Technical paper

Relationship between Physical Dough Properties and the Improvement of Bread-Making Quality during Flour Aging

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Received November 11, 2003; Accepted January 28, 2004

The relationship between physical dough properties and bread-making quality during flour aging was investigated for two Japanese domestic bread-making spring wheat cultivars (Haruyutaka, Haruyokoi) and the winter wheat cultivar (Kitanokaori). The specific loaf volume increased for 4 weeks after milling in all cultivars. The decrease in the breaking deformation of dough continued for 8 weeks in all cultivars and showed a higher negative correlation coefficient to the specific loaf volume. In addition, a greater increase of specific loaf volume was observed by decreasing the breaking deformation in a cultivar with less breaking deformation immediately after milling. Farinograph stability increased for 2 weeks after milling and also showed higher correlation coefficients to specific loaf volume. Water absorption showed higher correlation coefficients to the breaking deformation in Haruyutaka and Haruyokoi but a negative correlation in Kitanokaori. The breaking force, gassing power, and vacuum expansion volume of dough showed lower correlation coefficients to the specific loaf volume in all cultivars. Overall, a higher correlation coefficient was observed among breaking deformation decrease, farinograph stability, and specific loaf volume during flour storage. The relationship between the breaking deformation immediately after milling and the increasing rate of specific loaf volume would be a useful indicator of flour aging maturity.

Keywords: flour aging, bread-making quality, specific loaf volume, physical dough property, breaking deformation

Improvement of bread-making quality of wheat after harvesting or after milling is a well-known phenomenon, as aging (Nagao & Tanaka, 1982), and flour aging after milling is an essential treatment before processing (Kozmin, 1935; Fisher et al., 1937; Shellenberger, 1939). The changes of flour components during flour aging have been reported to be as follows: 1) an increase of free fatty acid that depends on the temperature during storage (Kozmin, 1935), 2) a decrease in the SH content by oxidation during storage (Tseng & Dempster, 1963; Yoneyama et al., 1970a; 1970b), and 3) a decrease in the glutathione content, which deteriorates dough quality as a reducing agent (Kuninori & Matsumoto, 1964; Chen & Schofield, 1996). Reports have indicated that flour aging continued for a longer time period in hard wheat than soft wheat (Fisher et al., 1937). Deterioration of the dough properties was reported in flour with a high content of glutathione (Archer, 1972; Coventry et al., 1972; Sarwin et al., 1993), and the variation of glutathione contents was reported among wheat cultivars (Sarwin et al., 1993; Schofield & Chen, 1995). Differences in the aging processes of different wheat cultivars have also been indicated (Chen & Schofield, 1996).

For bread production on a commercial scale and for dough handling, it is important to understand the changes that occur in the dough properties as a result of flour aging. However, few reports have been written about these changes (Yoneyama et al., 1970b), or about the relationships between dough properties and improvements in bread-making qualities. In addition, the key properties for improvements of bread-making qualities have not been elucidated.

Recently, the relationships between bread-making quality and dough properties were analyzed with the use of new measuring methods requiring a small amount of dough (Yamauchi et al., 2000; 2001). The bread-making quality of each wheat cultivar was precisely predicted.

In this study, we tried to clarify the effect of flour aging after milling by using samples harvested in the same season and stored at low temperature until milling. The changes in dough properties during flour aging were analyzed by the water absorption, breaking force, breaking deformation, gassing power, vacuum expansion volume, and specific loaf volume from immediately after milling to eight weeks after milling.

Three wheat cultivars were investigated for bread-making in Japan: two are spring wheat (Haruyutaka and Haruyokoi), and one is winter wheat (Kitanokaori), and how the changes in the breaking deformation play a key role in the improvement of bread-making performance in all cultivars was elucidated.
Materials and Methods

Preparation of wheat flour  The winter wheat cultivar ‘Kitanokaori,’ produced at a test field of the National Agricultural Research Center for Hokkaido Region (Memuro), and the spring wheat cultivars ‘Haruyutaka’ and ‘Haruyokoi,’ provided by the Yokoyama Milling Co., Ltd. (Sapporo, Japan), were employed for the following test. All materials were harvested in July or August, 2000, then stored at 4°C, and the milling was carried out in January, 2001. The wheat samples were milled in a Bühler test mill (Bühler Inc., Uzwil, Switzerland) after controlling the moisture content in the grain at 16%, and a 60% grade flour was obtained from the milling. The protein content of the flour was determined by nondestructive analysis using a near-infrared reflectance instrument (Inframat 8120, PerCon Co., Hamburg, Germany). The ash content was measured according to the American Association of Cereal Chemists (AACC) method (1991a). The absorbed water of the flours was measured with a farinograph (Brabender Co., Duisburg, Germany) that requires the use of small mixing bowls, according to the AACC method (1991b). The gelatinization characteristics of the flours and the peak viscosity were measured using a rapid viscoanalyzer (RVA) following the method developed by Watanabe and Suzuki (1991). Flour particle surface area was measured by the laser diffraction particle-size analyzer Heros and Rodos (Japan Laser Co., Ltd., Tokyo).

