

## Technical paper

# The Staling and Texture of Bread Made Using the Yudane Dough Method

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White breads with Yudane dough (Yudane bread) were made from commercial hard flour by the no first fermentation method. Yudane dough was prepared by mixing boiling water and flour at a ratio of 1:1. The dough at 20 and 40% (w/w, flour base) was added to the total bread dough. In the Yudane bread making method, an extended final proof, lower dough gas retention and gassing power, as well as specific loaf volume were observed compared to conventional bread making (control) without Yudane dough. Also, the moisture content of the Yudane breads increased with increasing water absorption for bread making. The total and reducing saccharide and maltose contents in the water-soluble fraction of Yudane bread also increased with the volume of added Yudane dough. The Yudane breads were very soft just after baking, and the staling (temporal changes in hardness) and starch retrogradation of the breads were somewhat reduced compared to the control. Further, the breads showed generally larger cohesiveness, i.e., the index of bread elasticity. Kinetic analysis indicated reduced bread staling and starch retrogradation rates compared to control. The data showed that the slow staling and unique texture of the Yudane breads were mainly due to the high moisture content, saccharide contents, and flour amylases-modification of swollen and gelatinized starch in the breads, which was related to the higher water absorption and starch swelling and gelatinization levels of the added Yudane dough.

Keywords: bread, staling, texture, starch, retrogradation

## Introduction

Recently, Yudane bread, which has a slightly sweet taste and texture that is similar to cooked rice, has become very popular in Japan and new items produced using the Yudane dough bread making method (Yudane method) are continuously being developed. The market scale of this bread is now more than a hundred billion yen and sales are continuing to increase in Japan. In this regard, the Yudane method has recently become the main bread making process, especially in large-scale Japanese bakeries. However, the reasons why Japanese consumers prefer this bread and the basis for its increasing popularity are not yet sufficiently

clarified. On the other hand, the particular texture and starch properties of bread produced using this method were partially investigated in comparison with conventional bread produced by some of the large-scale Japanese bakeries (Shibata and Kato, 2001; Fukazawa and Kainuma, 2004). Naito *et al.* (2005) also reported that the microstructure and gluten network of this bread differed from those of conventional bread. In addition, it was reported that the bread contained higher levels of dextrin and reducing saccharides (Yamada *et al.*, 2004).

However, no detailed studies investigating bread quality and texture, in particular staling, have been carried out with respect to

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the Yudane method. Hence, differences in the quality and staling of Yudane bread and conventional bread (control) require elucidation. Thus, in this study, the bread making quality of the Yudane dough method was evaluated compared to the control, and bread staling and textural characteristics were analyzed in detail using kinetic analysis (Yamauchi *et al.*, 1993; Yamauchi *et al.*, 2001). Further, staling was expressed by the temporal change in bread hardness, and the staling rate was discussed in relation to the staling rate constant.

## Materials and Methods

**Flour sample** Commercial hard flour, Camellia, purchased from the Nisshin Flour Milling Co., Ltd. (Tokyo, Japan) was used in this study. The protein and ash contents were 12.2 and 0.39% (w/w, 13.5% moisture base), respectively. The protein content was measured using a near-infrared reflectance instrument (Inframatic 8120; PerCon Co., Hamburg, Germany). The ash content was measured according to the method of the American Association of Cereal Chemists (AACC) (1991a).

**Bread making** 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 wet 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.*, 1992; Yamauchi *et al.*, 2001). Yudane dough was prepared by mixing boiling water and flour at a ratio of 1:1 in a dough mixer and then stored in a polyethylene bag at 5°C for one day. The dough was added at 20 and 40% (w/w, flour base) to the total bread dough. The optimal water absorption of the tests was determined 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 100 g pieces, rounded, and allowed to rest for 20 min in a fermentation cabinet at 30°C and 75% humidity. The pieces were panned, proofed at 38°C and 85% humidity until the top height of the dough expanded to a height of 1 cm from the top of the pan and then baked at 200°C for 25 min.

