Staling and Texture of Bread Prepared from New Japanese Bread Wheat Varieties with Slightly Low-Amylose Starch

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The bread-making quality of flour made from two new Japanese bread wheat varieties, Haruyokoi and Kitanokaori, was evaluated, and the staling and texture of bread made from these flour types were compared with those of flour made from representative bread wheat classes, No.1 Canada western red spring (1CW) and Hard red winter (HRW). There was not a large difference in the bread-making quality of the above four flour types, except that the water absorption of the Kitanokaori flour was high, and the gassing power of the dough was low. Bread made from the two above-mentioned Japanese flour types (two new bread varieties) were quite soft after baking, and the degree of staling (changes in hardness) were somewhat lower than those made with 1CW and HRW. The cohesiveness of the two new bread varieties, i. e., the index of bread elasticity, showed higher values than those of others up to 1 day of storage. From the analysis of bread staling and the retrogradation of starch in bread, it was proven that the staling rate and starch retrogradation rate constants of the two new bread varieties were approximately the same as those of bread made from 1CW and HRW but the starch retrogradation of the new bread varieties was somewhat slower than that of the others up to 2 days of storage. The analysis of hardness and cohesiveness of the flour and starch gel from the above four flour types indicated that the softness and high cohesiveness of the two new bread varieties after baking were, to a great extent, the result of the soft texture of starch gel in these varieties. These results showed that the somewhat slow staling, especially staling in the early stage, and the extreme softness after baking of the two new bread varieties were attributed to the soft texture and low retrogradation of starch gel in the bread, which was related to the lower amylose content of these new flour types.

Keywords: bread, staling, texture, wheat starch, retrogradation

Introduction

In recent years, the breeding of high-quality hard wheat with high protein content, used to make bread and Chinese yellow alkaline noodles, which are in significant demand, has been the focus of many breeding programs in Japan, especially in Hokkaido. As a result, the spring wheat, Haruyokoi, and the winter wheat, Kitanokaori, were successively raised. The expansion of the cultivation area used for these wheat cultivars is smoothly advancing, since the agricultural characteristics and baking quality of flour made from these cultivars are significantly better than those of conventional Japanese bread wheat, Haruyutaka (Yamauchi *et al.*, 2001b). At present, flour made from the two above-mentioned new Japanese bread wheat varieties are being used to make some of the

wheat bread for the domestic market, and the bread is receiving significant customer approval. The main reason for the good quality of these bread varieties is estimated to be that these new varieties are Wx-B1 null, a factor that results in slightly low amylose content. There have also been some reports on the influence of amylose content on the staling and texture of bread (Bhattacharya *et al.*, 2002; Lee *et al.*, 2001). It has also been reported that bread from double null and Wx-B1 null wheat flour types are soft and show slow staling (Baik *et al.*, 2003; Martin *et al.*, 2004), and that the staling of bread made from blends to which partially waxy starch and flour are added is lower (Ghiasi *et al.*, 1984; Morita *et al.*, 1998; Morita *et al.*, 2002; Takata *et al.*, 2005).

However, no detailed studies of the bread-making quality of the two new flour types and the texture of the resulting bread, especially, the staling of the bread, have been carried out to date. Therefore, differences in the

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baking quality and staling of bread between two new flour types and representative bread flour types, 1CW and HRW, remain to be clarified. Thus, in this study, the bread-making quality of two new flour types was evaluated and compared with those of 1CW and HRW, and the staling characteristics of the bread made from the above four flour types were analyzed in detail using kinetic analysis (Yamauchi *et al.*, 1993; Yamauchi *et al.*, 2001a). Subsequently, the retrogradation of the starch in the bread and the texture of the starch gel, among other features, were examined to clarify the effect of the flour starch properties on the staling and physical properties of the above bread varieties. In this study, staling is expressed by the change in bread hardness during storage, and the staling rate is discussed in relation to the staling rate constant.

