1107±16A	906±28AB
Mehran	962±13A	1036±49A	981±27A	984±23A	935±26AB
Abadgar	1134±97ABC	1094±49AB	973±46A	926±34A	870±7A ^a
Moomal	1011±26A	1202±11B	1078±64A	1014±19A	994±79AB
Anmol	1221±13BC	1215±11B	1165±19A	1126±25A	1088±11AB
SKD-1	1110±50ABC	1245±11B	1170±99A	1179±33A	1092±43AB
TJ-83	1252±62 C	1218±18B	1154±37A	1036±42A	1123±50B

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

results of present study revealed that the supplementation level of pentosan influences the PV of wheat flour. At 1-percent concentration, both types of pentosans exhibited a similar pattern (whether increase or decrease) on all cultivar flours except TD-1. However, the magnitude of influence was found to be different in each of the variety. Results also reflect that at 2% concentration levels, the WEP exhibited a negative impact on PV of all the cultivars (1.6–23.3% decrease in PV) whereas WUP was found to impart variable influence on PV in the tested varieties (Figure 1b and 2b).

Yin and Walker (1992) found a significant effect of pentosan on RVA peak viscosity of starch and reported that PV of starch decreases with the addition of water soluble pentosans. The results of Yin and Walker (1992) are not comparable to this study as they were related to a single commercial starch sample while a range of eight varieties were evaluated in the present study. The pasting properties of starch may not necessarily correspond to that of flour (Meredith and Pomeranz 1982; Lin and Czuchajowska 1997). In another study (Rao et al. 2007) reported that the peak viscosity of wheat flour increased with the addition of water-soluble non-starch polysaccharide obtained from other sources—rice and ragi. In the present study, the pentosans were isolated from wheat flour. Hence, the differences in results could be a result of different analytical technique; nature of sample; source and isolation procedure of pentosans; number of samples analyzed etc.

Time to reach peak viscosity

Time to reach Peak Viscosity (TPV) indirectly reflects the time required for cooking. The increase in time to reach peak viscosity indicates the utilization of more energy to gelatinize starch granules. This eventually results in an increase in the energy cost. It was found that flours of all varieties (except SKD-1) required more than 15 min to reach their maximum viscosity. However, flour of variety SKD-1 took least time span (13:50 min) to reach peak viscosity (Table 4). WEP and varietal difference had significant effect on TPV. Whereas, WUP caused negligible variation ($F=0.360$, $P=0.698$). Variety-by-WUP and variety-by-WEP interaction contributed significant variation in TPV.

A scrutiny of figure 1(c) reveals that at 1% level of addition of WEP caused inconsistent effect on TPV. However at 2% WEP addition, with the exception of SKD-1 all the varieties exhibited a decrease in TPV values.

Hot paste and cold paste viscosity

Hot paste viscosity is the viscosity measured after providing flour slurry a holding period of 10 min at 95 °C. Cold paste viscosity (CPV) is the viscosity measured after holding the slurry at 50 °C for 10 min. All cultivar flours were found to vary in their HPV (351–671BU) and CPV (865–1187BU)

Fig. 2 The magnitude of increase or decrease (in percentage) in pasting parameters of HWSW (hard white spring wheat) flours due to addition of water-unextractable pentosan ($n=4$)

Table 4 Time to reach peak viscosity (min) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	15.2±1.6AB	14.5±0.5A	15.2±1.3A	14.6±0.8AB	14.5±0.5AB
Imdad	15.6±0.5AB	16.1±0.4A	15.2±0.3A	15.6±0.1B	15.3±0.3B
Mehran	15.5±1.2AB	15.4±1.3A	14.2±1.1A	14.2±0.1A	14.2±0.1A
Abadgar	15.0±0.4AB	15.5±2.0A	15.4±0.7A	15.4±0.1B	14.5±0.5AB
Moomal	15.4±0.6AB	15.4±0.6A	15.5±0.5A	15.4±0.1B	15.3±0.1B
Anmol	16.3±0.1B	15.2±0.3A	15.6±0.3A	15.3±0.1B	15.1±0.5AB
SKD-1	13.5±0.8A	15.3±1.3A	15.6±0.7A	15.4±0.1B	15.1±0.2B
TJ-83	15.4±0.8AB	15.3±1.2A	15.3±1.2A	15.5±0.1B	15.0±0.6AB

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

values (Tables 5 and 6). The lowest value was exhibited by the flour of variety Mehran.