**Dough properties and bread evaluation** The vacuum expansion of the dough (the gas retention of dough (GRD)) was measured using the method of Yamauchi *et al.* (2000), which requires 20 g of dough after proofing. The GRD was evaluated by measuring the maximum volume of the dough in a cylinder under low pressure. The total gassing power (GP) with 20 g of dough after bench time was measured at 30°C for 1, 2, and 3 hrs with a Fermograph II (ATTO Co., Ltd., Tokyo, Japan). The specific loaf volume (SLV) of bread cooled at room temperature for 1 hr after baking was measured by the rapeseed displacement method. Images of breads were obtained using a digital camera (model EX-H15; Casio Computer Co., Ltd., Tokyo, Japan). Individual slices from breads were photocopied using a copy machine to evaluate

the crumb grain. The moisture content of the breads was measured using bread crumbs dried for 3 hrs at 135°C. To determine the saccharide contents in the water soluble fraction of the breads, filtrates were prepared as follows in reference to the method of Yamada *et al.* (2004). Five grams of bread crumbs were suspended in 50 mL of distilled water and homogenized at 10000 rpm for 5 min at room temperature (Type-HA; Teraoka Co., Ltd., Tokyo, Japan). The homogenates were centrifuged at 10000 x g for 10 min at 20°C, and the resultant supernatants were filtered through a 0.45 µm omnipore membrane filter (Millipore Japan Co., Ltd., Tokyo, Japan). The total and reducing saccharide contents of the filtrate were analyzed by the phenol-sulfuric acid and dinitrosalicylic acid methods reported by Dubois *et al.* (1956) and Luchsinger and Cornesky (1962), respectively. The glucose, fructose, sucrose and maltose contents of the filtrate were also determined with the method reported by Yamauchi *et al.* (2004). Total and reducing saccharide contents were calculated based on the glucose concentration.

**Bread staling and starch retrogradation** The staling characteristics of breads were evaluated by measuring the hardness and cohesiveness of crumbs using the method developed by Yamauchi *et al.* (2001). The loaves cooled for 3 hrs at room temperature after baking were cut into 2 cm-thick slices, and a square (3 cm X 3 cm) of crumb was cut from the center of the slices using an ultrasonic cutter (model USC-3305; Yamaden Co., Ltd., Tokyo, Japan). The cut crumbs were stored at 20°C for about 4 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. Initial measurements were taken at the time of crumb cutting. The limiting value of crumb hardness (the highest possible value) was determined from the hardness of cut crumbs stored at 4.7°C for 10 days, as reported by Axford *et al.* (1968). The staling rate constant of breads (SRC) and the retrogradation rate constant of starch in breads (RRC) were obtained using the method developed by Yamauchi *et al.* (2001). The former constant was determined using the equation:  $\ln \{(H_t - H_0)/(H_L - H_t)\} = kt$ . Where  $H_0$  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 hardness, SRC, and storage time, respectively. The latter constant (RRC) was computed by substituting the enthalpy for melting of retrograded amylopectin ( $\Delta H$ ), described below, for the hardness value in the above equation. The  $\Delta H$  of breads during storage was determined by differential scanning calorimetry (DSC) and X-ray diffraction patterns of dehydrated crumb samples, as reported by Yamauchi *et al.* (1992). The  $\Delta H$  of a dehydrated sample (about 50 mg) containing distilled water (150 mg) was measured using a micro DSCIII (Setaram Co., Ltd., Caluire, France) programmed at a heating rate of 1°C/min from 30 to 110°C. The  $\Delta H$  was determined from the DSC-endothermic peak appearing around 50°C, which was derived from the melting of

retrograded amylopectin in bread. X-ray diffraction patterns were taken using an X-ray diffractometer (Rint 2100; Rigaku Co., Ltd., 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 prior to obtaining X-ray diffraction patterns.

**Statistical analysis** Measurements of protein and ash were performed in duplicate. The GRD, GP, final proofing time and SLV were measured in quadruplicate. The hardness and cohesiveness of the crumbs were measured sextuplicate. Measurements of moisture content, saccharides and DSC were performed in triplicate. All data in Tables 1, 2 and 3 except for the water absorption for bread-making, SRC, RRC,  $H_L-H_0$  and  $\Delta H_L-\Delta H_0$  and all data in Figs. 2 and 3 are shown as the mean  $\pm$  standard deviation (SD), respectively. Significant differences in the data presented in Tables 1, 2 and 3, except for the water absorption for bread-making, SRC, RRC,  $H_L-H_0$  and  $\Delta H_L-\Delta H_0$ , were evaluated using analysis of variance with Tukey's multiple range test of Excel statistical software 2012.