Materials and Methods

Flour and starch samples Two bread wheat classes, 1CW and HRW, and two varieties of Japanese domestic bread wheat, Haruyokoi and Kitanokaori, were used in this study. These domestic varieties have recently been released, and Wx-B1 protein deficiency was identified using the method of Nakamura *et al.* (1993). The bread-making quality of these flour types was demonstrated to be better than that of the conventional domestic bread wheat variety, Haruyutaka. The commercial flour types, 1CW, HRW, and Kitanokaori were purchased from Ebetsu Flour Milling Co., Ltd. (Ebetsu, Japan), and the commercial flour, Haruyokoi was bought from Yokoyama Flour Milling Co., Ltd. (Sapporo, Japan). To prevent quality degradation of the flour types, they were preserved at 5°C and used after returning to room temperature under controlled conditions in which the flours did not absorb moisture. Starch preparation from the flour followed the traditional method of Mangalika *et al.* (2003) and moisture content was estimated by oven-drying a 1 g sample at 115°C for 3 h.

Flour and starch properties The amylose content per 100 mg of starch granules was colorimetrically determined using an Auto Analyzer System II (Bran+Lubbe Co., Ltd., Norderstedt, Germany), as described by Miura and Tanii (1994). In this system, estimates of the amylose content were compared to the amylose content of commercial wheat starch standards in which the amylose content has been proven. The protein content of the flour types was measured using a near-infrared reflectance instrument (Inframatic 8120, PerCon Co., Hamburg, Germany). The ash content of the flour types was measured according to the method of the American Association of Cereal Chemist (AACC) (1991a). The pasting properties of the flour types were measured using a Rapid Visco Analyser (RVA) (RVA-4, Newport Scientific Pty. Ltd., Warriewood, Australia). Flour (2.82 g, dwb) was mixed with 25 ml of distilled water to prepare a 10.0% flour suspension (w/w). The suspension was held for 1 min at 50°C, heated to 95°C at 12.6°C/min, kept at 95°C for 2.5 min, then cooled to 50°C at 11.8°C/min, and finally kept at 50°C for 2 min. The peak viscosity, breakdown (difference between peak and minimum viscosity), setback viscosity (difference between the final and minimum viscosity), and

pasting temperature were recorded from the RVA curve. All values for viscosity parameters were expressed in RVA units (RVU).

Bread-making and bread evaluation The bread-making tests were conducted using the no-time method, following the standard white bread formulation: 200 g of flour, 10 g of sugar, 10 g of shortening (Snowlight, Kaneka Corp., Osaka, Japan), 4 g of salt, 4 g of yeast (Regular yeast, Nippon Beet Sugar Mfg Co., Ltd, Tokyo, Japan), 20 mg of ascorbic acid, and a suitable quantity of water (Yamauchi *et al.*, 2001a). The optimal water absorption of the tests was estimated using a Farinograph at 500 BU, according to the method used by the AACC (1991b). The dough was mixed to just beyond peak development, as indicated by the current curve of the mixing motor, and then divided into two 100 g pieces, rounded, and allowed to rest for 20 min in a fermentation cabinet at 30°C. The pieces were panned and proofed at 38°C and 85% humidity for 70 min and then baked at 200°C for 25 min. A slice of each bread variety was photocopied using a copy machine to evaluate the crumb grain. The specific loaf volume (SLV) after cooling at room temperature for 1 hr after baking was measured by the rapeseed-replacement method. The moisture content of the bread was measured using bread-crumbs dried for 3 h at 115°C.

Dough properties The vacuum expansion of the dough (gas retention) was measured using the method of Yamauchi *et al.* (2000), which requires 20 g of dough after proofing. The gas retention was evaluated by measuring the maximum volume of the dough in a cylinder under low pressure. Total gassing power at 30°C for 1, 2, and 3 h was measured with a Fermograph II (ATTO Co., Ltd., Tokyo, Japan) with 20 g of dough after bench time.