The condition of flour preservation Two hundred g of each type of flour was preserved in a polyethylene bag and stored immediately after milling in an incubator at 20°C. Flour samples immediately after milling, one week after milling, two weeks after milling, four weeks after milling, and eight weeks after milling were employed to measure the dough properties and conduct the bread-making experiments.

Bread-making test The bread-making test was carried out following the no-time method for the formulation of standard white bread, according to Yamauchi et al. (2000). The water absorption was determined by optimal Farinograph (Brabender Co., Duisburg, Germany) absorption for a consistency of 500BU. The mixing peak pattern (mixing motor current value) during the mixing of the dough was measured by a method of Takata et al. (1999) using a clamp meter. The mixing time was optimized by the peak time of electronic currency (the time of currency peak time plus 1/10 of peak time). The specific loaf volume was measured by the rapeseed replacement method of Yamauchi et al. (1999).

Dough properties The total gassing power at 30°C for 80 min was measured with a Fermograph II (ATTO Co., Ltd., Tokyo) with 20 g of dough after bench time. The breaking force and breaking deformation of doughs were measured using 10g of dough by the method of Yamauchi et al. (2001). The breaking deformation showed a negative effect on the specific loaf volume, and the breaking force showed a positive effect on specific loaf volume (Yamauchi et al., 2001). The data regarding the vacuum expansion volume (gas retention) of dough were measured by a method developed by Yamauchi et al. (2000), which required the use of 20 g of dough following proofing. One report indicated that the vacuum expansion volume showed a higher correlation coefficient to the specific loaf volume (Yamauchi et al., 2000). The data regarding the physical properties and vacuum expansion of dough are shown as an average value of two and three samples, respectively.

Results and Discussion

Flour properties The results of flour compositions, flour yield (FY), flour protein content (PC), peak viscosity (RVU), flour particle surface area (PSA), and flour ash content (Ash) of wheat flour entries are shown in Table 1. The flour yield was the highest in Haruyutaka, and that of Haruyutaka was close to that, while Kitanokaori had the lowest value. The flour protein content was higher in Haruyutaka; Kitanokaori was in the middle; and Haruyokoi had the lowest value. The peak viscosity of each flour indicated that no flour was damaged by α-amylase activity. The flour particle surface area and ash content had similar values in all flours.

Specific loaf volume All cultivars showed the lowest specific loaf volume immediately after milling, and this volume increased until 4 weeks after milling in all cultivars (Fig. 1). Haruyutaka showed 5.10 just after milling and increased to 5.33 at 2 weeks after milling, thereafter showing between 5.33 and 5.38 until 8 weeks after milling. Haruyokoi was 5.03 immediately after milling, increased to 5.47 at 4 weeks after milling and was 5.46 at 8 weeks. Kitanokaori was 5.21 immediately after milling, increased to 5.50 at 4 weeks after milling. And at 8 weeks was 5.48. The increase in specific loaf volume was thus 0.28 in Haruyutaka, 0.44 in Haruyokoi, and 0.29 in Kitanokaori.

Farinograph properties The Farinograph water absorption of Haruyutaka was 68.0% immediately after milling and decreased to 63.5% at 1 week. After that, it was between 63.4% and 63.8% until 8 weeks after milling. That of Haruyokoi was 70.2% immediately after milling and decreased to 65.5% at 1 week, then was between 65.4% and 65.8% until 8 weeks after milling.
milling. The percentage of decrease of water absorption at 1 week after milling was the same value, 4.5%, in Haruyutaka and Haruyokoi. The water absorption value was stable in Kitanokaori, between 69.5% and 70.2% immediately after milling until 8 weeks after milling (Fig. 2).

Farinograph stability increased for 2 weeks after milling in all cultivars, while the water absorption and breaking deformation changed within 1 week after milling (Figs. 2, 3, and 4).

The amounts of increase in the stability of the farinograph were about the same in Haruyutaka and Haruyokoi (10.1 min and 8.9 min) only about half those values in Kitanokaori (5.0 min). The change in the stability of the Farinograph in Kitanokaori was smaller than that in the others. Farinograph stability was about the same value at 8 weeks after milling in all cultivars.

**Breaking deformation** The breaking deformation decreased in all cultivars at all stages after milling (Fig. 3). Haruyutaka was 74.5 mm immediately after milling, decreased to 60.5 mm at 1 week and to 58.3 mm at 8 weeks. Haruyokoi was 62.3 mm immediately after milling, decreased to 46.8 mm at 1 week and to 44.0 mm at 8 weeks. Kitanokaori was 45.2 mm immediately after milling and decreased to 40.3 mm at 1 week and to 38.7 mm at 8 weeks. The amount of decrease in the breaking deformation was similar in Haruyutaka and Haruyokoi (16.2 mm and 18.3 mm) but about one-third of those values in Kitanokaori (6.5 mm).