## Results and Discussion

**Dough properties and bread making quality using the Yudane method** The results of dough properties and bread making quality using the Yudane method are shown in Table 1 and Fig. 1. The

water absorption for bread making and final proofing time in this method increased according to the increase in added Yudane dough volume. On the other hand, the GRD, GP and SLV decreased with the increase in the amount of added Yudane dough. Bread appearance and crumb grain were also slightly degraded with the increase of added Yudane dough. Meanwhile, the moisture content of the bread increased significantly according to the volume of added Yudane dough, reflecting the increase of water absorption for bread making. The above results indicated that the general bread making quality of the Yudane method, such as final proofing time, GRD, SLV, bread appearance, etc., was inferior to that of the conventional method, with the exception that bread with a high moisture content was obtained.

It is generally known that bread produced using the Yudane method has a slightly sweet taste, as well as a soft and elastic texture. Meanwhile, the bread making quality of this method is slightly inferior to that of the normal method; the SLV of bread made with this method is low compared to that of the normal method (Naito *et al.*, 2005, Yamada *et al.*, 2004). Naito *et al.* (2005) also reported that the gluten fibrils of bread made with the Yudane dough method were thick and coarse compared to the control, and differed structurally, i.e., gluten network and pore number, etc, from bread made using the normal method.

In this study, it was proven that the bread making quality of

**Table 1.** Assessment of the bread making quality of the Yudane method<sup>1)</sup>

Bread making level <sup>2)</sup>	Water absorption for bread making (%)	Final proofing time (min)	GRD <sup>3)</sup> (mL)	GP <sup>4)</sup> (mL)			SLV <sup>5)</sup> (mL/g)	Moisture content of bread (%)
				1h	2h	3h		
Yudane dough 0% (Control)	68	84.0 $\pm$ 0.0 <sup>b</sup>	130 $\pm$ 4 <sup>a</sup>	31.0 $\pm$ 0.6 <sup>a</sup>	69.6 $\pm$ 0.3 <sup>a</sup>	105.7 $\pm$ 0.7 <sup>a</sup>	5.99 $\pm$ 0.08 <sup>a</sup>	45.3 $\pm$ 0.2 <sup>b</sup>
Yudane dough 20%	71	86.0 $\pm$ 0.0 <sup>a</sup>	119 $\pm$ 4 <sup>b</sup>	29.6 $\pm$ 0.3 <sup>b</sup>	66.1 $\pm$ 1.1 <sup>b</sup>	99.8 $\pm$ 2.5 <sup>b</sup>	5.79 $\pm$ 0.06 <sup>b</sup>	45.7 $\pm$ 0.1 <sup>b</sup>
Yudane dough 40%	74	86.5 $\pm$ 0.5 <sup>a</sup>	108 $\pm$ 6 <sup>c</sup>	29.4 $\pm$ 0.5 <sup>b</sup>	65.9 $\pm$ 1.7 <sup>b</sup>	100.2 $\pm$ 3.0 <sup>b</sup>	5.37 $\pm$ 0.07 <sup>c</sup>	46.3 $\pm$ 0.2 <sup>a</sup>

<sup>1)</sup>Each value except for water absorption for bread making is the mean  $\pm$  SD. Values followed by the same letter in a row are not significantly different ( $p < 0.05$ ). The analysis of variance between the data was evaluated by using Tukey's multiple range test of Excel statistical software 2012.

<sup>2)</sup>The Yudane dough was added to total bread dough based on w/w % flour.

<sup>3)</sup>GRD: Gas retention of dough.

<sup>4)</sup>GP: Gassing power of dough.

<sup>5)</sup>SLV: Specific loaf volume.

**Table 2.** Saccharide contents in water soluble fraction on breads made using the Yudane method<sup>1)</sup>

Bread making level <sup>2)</sup>	Total saccharide (mg/g bread)	Reducing saccharide (mg/g bread)	Glucose (mg/g bread)	Fructose (mg/g bread)	Maltose (mg/g bread)
Yudane dough 0% (Control)	49.0 $\pm$ 5.7 <sup>c</sup>	30.4 $\pm$ 0.6 <sup>c</sup>	3.5 $\pm$ 0.3 <sup>a</sup>	11.1 $\pm$ 0.4 <sup>a</sup>	24.1 $\pm$ 0.3 <sup>c</sup>
Yudane dough 20%	73.0 $\pm$ 6.9 <sup>b</sup>	38.6 $\pm$ 0.5 <sup>b</sup>	3.5 $\pm$ 0.5 <sup>a</sup>	10.5 $\pm$ 0.2 <sup>a</sup>	33.9 $\pm$ 1.3 <sup>b</sup>
Yudane dough 40%	96.7 $\pm$ 3.8 <sup>a</sup>	46.9 $\pm$ 0.5 <sup>a</sup>	2.9 $\pm$ 0.1 <sup>a</sup>	10.5 $\pm$ 0.1 <sup>a</sup>	47.2 $\pm$ 0.6 <sup>a</sup>

<sup>1)</sup>Each value is the mean  $\pm$  SD. Values followed by the same letter in a row are not significantly different ( $p < 0.05$ ). The analysis of variance between the data was evaluated by using Tukey's multiple range test of Excel statistical software 2012. As the sucrose contents of all samples were nearly zero, a description was omitted.