Bread staling and starch retrogradation The staling characteristics of the bread were evaluated by measuring the hardness and cohesiveness of crumbs using the method developed by Yamauchi *et al.* (2001a). Immediately after baking, the loaves were cut into 2 cm-thick slices, and a square (3 cm × 3 cm) of crumbs was cut from the center of the slice using an ultrasonic cutter (model USC-3305, Yamaden Co., Ltd., Tokyo, Japan). The cut crumbs were stored at 20°C for 5 days in an aluminum laminate bag to prevent water evaporation. The hardness and cohesiveness of six crumbs were measured by twice compressing the crumbs from a 2 cm to a 1 cm thickness at approximately daily intervals. The measurement was begun at the time the crumbs were cut. The limiting value of crumb hardness (the highest possible value) was determined from the hardness of the cut crumbs stored at 4.7°C for 10 days, as reported by Axford *et al.* (1968). The staling rate constant (SRC) of the bread and the retrogradation rate constant (RRC) of starch in the bread were obtained using the method developed by Yamauchi *et al.* (2001a). The former constant was determined using the equation: $\ln \{(H_L - H_0)/(H_L - H_t)\} = kt$. H_0 and H_t are the hardness of the cut crumbs at time zero and t , respectively. H_L , k , and t are the limiting value of the hardness, the SRC, and the storage time, respectively. The latter constant (RRC) was decided by substituting the

Table 1. Amylose content of starches from flours, protein and ash contents, and pasting properties of flours^a.

Flour Samples	Wx protein ^b			Amylose content (%)	Protein content (%)	Ash content (%)	Peak Viscosity (RVU)	Breakdown (RVU)	Setback (RVU)	Pasting temperature(°C)
	A1	B1	D1							
1CW ^c	-----			28.2b	11.4a	0.40b	197ab	70b	98b	66.5a
HRW ^d	-----			28.4a	10.6c	0.37c	167c	59c	107a	68.2a
Haruyokoi	+	-	+	26.5c	11.0b	0.41b	204a	93a	83c	67.5a
Kitanokaori	+	-	+	26.6c	10.1d	0.48a	179bc	75b	87c	66.9a

^aValues followed by the same letter in the column are not significantly different ($p < 0.05$, $n = 2$).^bUnknown (-----), present (+), and absent (-).^c1CW: NO.1 Canada western red spring.^dHRW: Hard red winter.**Table 2.** Results of bread making quality of flours^a.

Flour Samples	Water absorption (%)	Gas retention (ml)	Gassing power (ml)			SLV ^b (ml/g)	Moisture content of bread (%)
			1h	2h	3h		
1CW ^c	67.0	125a	33.2a	74.2b	109.7b	5.47a	43.8b
HRW ^d	65.0	123a	32.9ab	74.4b	108.6b	5.39a	43.5c
Haruyokoi	66.5	126a	33.4a	76.1a	113.7a	5.44a	43.4c
Kitanokaori	72.0	125a	32.6b	70.7c	102.7c	5.47a	45.6a

^aValues followed by the same letter in the column are not significantly different ($p < 0.05$, gas retention and gassing power : $n = 2$, others : $n = 3$).^bSLV: Specific loaf volume.^c1CW: NO.1 Canada western red spring.^dHRW: Hard red winter.

amylopectin retrogradation enthalpy (ΔH), described below, with the hardness values on the above equation. The ΔH for bread determined by differential scanning calorimetry (DSC) and the X-ray diffraction patterns of the bread varieties during storage were measured using dehydrated crumb samples, as reported by Yamauchi *et al.* (1992). The ΔH of a dehydrated sample (50 mg) containing distilled water (150 mg) was measured using a micro DSCIII (Setaram, Caluire, France) programmed at a heating rate of 1°C/min from 5 to 110°C. X-ray diffraction patterns were taken with an X-ray diffractometer (Rint 2100, Rigaku, Tokyo, Japan) under the following conditions: target, Cu; voltage, 40 kV; current, 40 mA; step width, 0.02°; emission slit, 1/2°; light reception slit, 0.3 mm. The dehydrated samples were conditioned at 100% relative humidity for three days before the X-ray diffraction patterns were obtained.