It is apparent that variety, WEP, WUP and variety-by-WEP interaction significantly influenced the HPV and CPV of HWSW flours (Table 1). However, WEP contributed much greater variation in HPV and CPV of HWSW flours when compared to variety and WUP. It was found that both fractions of pentosans exhibited different types of impacts on HPV and CPV. The WEP considerably reduced the HPV and CPV of all cultivar flours, whereas, WUP induced irregular changes in HPV and CPV values. This may be a result of hydrophilic nature of WEP that increases the rupturing tendency among starch granules during isothermal phase or under induced mechanical stress while they are suspended in flour. Moreover, WEP weakens the gelling tendency of wheat flour possibly by hindering the reassociation of amylose molecules while they aggregate on cooling. Rao et al. (2007) reported an increase in HPV and CPV

values when the water-soluble non-starch polysaccharides obtained from rice and ragi were added at 0.5% level to a wheat flour sample. This is in contrast to present study in which pentosans were isolated from a hard-type wheat flour and were substituted at 1% and 2% levels to eight different genotypes of HWSW. The differences in pentosan source; supplementation level; number and quality of wheat flour samples analyzed might be the possible reasons for contrary results.

As shown in figure 1(d), the magnitude of reduction in HPV at 1%WEP varied from variety to variety in the range of 15 and 66%. The highest reduction was observed in the variety TJ-83, followed by TD-1 (56%) and Abadgar (51%). At 2% supplementation level, the reduction (35%–74%) was found to have further increased with maximum decrease in variety TD-1.

It was also found that the magnitude of CPV reduction also varied among varieties upon the addition of same level of WEP (Figure 1e). At 1-percent supplementation level, the

Table 5 Hot paste viscosity (BU) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	550±12A	542±21AB	431±21A	242±38AB ^a	142±57A ^a
Imdad	616±31A	666±25BC	586±48A	372±26AB ^a	207±57A ^a
Mehran	351±14B	473±78A	315±38A	242±69AB ^a	165±54A ^a
Abadgar	612±51A	685±83 C	540±38A	302±59AB ^a	211±37A ^a
Moomal	510±63AB	672±21BC	525±28A	431±41B	330±19A ^a
Anmol	671±16A	732±62 C	606±29A	351±42AB ^a	238±32A ^a
SKD-1	549±1A	635±52BC	581±45A	342±47AB ^a	245±44A ^a
TJ-83	604±4A	621±64BC	587±46A	206±36A ^a	190±20A ^a

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

Table 6 Cold paste viscosity (BU) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	1054±63AB	1048±46AB	916±3AB	682±69AB ^a	426±61A ^a
Imdad	1190±33B	1227±18BC	1144±60B	913±55 C	665±60A ^a
Mehran	865±58A	982±34A	802±61A	661±32A	484±56A ^a
Abadgar	1152±58B	1261±38 C	1097±57B	840±15ABC ^a	666±63A ^a
Moomal	1048±60AB	1209±20BC	1040±29B	937±69 C	816±20A
Anmol	1187±42B	1213±59BC	1124±52B	891±1BC ^a	675±68A ^a
SKD-1	926±51A	1060±39AB	1036±52B	780±59ABC	614±46A ^a
TJ-83	1052±55AB	1085±7ABC	1025±10AB	638±56A ^a	524±64A ^a

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

percent reduction varied between 11 and 39%. The highest CPV reduction was found in variety TJ-83. At 2-percent level, further decrease (22–60%) was found in CPV of all varieties. At this concentration level, the maximum decrease was found in the CPV of variety TD-1 followed by TJ-83. The CPV reduction with increasing WEP concentration reflects a further weakening in the paste stability. It is evident that the increase in WEP molecules may have more strongly hindered the reassociation of amylose molecules upon cooling and resulted in further reduction in CPV.