<sup>2)</sup>The Yudane dough was added to total bread dough based on w/w % flour.

**Table 3.** Staling and retrogradation rate constants,  $H_L$ ,  $H_0$ ,  $H_L-H_0$ ,  $\Delta H_L$ ,  $\Delta H_0$  and  $\Delta H_L-\Delta H_0$  of breads made using the Yudane method<sup>1)</sup>

Bread making level <sup>2)</sup>	SRC <sup>3)</sup> ( $h^{-1} \times 10^{-2}$ )	RRC <sup>4)</sup> ( $h^{-1} \times 10^{-2}$ )	$H_L$ <sup>5)</sup> ( $N/m^2 \times 10^3$ )	$H_0$ <sup>6)</sup> ( $N/m^2 \times 10^3$ )	$H_L-H_0$ ( $N/m^2 \times 10^3$ )	$\Delta H_L$ <sup>7)</sup> (J/g)	$\Delta H_0$ <sup>8)</sup> (J/g)	$\Delta H_L-\Delta H_0$ (J/g)
Yudane dough 0% (Control)	0.97	2.68	$7.42 \pm 0.47^a$	$1.53 \pm 0.11^a$	5.80	$3.20 \pm 0.13^a$	$0.22 \pm 0.02^a$	2.99
Yudane dough 20%	0.92	2.16	$6.96 \pm 0.45^{ab}$	$1.38 \pm 0.12^a$	5.65	$3.06 \pm 0.11^a$	$0.31 \pm 0.09^a$	2.75
Yudane dough 40%	0.89	2.07	$6.67 \pm 0.50^b$	$1.19 \pm 0.08^b$	5.58	$2.98 \pm 0.14^a$	$0.44 \pm 0.12^a$	2.54

<sup>1)</sup>Each value except for SRC, RRC,  $H_L-H_0$  and  $\Delta H_L-\Delta H_0$  is the mean  $\pm$  SD. Values followed by the same letter in a row are not significantly different ( $p < 0.05$ ). The analysis of variance between the data was evaluated by using Tukey's multiple range test of Excel statistical software 2012.

<sup>2)</sup>The Yudane dough was added to total bread dough based on w/w % flour.

<sup>3)</sup>SRC: Staling rate constant. The SRC was determined from data of bread's hardness shown in Fig.2.

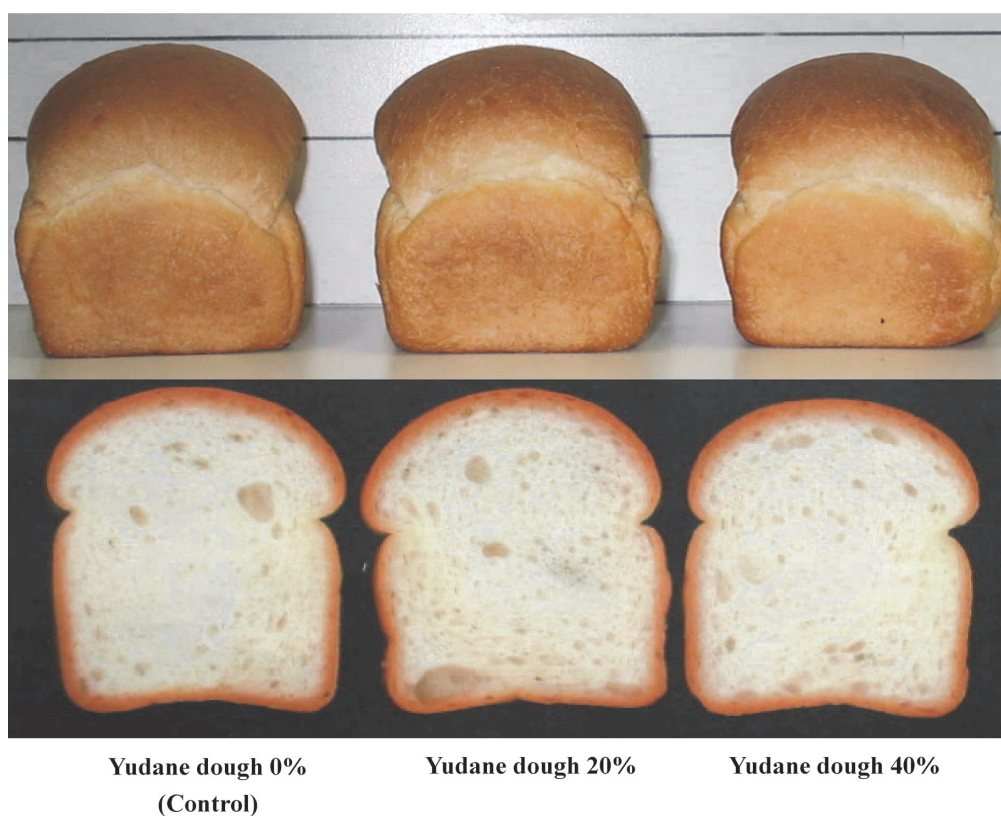
<sup>4)</sup>RRC: Retrogradation rate constant. The RRC was determined from data of  $\Delta H$  shown in Fig.3.