Physical properties of the flour and starch gels The flour and starch gels were prepared as follows. Flour and starch gelatinization was achieved in an RVA. The RVA conditions were equivalent to those described above except that cooling was stopped at 70°C. The obtained 6 g of paste was put into a 50 ml plastic tube with a flat bottom. The tube was centrifuged at 3000 rpm for 5 min in order to remove bubbles from the paste and obtain cylinders of gel of 2.5 cm diameter and 1 cm height. Afterwards, the tube was kept in a water bath at 20°C for 2 hrs to completely change the paste to a gel. A compression test of the flour and starch gels was also performed with a REONER (model RE-33005, YAMADEN Co., Ltd., Tokyo, Japan). The hardness and cohesiveness of the flour and starch gels

were measured by twice compressing the gels from 1 cm to 0.5 cm thickness using a circular plunger (Type No. 3, YAMADEN Co., Ltd., Tokyo, Japan) at a speed of 1 mm/s. Maximum compressing stress (hardness) and cohesiveness were determined from the force-deformation curve by compression.

Statistical analysis Measurements of the amylose, protein, ash, RVA, gas retention, and gassing power were made in duplicate. SLV and moisture were measured three times. The hardness and cohesiveness of the crumbs were measured six times. Measurements of the DSC and flour and starch gel texture were performed four and three times, respectively. All data in Tables 1 to 4, (excluding water absorption during bread-making, SRC, and RRC) and all data in Figs. 2 and 3 are expressed as mean, and mean $\pm$ standard deviation, respectively, and the significance of the difference between each variable in Tables 1, 2, and 4 (excluding water absorption during bread-making) was evaluated by analysis of variance using Duncan's multiple range test.

Results

Amylose content of starch and properties of flour types The amylose content of the starch types and the properties of the flour types are shown in Table 1. The amylose content of the starch of HRW was the highest, and the value of 1CW was slightly lower. On the other hand, those of the two new wheat varieties with Wx-B1 protein deficiency showed a significantly lower amylose content (about 2%) than both 1CW and HRW. The protein content varied among the four flour samples, and the

Table 3. Staling and retrogradation rate constants, $H_L-H_0^a$, and $\Delta H_L-\Delta H_0^b$ of four breads during storage.

Flour Samples	SRC ^c (h ⁻¹ ×10 ⁻²)	RRC ^d (h ⁻¹ ×10 ⁻²)	$H_L-H_0^a$ (N/m ² ×10 ³)	$\Delta H_L-\Delta H_0^b$ (J/g)
1CW ^e	1.30	1.05	6.53	4.35
HRW ^f	1.39	1.10	6.85	4.63
Haruyokoi	1.35	1.29	6.49	4.28
Kitanokaori	1.18	1.05	5.94	4.08

^a H_L-H_0 : Difference between H_L and H_0 .^b $\Delta H_L-\Delta H_0$: Difference between ΔH_L and ΔH_0 .^cSRC: Staling rate constant. SRC was determined from data of bread's hardness shown in Fig.2.^dRRC: Retrogradation rate constant. RRC was determined from data of ΔH shown in Fig.3.^e1CW: NO.1 Canada western red spring.^fHRW: Hard red winter.**Table 4.** Hardness and cohesiveness of breads just after baking and, flour and starch gels^a.

Flour Samples	Bread		Flour gel		Starch gel	
	Hardness (N/m ² ×10 ³)	Cohesiveness (-)	Hardness (N/m ² ×10 ³)	Cohesiveness (-)	Hardness (N/m ² ×10 ³)	Cohesiveness (-)
1CW ^b	1.68b	0.815b	5.90b	0.683b	1.82b	0.647b
HRW ^c	1.99a	0.799c	6.79a	0.585c	2.37a	0.463c
Haruyokoi	1.13d	0.828a	4.97c	0.768a	1.36d	0.718a
Kitanokaori	1.44c	0.825a	5.05c	0.667b	1.70c	0.720a

^aValues followed by the same letter in the column are not significantly different (p<0.05, bread : n=2, gels : n=3).^b1CW: NO.1 Canada western red spring.^cHRW: Hard red winter.

value for Kitanokaori was somewhat lower than those of the others. The ash content varied considerably among the four flour types. With regard to the RVA pasting properties, the peak viscosity of the Haruyokoi flour showed the highest value, followed by 1CW and Kitanokaori, and HRW had the lowest value. With reference to breakdown, the Haruyokoi flour had the highest value, followed by Kitanokaori and 1CW, and HRW again had the lowest value, indicating a basic relationship between high breakdown and low amylose content. On the contrary, the setback values basically decreased when the amylose content was lower. The gelatinizing temperature of the flour types was almost the same value, except that the value of HRW was slightly higher.