Breakdown viscosity

Breakdown viscosity (BD) is the measure of fragility of starch granules. The BD viscosities of flours varied insignificantly between 487 BU to 644 BU (Table 7). Singh et al. (2010) investigated the relationship between the BD viscosities of flours with the climatic conditions and found the decrease in breakdown viscosity in wheat cultivated under

rain-fed conditions. In the present study, the highest breakdown viscosity was found in the flour of variety TJ-83 followed by Mehran, SKD-1 and Anmol (Table 7). It is evident that the variety and WEP contributed significant variation in BD viscosity of HWSW flours. WUP, variety-by-WEP and variety-by-WUP interaction did not cause significant variation in BD viscosity (Table 1).

The influence of WEP was found consistently positive on BD of all the cultivar flours. Whereas, the effect of WUP on BD values was found to be inconsistent and possibly regulated by the concentration of WUP and genotype of wheat flour. There is every likelihood that the presence of WEP being hydrophilic exerts more stress on wheat starch granules that may result in rapid decline in viscosity of wheat flour suspensions. Sasaki et al. (2000) studied the influence of non-starch polysaccharide on gelatinization properties of wheat starch. They found higher breakdown values in non-starch polysaccharide added starch as compared to starch without such addition.

Table 7 Breakdown viscosity (BU) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	504±34A	559±22BC	612±62A	759±56AB ^a	820±54BCD ^a
Imdad	487±29A	563±47BC	546±73A	735±11AB ^a	698±51AB ^a
Mehran	610±18A	561±31BC	665±60A	742±54AB	770±50ABC
Abadgar	522±67A	410±33A	433±66A	624±93AB	660±43A
Moomal	501±48A	528±27BC	554±64A	583±10A	664±30A
Anmol	556±19A	481±48AB	557±50A	774±17AB ^a	850±44CD ^a
SKD-1	560±52A	609±59 C	588±57A	838±20B ^a	847±1CD ^a
TJ-83	644±53A	598±47 C	567±13A	830±16B	932±31D ^a

Values are Means±SD ($n=4$)

Different capital letters within column are significantly different at $P<0.05$

^a means significant difference from control at $P<0.05$

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

Despite that WEP effect on BD viscosity was found to be positive at both the levels of fortification, but the magnitude of effect was found to be inconsistent and possibly dependent on the concentration of WEP and genotype of wheat. At 1% concentration, the increase in BD values varied between 16% and 51% higher to the BD values of control flours (Figure 1f). The BD values exhibited a further increase and reached up to 63% when WEP supplementation was increased to 2% level.

The WUP at both levels of concentrations, exhibited similar type of influence (whether positive or negative) on all the varieties except Mehran (Figure 2f).

Setback viscosity

Setback viscosity is the measure of retrogradation tendency of starch granules (Abd Karim et al. 2000). After gelatinization, the leached out linear amylose chains starts reassociating with each other on cooling that subsequently results in increased viscosity of flour pastes. Retrogradation of starch is a good indicator of bread staling. The setback value of all cultivar flours (except Imdad) was found to range between 459 and 571BU. The SB viscosity of Imdad had SB viscosity (641BU) was found exceptionally higher than all the other varieties (Table 8).