<sup>5)</sup> $H_L$ : Limiting value of hardness.

<sup>6)</sup> $H_0$ : Hardness at time zero.

<sup>7)</sup> $\Delta H_L$ : Limiting value of enthalpy for melting of retrograded amylopectin.

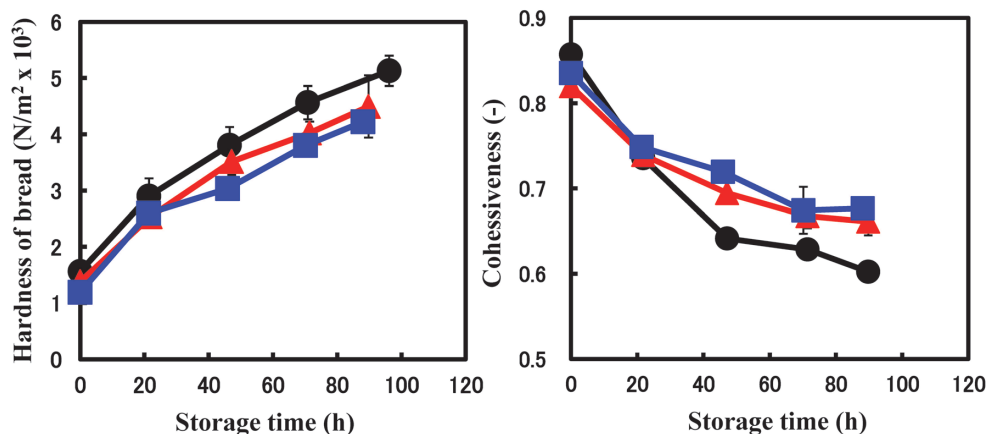
<sup>8)</sup> $\Delta H_0$ : Enthalpy for melting of retrograded amylopectin at time zero.



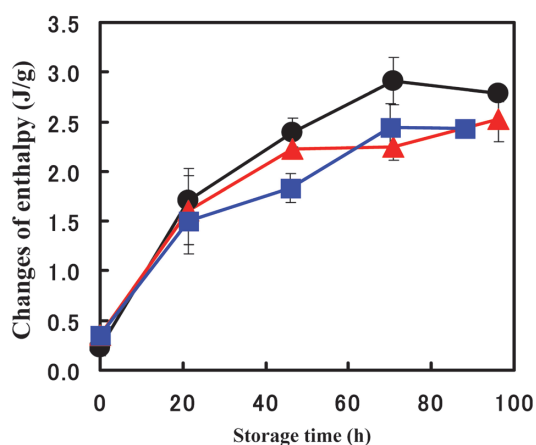
**Fig. 1.** Image of the appearance of breads made using the Yudane method Yudane dough was added to the total bread dough based on w/w % flour.

dough with added Yudane dough, as shown by the low GRD and SLV, etc. (Table 1 and Fig. 1), was clearly degraded in comparison to that of the control. These results are similar to previous findings reported by Naito *et al.* (2005) and Yamada *et al.* (2004). It is proposed that the decline of bread making quality in the Yudane method is mainly caused by the lowering of GRD; further, the resultant starch swelling and gelatinization and protein denaturation in Yudane dough make the gluten networks of the bread dough thick and rough. This is supported by the following results: (1) The GRD, especially for the 40% Yudane-added dough (Yudane dough

40%), in the Yudane method was significantly lower than the control (Table 1). (2) It was reported that the protein in the dough was denatured at about 50°C and the starch in the dough swelled and gelatinized at about 60°C (León *et al.*, 2003; Micard and Guilbert, 2000; Noel *et al.*, 1995; Zaidul *et al.*, 2008); these temperatures were evidently lower than that observed during mixing with Yudane dough making. (3) Naito *et al.* (2005) reported that the gluten network of the Yudane method dough became significantly thick and rough compared to that of the normal method.