Dough properties and bread-making qualities of the flour types The results of the dough properties and bread-making qualities of the four flour types are shown in Table 2 and Fig.1. The water absorption during bread-making was quite similar for the four flour types, except that Kitanokaori had a very high value. No significant difference was observed in the gas retention values of any of the dough types. The gassing power of Haruyokoi after fermenting for 1 h was higher than those of 1CW and HRW, and that of Kitanokaori was significantly low compared with the others. There was no significant difference in the SLV of bread from the four flour types. Though the crumb grain of Kitanokaori bread was somewhat yellow, the appearance and crumb grain of the four bread varieties was not very different. Regarding the moisture content of the bread, the value for Kitanokaori

bread was considerably higher than those of the others, reflecting the high water absorption of Kitanokaori flour. The above results showed that the bread-making qualities of these flour types, including the SLV, appearance, and crumb grain, was similar, except that the dough properties, such as water absorption during baking and gassing power, were somewhat different among the four flour types.

Staling and cohesiveness of bread and retrogradation of starch in bread As shown in Fig. 2, bread made from the two new flour types were much softer than those of 1CW and HRW up to 2 days, and the staling of the former bread varieties, especially that of Kitanokaori, was much slower than that of the latter varieties. The cohesiveness of the new bread varieties showed somewhat high values in comparison to those made from 1 CW and HRW up to 1 day, and then the bread made from Kitanokaori and 1CW had higher cohesiveness values than those made from Haruyokoi and HRW. These results indicate that bread made from Haruyokoi and Kitanokaori have higher recovery against compression during early storage than those made from 1CW and HRW. As shown in Fig. 3, the changes in ΔH during storage, measured by the DSC, as well as the index of starch retrogradation in bread, were almost the same among all bread varieties. However, the exception was that the change observed in Kitanokaori bread during storage was somewhat smaller compared with those of the others, and the changes observed in bread made from 1CW and HRW, especially the latter, during early storage were rather large. The starch retro-

Fig. 1. Photocopy of crumb grain of bread made from four flour types.

^a1CW: NO.1 Canada western red spring. ^bHRW: Hard red winter.

Fig. 2. Changes in hardness and cohesiveness of flour bread during storage.

The vertical bar represents the standard deviation for each value. ○: NO. 1 Canada western red spring (ICW), △: Hard red winter (HRW), □: Haruyokoi, ◇: Kitanokaori.

Fig. 3. Changes in the amylopectin retrogradation enthalpy of flour bread during storage.

The vertical bar represents the standard deviation for each value. The symbols are shown in Fig. 2.

gradation changes observed by X-ray diffraction in bread during storage in Fig. 4 (which shows only data of HRW and Kitanokaori breads) also showed a similar tendency to those of the ΔH in Fig. 3. Namely, the tendency toward increasing changes in the representative peak (2θ , around 17°) of the starch retrogradation in the X-ray diffraction pattern among the four bread varieties during storage was nearly the same. But the exception was that the peak change of Kitanokaori bread during storage was somewhat smaller compared with those of the others, and

the peak change observed during the early stage in 1CW and HRW bread, especially the latter, were rather large. These results show that amylose content has a rather strong influence on bread staling and retrogradation of starch in bread during early storage. The SRC, RRC, difference between H_L and H_0 ($H_L - H_0$), and the difference between ΔH_L and ΔH_0 ($\Delta H_L - \Delta H_0$) are shown in Table 3. ΔH_L and ΔH_0 are the limiting values of ΔH and ΔH at time zero, respectively. Although somewhat of a difference was observed between the two kinds of constants, SRC and RRC, the two constants of all bread varieties showed similar values, except that the SRC of Kitanokaori and the RRC of Haruyokoi were respectively somewhat small and large in comparison to those of the others. As regards the $H_L - H_0$ and $\Delta H_L - \Delta H_0$ values, the HRW and Kitanokaori bread varieties respectively showed somewhat high and low values compared with those of the 1CW and Haruyokoi bread varieties. This suggests that the starch properties of the four flour types and the order of their amylose content are not directly related to the order of SRC, RRC, $H_L - H_0$, and $\Delta H_L - \Delta H_0$.