Variety, WEP and WUP contributed significant variation in SB viscosity. But WEP caused much greater effect on setback when compared to variety and WUP (Table 1). Figure 1(g) and 2(g) clearly indicates that both type of pentosan influences differently on setback values of each cultivar flour. WEP reduced the setback viscosity whereas WUP was found to have increased the setback value of flour. The reduction in setback viscosities of flours indicates that WEP possess the ability to reduce the staling tendency of wheat flours. WEP being hydrophilic in nature possibly binds the water molecules that interacts with solubilized amylose chains to curtail the reassociative tendency of amylose chains. Based on the

low firmness values, it has been found in previous reports that pentosan reduce the starch retrogradation and bread staling (Kim and D'Appolonia 1977a; b); Jankiewicz and Michniewicz 1987). Schiraldi et al. (1996) explored the role of water-soluble pentosans besides other ingredients in bread staling through DSC and confirmed an indirect anti-staling role of soluble pentosans. Gul and Dizlek (2008) also reported that pentosan decreases the staling rate of bread by retarding the starch retrogradation.

The setback value of flours was found to have reduction in a non-linear fashion with the increasing concentration of WEP. At 1% concentration level, the reduction in setback value varied between 2 and 14% (Figure 1g). The degree of reduction also increased with increasing pentosan concentration (2% level) and the setback values reduced upto 44%. It was also found that the WUP insignificantly increased the setback viscosities of all varieties except Imdad (Figure 2g). Only 5% reduction in setback value of variety Imdad was found at the addition of 2% WUP substitution level. The WUP possibly facilitated the reassociation of amylose chains upon cooling after gelatinization that subsequently increased the viscosity of flour pastes.

Conclusion

The results have indicated that water-extractable and water-unextractable pentosans exhibited different impacts on various pasting parameters between varieties as well as within the variety. The effects of WEP were more pronounced as it caused significant variation in all pasting properties except PT. WEP induced considerable reductions in hot paste, cold paste and setback viscosities and increased the breakdown viscosities of all cultivar flours. The magnitude of increase or decrease however varied from cultivar to cultivar. WUP did induce significant variation in viscosity attributes (except BD)

Table 8 Setback viscosity (BU) of control and pentosan substituted flours obtained from different HWSW varieties

Sample	Control	1% WUP	2% WUP	1% WEP	2% WEP
TD-1	459±15A	615±13AB	537±62A	438±68A	258±15A ^a
Imdad	641±40B	657±32B	610±61A	553±23A	387±79A ^a
Mehran	492±35A	580±43AB	509±34A	438±17A	286±16A
Abadgar	571±20AB	650±62B	622±2A	567±68A	397±19A ^a
Moomal	571±11AB	609±54AB	578±11A	517±62A	454±37A
Anmol	564±4AB	588±22AB	578±55A	551±13A	423±36A
SKD-1	498±36A	543±6A	569±62A	464±35A	336±38A
TJ-83	508±10A	568±53AB	560±25A	481±4A	343±23A ^a

Values are Means±SD (*n*=4)

Different capital letters within column are significantly different at *P*<0.05

^a means significant difference from control at *P*<0.05

HWSW hard white spring wheat; WEP water-extractable pentosan; WUP water-unextractable pentosan

but to a lesser degree comparing to WEP. The variable type of effect of WUP did not reveal meaningful findings. Both the pentosan fractions were found to have produced inconclusive and inconsistent responses on PV and TPV, whereas, WEP marginally increased the PT of almost all cultivar flours.

It is most likely that substitution of WEP in flour may have significantly reduced retrogradation process of starch granules. The process is known to cause syneresis in food gels intended for refrigerated storage and could improve their stability and also prevent staling of bread.