**Fig. 2.** Temporal changes in hardness and cohesiveness of breads made using the Yudane dough method. Vertical bars indicate the standard deviation of each value. Yudane dough was added to total bread dough based on w/w % flour. ●: Yudane dough 0% (Control), ▲: Yudane dough 20%, ■: Yudane dough 40%.



**Fig. 3.** Enthalpy changes in the melting of retrograded amylopectin in breads made using the Yudane method. Vertical bars indicate the standard deviation of each value. Yudane dough was added to total bread dough based on w/w % flour. The symbols are as shown in Fig. 2.

The result of saccharides content analysis of Yudane breads is shown in Table 2. As the sucrose contents of all samples were nearly zero, this description was omitted. All saccharide contents in Yudane breads except for glucose and fructose were significantly higher than those of the control. Especially, the total saccharide and maltose contents of Yudane 40% were about 2 times those of the control. These results basically agreed with those reported for Yudane bread by Yamada *et al.* (2004). They also reported that the dextrin and maltose contents in Yudane bread were significantly higher than those of the control bread, which was a result of the greatly swollen and gelatinized starch in the doughs due to the Yudane dough addition being degraded by flour amylases during the baking process (Yamada *et al.*, 2004). From the above results, it is likely that the increase in total and reducing saccharides and maltose contents of the Yudane breads in this study was also caused by similar factors.

#### *Staling and texture of Yudane bread and starch retrogradation*

As shown in Fig. 2, the Yudane breads just after baking, especially

that of the Yudane dough 40% (Yudane 40%), were softer and the staling of the breads, especially Yudane 40%, was retarded compared with the control. In the same manner, the cohesiveness at all storage times except for time zero showed a higher value than that of the control. These results indicated that the Yudane breads had a softer texture and higher recovery for compression during storage compared to the control. This texture is similar to that of cooked rice and bread made from wheat flour with a slightly low amylose starch content (Ito *et al.*, 2007). As shown in Fig. 3, the changes in  $\Delta H$  of the Yudane breads, especially Yudane 40%, at all storage times except for zero, as well as the index of starch retrogradation in bread, were smaller compared to the control. The starch retrogradation changes observed by X-ray diffraction in these breads during storage are shown in Fig. 4 (which shows data for the control and Yudane 40%). In the X-ray diffraction analysis of bread, the peak at  $2\theta$  of around  $17^\circ$  as a typical peak of starch retrogradation in bread has been reported in many papers (Dragsdorf *et al.*, 1980; Primo-Martin *et al.*, 2007; Ribotta *et al.*, 2004). From a comparison of the time-dependent changes of the peak at  $2\theta$  of around  $17^\circ$  between the control and Yudane 40%, the starch retrogradation changes by X-ray diffraction in these breads also showed a similar trend during early storage as those of the  $\Delta H$  in Fig. 3. Namely, the increasing changes in the representative peak ( $2\theta$ , around  $17^\circ$ ) of the starch retrogradation in the X-ray diffraction pattern of Yudane 40% in the early stage, especially until 1 day storage, were slightly smaller than those of the control. These results showed that the Yudane method had an influence on bread staling and starch retrogradation in bread during storage, resulting in bread with a softer texture and slower staling.

In general, as the characteristics of Yudane bread, it is known that the staling of Yudane bread, as well as the features described above, are obviously retarded. However, rigorous scientific data regarding staling of this bread was required. From the data of the time course changes concerning bread hardness and the amount of starch retrogradation (the enthalpy for melting of retrograded