Hardness and cohesiveness of fresh bread, flour and starch gel The results of the measurements of hardness and cohesiveness of fresh bread and the flour and starch gel are shown in Table 4. The hardness of the bread types and gel was enhanced, and their cohesiveness showed a low value concurring with higher amylose content (shown in Table 1). The hardness and cohesiveness of bread made from the new flour types showed low and high

Fig. 4. Changes in the X-ray diffraction patterns of flour bread made from Hard red winter (HRW) and Kitanokaori during storage.

values compared with those of 1CW and HRW, respectively. These results indicate that, after baking, bread made from the two new wheat varieties described in this study, which have the *Wx-B1* null gene and are somewhat low in their amylose content, have a soft and high elastic texture. This texture is similar to that of cooked rice, which is greatly related to the somewhat lower amylose content of the new flour types.

Discussion

In this study, the bread-making quality, especially staling and texture, of bread made from two new bread wheat varieties was investigated. These new flour types have similar flour qualities compared with those of representative bread wheat brands, 1CW and HRW, yet their amylose content is somewhat lower. Since these new wheat varieties have the above characteristics, bread from these new flour types are said to be soft with a slow staling process. Therefore, a scientific investigation into the features of these new flour types was undertaken.

Amylose content The amylose content in the starch of the new flour types was clearly lower than that of the starch of 1CW and HRW, and the RVA characteristics showed a high breakdown and low setback (Table 1), typical features of a low amylose flour, as reported by Oda *et al.* (1980). These results indicate that the starch and flour properties, especially the amylose content, of these new flour types are different from those of 1CW and HRW.

Staling and texture The two new bread varieties, especially the Kitanokaori bread, remained quite soft from immediately after baking to the end of storage, and staling was significantly retarded in comparison to 1CW and HRW (Fig. 2). It was also evident that the retrogradation changes in the starch of the new bread varieties during early storage were somewhat lower than those of 1CW and HRW (Fig. 3, 4); however, all data of the new bread varieties shown in Table 3 are almost the same as those of 1CW and HRW, except for H_L-H_0 and $\Delta H_L-\Delta H_0$ in the bread made from HRW and Kitanokaori. On the other hand, Table 4 demonstrates that the hardness of the new bread varieties after baking was significantly smaller than that of 1CW and HRW. Furthermore, the order of the hardness and cohesiveness of the four bread varieties after baking is in agreement with that of the flour and

starch gels and, more importantly, the order of all hardness values corresponds to that of the amylose content in Table 1. These results suggest that the slow staling, particularly in the early stage, of the new bread varieties is caused by the somewhat slow starch retrogradation in the bread during that time, as well as the extreme softness of the starch gel in the breads, and, furthermore, the overall slow staling of the Kitanokaori bread is related to the overall slow starch retrogradation, small H_L-H_0 , and $\Delta H_L-\Delta H_0$. Baik *et al.* (2003) and Martin *et al.* (2004) reported that bread made from low amylose flour types are very soft, and that the staling of the breads is slow. The softness and slow staling of the new two bread varieties in comparison to those of 1CW and HRW correspond to the results of the above-mentioned reports. When conditions of moisture transport in bread and water evaporation from bread during storage are controlled for, as in this study, the main factors affecting bread staling were the SRC and H_L-H_0 . The chief control factor of SRC was the retrogradation rate of the starch in the bread (RRC), and the main factors controlling H_L-H_0 were the bread structure, including the SLV and crumb grain, and the starch gel texture in bread (Yamauchi *et al.*, 2001a). Based on the above findings, the following conclusions were drawn regarding the staling of the four bread varieties. All data for Kitanokaori bread were somewhat lower than those of others (Table 3), and only the H_L-H_0 and $\Delta H_L-\Delta H_0$ of the HRW bread were high compared with those of 1CW and Haruyokoi. There was not a large difference in bread structure, including the SLV and crumb grain, among the four bread varieties, as evident from Table 2 and Fig. 1. Therefore, the overall slow staling of the Kitanokaori bread and the rather fast staling of the HRW bread can be attributed, to some extent, to the small SRC and H_L-H_0 , and the large H_L-H_0 , respectively, which seem to be related to the starch gel texture in each bread. In addition, it seems that the small SRC and H_L-H_0 of the Kitanokaori bread are influenced by the lower amylose content and high moisture content of this bread, especially the latter, as described below.