References

- AACC (2000) Approved methods, 10th edn. American Association of Cereal Chemists Inc, Minnesota
- Abd Karim A, Norziah MH, Seow CC (2000) Methods for the study of starch retrogradation. *Food Chem* 71:9–36
- Armero E, Collar C (1998) Crumb firming kinetics of wheat breads with antistaling additives. *J Cereal Sci* 28:165–174
- Azizi MH, Rao GV (2004) Effect of surfactant gel and gum combinations on dough rheological characteristics and quality of bread. *J Food Quality* 27:320–336
- Benamrouche S, Cronier D, Debeire P, Chabbert BA (2002) A chemical and histological study on the effect of (1→4)- β -endo-xylanase treatment on wheat bran. *J Cereal Sci* 36:253–260
- Bhattacharya M, Jafari-Shabestari J, Qualset CO, Corke H (1997) Diversity of starch pasting properties in Iranian hexaploid wheat landraces. *Cereal Chem* 74(4):417–423
- Biliaderis CG, Izydorczyk MS, Rattan O (1995) Effect of arabinoxylans on bread-making quality of wheat flours. *Food Chem* 5:165–171
- Buksa K, Nowotna A, Praznik W, Gambus H, Ziobro R, Krawontka J (2010) The role of pentosans and starch in baking of wholemeal rye bread. *Food Res Int* 43(8):2045–2051
- Cleemput G, Van Oort M, Hessing M, Bergmans MEF, Gruppen H, Grobet PJ, Delcour JA (1995) Variation in the degree of D-xylose substitution in Arabinoxylan extracted from a European wheat flour. *J Cereal Sci* 22:73–84
- Collar C (2003) Significance of viscosity profile of pasted and gelled formulated wheat doughs on bread staling. *Eur Food Res Technol* 216:505–513
- Davidou S, Le Meste M, Debever E, Bekaert D (1996) A contribution to the study of staling of white bread: effect of water and hydrocolloid. *Food Hydrocolloid* 10:375–383
- Devesa A, Martinez-Anaya MA (2003) Influence of pentosans on texture of starch gels during storage and effects after enzyme treatment. *Eur Food Res Technol* 216:323–330
- Dickinson E (2003) Hydrocolloids at interfaces and the influence on the properties of dispersed systems. *Food Hydrocolloid* 17:25–39
- El-Wakeil FA, Abdel-Akher M, Awad AA, Morad MM (1976) Wheat proteins and pentosans, their isolation and their effect on the rheological properties of dough and bread. I. identification of wheat flour pentosans and their effect on dough rheology. *Deut Lebensm-Rundsch* 71(9):317–320
- Gavilighi HA, Azizi MH, Barzegar M, Ameri MA (2006) Effect of selected hydrocolloids on bread staling as evaluated by DSC and XRD. *J Food Technol* 4(3):185–188
- Gul H, Dizlek H (2008) Effects of pentosans on dough and bread quality. *Gida Dergisi* 33(6):291–295
- Hong BH, Rubenthaler GL, Allan RE (1989) Wheat pentosans. I. Cultivar variation and relationship to kernel hardness. *Cereal Chem* 66:369–373
- Jankiewicz M, Michniewicz J (1987) The effect of soluble pentosans isolated from rye grain on staling of bread. *Food Chem* 25:241–249
- Juszczak L, Witczak M, Fortuna T, Babachowicz A (2004) Effect of some hydrocolloid on the rheological properties of rye starch. *Int J Food Sci Tech* 10(2):125–131
- Kim SK, D'Appolonia BL (1977a) Bread staling studies. III. Effect of pentosans on dough, bread and bread staling rate. *Cereal Chem* 54:225–229
- Kim SK, D'Appolonia BL (1977b) Effect of pentosans on the retrogradation of wheat starch gels. *Cereal Chem* 54:150–160
- Lee MH, Baek MH, Cha Park DSHJ, Lim ST (2002) Freeze-thaw stabilization of sweet potato starch gel by polysaccharide gums. *Food Hydrocolloid* 16:345–352
- Lin P-Y, Czuchajowska Z (1997) Starch properties and stability of club and soft whit winter wheats from the pacific northwest of the United States. *Cereal Chem* 74(5):639–646
- Lutfi Z, Hasnain A (2009) Effect of different hydrocolloids on pasting behavior of native water chestnut (*Trapa bispinosa*) starch. *Agric Conspec Sci* 74(2):111–114