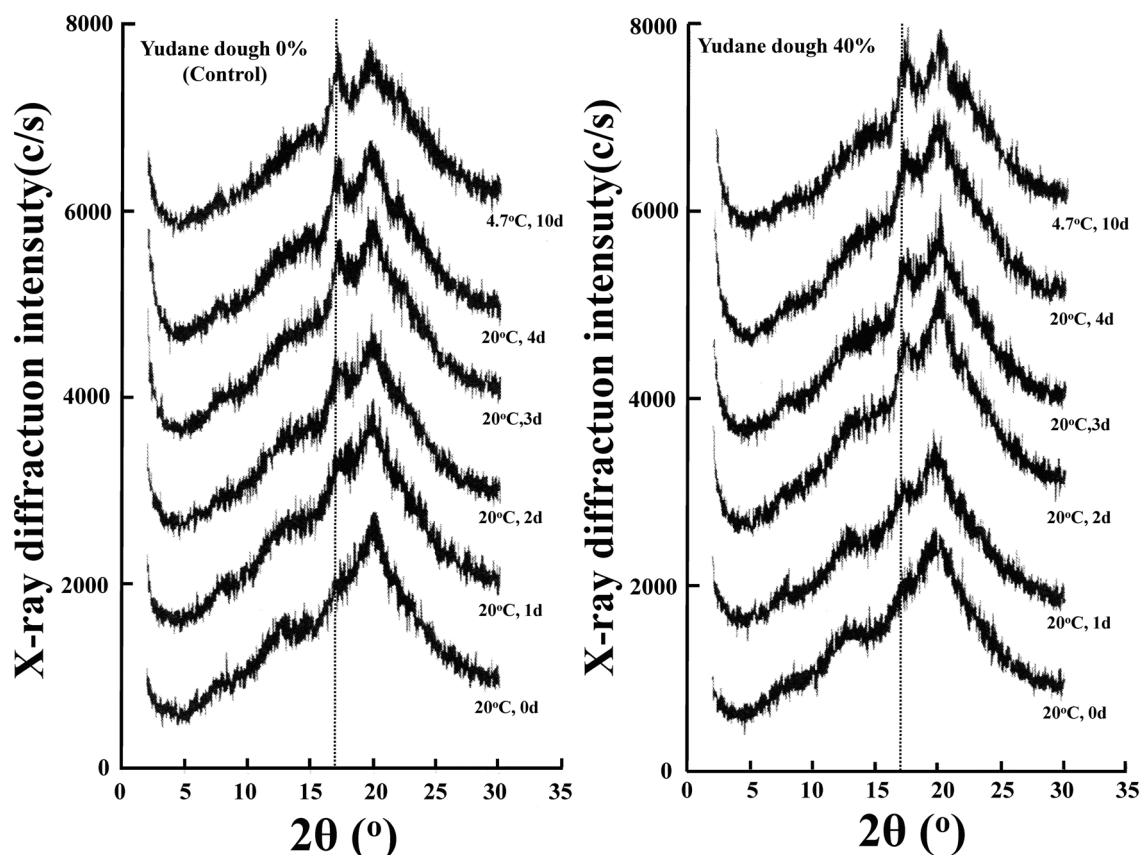


Fig. 4. Changes in X-ray diffraction patterns of bread made using the Yudane method Yudane dough was added to total bread dough based on w/w % flour.

amylopectin) shown in Figs. 2 and 3, the staling of the Yudane breads, particularly Yudane 40%, is obviously slower than the control. Hence, these results basically corresponded to that reported by a number of large-scale Japanese bakeries (Shibata and Kato, 2001; Fukazawa and Kainuma, 2004).

The SRC, RRC,  $H_L$ ,  $H_0$ ,  $H_L-H_0$ ,  $\Delta H_L$ ,  $\Delta H_0$ , and  $\Delta H_L-\Delta H_0$  are shown in Table 3.  $\Delta H_L$  and  $\Delta H_0$  are the limiting values of the  $\Delta H$  and the  $\Delta H$  at time zero, respectively. Furthermore, since the correlation coefficient of the regression line for determining the values of SRC and RRC were more than 0.99 and 0.94 (high values) in all breads, respectively, analysis of the staling of these breads by the first order reaction is reasonable. All the data except for  $\Delta H_0$  of the Yudane breads, especially Yudane 40%, were smaller compared with the control. These results showed that the SRC of Yudane breads and the RRC of starch in Yudane breads, particularly Yudane 40%, were lower than the control, and that the Yudane breads were soft just after baking and the total quantities of bread staling (the changes in hardness) and starch retrogradation in the breads were smaller than the control, as shown by the small  $H_L-H_0$ , and  $\Delta H_L-\Delta H_0$ .