Characteristics of Haruyokoi On the other hand, since all data of the 1CW and Haruyokoi bread in Table 3 are very similar, a clear difference between them can not be

identified using the SRC and $H_L - H_0$. However, it seems that, as described above, the comparably slow staling of the Haruyokoi bread, particularly in the early stage, is mainly due to its extremely soft texture and somewhat slow retrogradation of starch gel during the early stage, which is certainly related to the low amylose content of the Haruyokoi flour.

Effect of moisture content The difference in the staling of the two bread varieties from the new flour types, which do not differ greatly in both starch characteristics, such as their amylose content, and bread-making qualities, such as the SLV and crumb grain, is as follows. The moisture content of Kitanokaori bread was about 2% higher than that of Haruyokoi (Table 2), which was due to the high water absorption of Kitanokaori flour. Therefore, it seems that bread moisture content is one of the only factors affecting the staling of bread that differed largely between these two bread varieties. It has been reported that high-moisture bread and starch gel were responsible for slow staling and retrogradation, respectively (Piazza and Masi, 1995; Rogers *et al.*, 1988; Zeleznak and Hoseney, 1986). Therefore, it would seem that the most significant factor responsible for the slower staling of Kitanokaori bread compared to Haruyokoi bread was the high moisture content of the former bread and that, from the considerable difference in the SRC and $H_L - H_0$ between these bread varieties (Table 3), it seems that the moisture content of bread has a more significant influence on overall bread staling than the amylose content of flour.

Texture of the new two bread varieties The data, except for some data in Table 4, show that the hardness and cohesiveness of the new flour types were respectively lower and higher than those of ICW and HRW. These results indicate that the texture of starch gel in bread greatly influences the hardness and cohesiveness of bread after baking, and that these features of the new bread varieties after baking are chiefly due to the specific starch characteristics of these flour types, such as the relatively low amylose content. Furthermore, it seems that the soft texture of starch gel in the new bread varieties greatly influences the softness and slow starch retrogradation of the bread during the early stage. These results correspond to previous research, which demonstrated that bread made from low amylose flour and gel from low amylose starch are very soft, which contributes to slow staling and retrogradation (Baik *et al.*, 2003; Bhattacharya *et al.*, 2002; Hayakawa *et al.*, 1997; Lee *et al.*, 2001; Martin *et al.*, 2004).

Characteristics of the two new Japanese bread wheat varieties As shown above, it was proven that the new flour types prepared from the new, recently raised Japanese bread wheat varieties displayed almost the same bread-making and dough properties as the representative bread flour types, ICW and HRW. Furthermore, it was demonstrated that the staling of the resulting bread was somewhat slow, and, during the short storage time after baking, had good texture, as shown by their softness and high elasticity. These features of the new bread varieties were mainly caused by the specific starch characteristics

of the new flour types, such as the low amylose content.

In general, Japanese tend to prefer a soft and elastic bread texture similar to that of cooked rice. Therefore, many large Japanese baking companies have recently developed bread with such a texture by improving the baking method and composition. These bread varieties have now become major products for these companies. The bread made from the new flour types in this study have the texture that Japanese people generally prefer, regardless of baking method and composition. Therefore, if these new Japanese wheat varieties increase in popularity and stable production is established, bread with good texture made from these flour types are expected to be produced in abundance in the near future.

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