- Martin ML, Hoseney RC (1991) A mechanism of bread firming. II. Role of starch hydrolyzing enzymes. *Cereal Chem* 68:503–508
- Massaux C, Sindic M, Lenartz J, Sinnaeve G, Bodson B, Falisse A, Dardenne P, Deroanne C (2008) Variation in physicochemical and functional properties of starches extracted from European soft wheat (*Triticum aestivum* L.): the importance to preserve the varietal identity. *Carbohydr Polym* 71(1):32–41
- Meredith P, Pomeranz Y (1982) Inherent amylograph pasting ability of U.S. wheat flours and starches. *Cereal Chem* 59:355–360
- Murty VLN, Chhouchury D, Bagchi P (1962) Physicochemical studies of water chestnut starch (*Trapa bispinosa* Roxb.). *Can J Chem* 40:2260–2266
- Nagao S (1995) The science of wheat, 1st edn. Asakura Syoten, Tokyo
- Ozkoc SE, Sumnu G, Sahin S, Turabi E (2009) Investigation of physicochemical properties of breads baked in microwave and infrared-microwave combination ovens during storage. *Eur Food Res Technol* 217:8–19
- Ragaei S, Abdel-Aal ESM (2006) Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chem* 95(1):9–18
- Rao RSP, Manohar RS, Muralikrishna G (2007) Functional properties of water-soluble non-starch polysaccharides from rice and ragi: effect on dough characteristics and baking quality. *Food Sci Technol-LEB* 40(10):1678–1686
- Rosell CM, Rojas JA, Bendito de Barber C (2001) Combined effect of different antistaling agents on the pasting properties of wheat flour. *Eur Food Res Technol* 212:473–476
- Santos D, Gama A, Da Silva JL (2002) A rheological study of wheat starch-water soluble pentosan mixtures under hydrothermal gelling conditions. *J Food Sci* 67:3372–3380
- Sasaki T, Yasui T, Matsuki J (2000) Influence of non-starch polysaccharides isolated from wheat flour on the gelatinization and gelation of wheat starches. *Food Hydrocolloid* 14(4):295–303
- Saulnier L, Peneau N, Thibault JF (1995) Variability in grain extract viscosity and water-soluble arabinoxylan content in wheat. *J Cereal Sci* 22:259–264
- Schiraldi A, Piazza L, Brenna O, Vittadini E (1996) Structure and properties of bread dough and crumb calorimetric, rheological and mechanical investigations on the effects produced by hydrocolloids, pentosans and soluble proteins. *J Therm Anal Calorim* 47(5):1339–1360
- Scientific N (1995) Operational manual for the series 4 Rapid Visco analyzer. Newport Scientific Pvt. Ltd., Australia
- Singh S, Gupta AK, Gupta SK, Kaur N (2010) Effect of sowing time on protein quality and starch pasting characteristics in wheat (*Triticum aestivum* L.) genotypes grown under irrigated and rain-fed conditions. *Food Chem* 122(3):559–565

- Singh S, Singh N, MacRitchie F (2011) Relationship of polymeric proteins with pasting, gel dynamic and dough empirical-rheology in different Indian wheat varieties. *Food Hydrocolloid* 25(1):19–24
- Tao RP, Pomeranz Y (1967) Water-soluble Pentosans in flours varying widely in bread-making potential. *J Food Sci* 32(2):162–168
- Toshiki I, Paula AS (1992) Firming of bread crumb with cross-linked waxy barley starch substituted for wheat starch. *Cereal Chem* 69(3):321–325
- Wang M-W, Hamer RJ, Van Vliet T, Gruppen H, Merseille JP, Weegels PL (2003) Effects of water unextractable solids on gluten formation and properties: mechanistic considerations. *J Cereal Sci* 37:55–64
- Wootton M, Bamunuarachchi A (1980) Application of differential scanning calorimetry to starch gelatinization. III. Effect of sucrose and sodium chloride. *Staerke* 32:126
- Yin Y, Walker CE (1992) Pentosans from gluten washing wastewater: isolation, characterizations and role in baking. *Cereal Chem* 69(6):592–596
- Zelevnak KJ, Hoseney RC (1986) The role of water in the retrogradation of wheat starch gels and bread crumb. *Cereal Chem* 63:407–411