*Slow staling mechanism of Yudane bread* When, as in this study, the moisture transport in bread and water evaporation from bread during storage were prevented as long as possible, the main factors in bread staling (changes in hardness) were SRC and  $H_L-H_0$ . Meanwhile, the chief control factor of SRC was RRC. Moreover,

the main factor in controlling  $H_L-H_0$  was the bread structure, including SLV and crumb grain, and the starch gel texture of the bread (Yamauchi *et al.*, 2001). Based on the above findings, the following is proposed regarding the slow staling of Yudane breads. All data for the Yudane breads except for  $\Delta H_0$  in Table 3 were lower than the control. As the structure of the Yudane breads, such as the SLV and crumb grain, is also rather inferior to that of the control, as shown in Table 1 and Fig. 1, it is considered that the small  $H_L-H_0$  of the Yudane breads is mainly affected by the texture of the starch gels in the breads.

Therefore, the overall slow staling of the Yudane breads, especially Yudane 40%, can be attributed to the small SRC and  $H_L-H_0$ , which seem to be largely related to the small RRC and the soft starch gel texture of the breads, respectively. The small RRC is also involved in characteristics of the soft starch gel as shown in Table 3. In addition, it seems that the small SRC and  $H_L-H_0$  of the Yudane breads are mainly caused by the high moisture and various saccharide (total and reducing saccharides and maltose) contents and the greater flour amylases-modification (partial decomposition) of swollen and gelatinized starch in the breads as explained in detail below. The above discussion is reasonable because the moisture and saccharide contents of the Yudane breads showed significantly high values compared with the control (Table 1, 2); the high saccharide contents of the Yudane breads suggest that the starch in the Yudane breads is decomposed more than the control.

The previous studies reported that the high moisture bread and starch gel are responsible for the soft texture of bread and starch gel, slow bread staling and starch retrogradation (Piazza and Masi, 1995; Rogers *et al.*, 1988; Zeleznak and Hoseney, 1988). It is also reported that oligosaccharides such as low molecular dextrin and maltose, etc., and amylases- modification (partial decomposition) of starch in bread and starch gel, especially the latter, significantly retard bread staling and retrogradation of starch gel and decrease the strength of the starch gel matrix (Duran *et al.*, 2001; Gerrard *et al.*, 1997; León *et al.*, 2002; Miyazaki *et al.*, 2004; Palacios *et al.*, 2004a; Palacios *et al.*, 2004b). Furthermore, Martin *et al.* (1991a; 1991b) reported that the strength of crosslinks between protein fibrils and starch remnants in bread greatly affected the bread staling, and the presence of low molecular weight dextrin in the bread may weaken the bonds.

In reference to the findings of these previous studies, the mechanism of slow staling of the Yudane breads in this study is concluded as follows. Since the SLV and crumb grain, except for the starch gel properties affecting  $H_L-H_0$ , are clearly inferior in the Yudane breads, it seems that the small  $H_L-H_0$  of the Yudane breads is caused by the soft starch gel properties as well as decrease in bonding of the starch and gluten by low molecular dextrin, etc. This may be due to the high moisture and various saccharide (total and reducing saccharides and maltose) contents and greater flour amylases-modification (partial decomposition) of starch in the Yudane breads. It is also considered that although the low SRC of the Yudane breads is directly involved in the low RRC, the low RRC as well as the small  $H_L-H_0$  are greatly influenced by the above same factors. The main factors of the low staling of Yudane breads in this study seem to be the low SRC and small  $H_L-H_0$  caused by the soft and low retrogradation starch gel properties in the breads. In addition, despite the low SLV and rough crumb grain (negative factor for slow bread staling) of Yudane breads compared with the control, these breads clearly exhibited slower staling. The soft and slow retrogradation properties of the starch gel in the breads (positive factor for slow bread staling) have a more valuable quality effect compared to the above negative factor.

## Conclusion

Using kinetic analysis, the following observations were made about the characteristics of bread made by the Yudane method, a very popular product representing an enormous market share in Japan. Although a decline in bread making quality, such as the lowering of GRD, GP and SLV, occurred with the Yudane method, the moisture and saccharides contents of the bread increased as a reflection of the increase of water absorption and high decomposition of starch during bread making. The Yudane bread was soft just after baking and became stale slower than the conventional bread (control). Kinetic analyses of bread staling and starch retrogradation also revealed that the rate constants of staling and starch retrogradation of the bread were obviously lower than

those of the control. The slow staling and unique texture of the Yudane bread were related to the increase of moisture and various saccharide contents in the bread, which resulted in the promotion of starch pre-swelling and gelatinization in this bread.

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