**Breaking force** The breaking force increased in all cultivars until 2 weeks after milling and decreased after that (Fig. 5). Haruyutaka was 1.9 N immediately after milling and increased to 2.8 N at 2 weeks, then decreased to 2.2 N at 8 weeks. Haruyokoi was 2.0 N immediately after milling, increased to 2.9 N at 2 weeks and then decreased to 2.4 N at 8 weeks. Kitanokaori was 2.5 N immediately after milling, increased to 2.8 N at 2 weeks. It then decreased to 2.2 N at 8 weeks. The percentage of decrease of water absorption at 1 week after milling was the same value, 4.5%, in Haruyutaka and Haruyokoi. The water absorption value was stable in Kitanokaori, between 69.5% and 70.2% immediately after milling until 8 weeks after milling (Fig. 2).
weeks. The amount of increase in the breaking force to the peak was 0.9 N in Haruyutaka and Haruyokoi but just one-third of those values in Kitanokaori, 0.3 N. The amounts of decrease in the breaking force from the peak were 0.5 N or 0.6 N in all cultivars.

Gassing power and vacuum expansion volume The gassing power of dough was stable in each cultivar until 8 weeks after milling (Fig. 6). Haruyokoi had the highest gassing power, and Haruyutaka had a lower value while Kitanokaori had a much lower value than either of the others. The vacuum expansion volume showed no tendency in all cultivars until 8 weeks after milling (Fig. 7).

Our results indicate that the increase in the specific loaf volume and the dynamic changes in the properties of the dough continued for 4 weeks after milling (Fig. 1). According to some reports, the increase in the dough viscosity and dough consistency continued for 20 days after milling at 30°C air atmosphere preservation (Yoneyama et al., 1970b), and the increase in the specific loaf volume continued for 20 days after milling at 20°C air atmosphere preservation (Chen and Schofield, 1996). The length of the flour aging effect for specific loaf volume was similar to that in other reports.

The correlation coefficients between specific loaf volume and dough properties in each cultivar are shown in Table 2. Concerning the improvements in the bread-making quality during the aging process, breaking deformation and farinograph stability showed higher correlation coefficients to the specific loaf volume in all cultivars. However, only farinograph stability and gassing power in Haruyutaka showed significant correlation coefficients to the specific loaf volume. Breaking force, water absorption and gassing power showed similar correlation coefficients to the specific loaf volume in Haruyutaka and Haruyokoi, while they showed different values in Kitanokaori. Vacuum expansion volume showed lower correlation coefficients to the specific loaf volume in all cultivars (Table 2A).

Concerning the relationship between farinograph stability and other dough properties, breaking force and water absorption showed similar correlation coefficients in Haruyutaka and Haruyokoi, while they showed different values in Kitanokaori. The correlation coefficients between farinograph stability and gassing power were different in each cultivar, and vacuum expansion volume showed lower correlation coefficients to farinograph stability in all cultivars (Table 2C).

Overall, breaking deformation and farinograph stability showed higher correlation coefficients to the specific loaf volume in all cultivars. Breaking force and water absorption showed similar correlation coefficients to the breaking deformation and the farinograph stability in spring wheat (Haruyutaka and Haruyokoi), while that was different in winter wheat (Kitanokaori).

In all cultivars the changing of breaking deformation started 1 week after milling (Fig. 3), and the changing of farinograph stability 2 weeks after milling (Fig. 4). The changes of dough properties can be divided by the starting time of changing; they occur either less than 1 week or 2 weeks after milling. Reports indicated flour aging consisted of change in three types of chemical components (Kozmin, 1935; Kuninori and Matsumoto, 1964; Yoneyama et al., 1970a, 1970b). The duration of chemical component change was reported to be 90 days in SH (Kitanokaori). However, the relationship between these chemical component changes and changes in dough properties has not been elucidated. In this study, we found that the decrease of the breaking deformation is apparently a first step in the results of chemical component change, and the extension of the farinograph stability is considered to be the following.

### Table 2. Correlation coefficients between dough properties in trial flours.

<table>
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<tr>
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<th>Haruyutaka</th>
<th>Haruyokoi</th>
<th>Kitanokaori</th>
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<tbody>
<tr>
<td>BD^a</td>
<td>-0.874</td>
<td>-0.837</td>
<td>-0.805</td>
</tr>
<tr>
<td>BF^a</td>
<td>0.796</td>
<td>0.587</td>
<td>-0.314</td>
</tr>
<tr>
<td>WA^a</td>
<td>-0.767</td>
<td>-0.739</td>
<td>0.475</td>
</tr>
<tr>
<td>FS^a</td>
<td>0.948*</td>
<td>0.784</td>
<td>0.844</td>
</tr>
<tr>
<td>GP^a</td>
<td>-0.948*</td>
<td>-0.626</td>
<td>0.792</td>
</tr>
<tr>
<td>VE^a</td>
<td>0.349</td>
<td>0.144</td>
<td>0.386</td>
</tr>
</tbody>
</table>

^aBreak deformation, ^bBreaking force, ^cWater absorption, ^dFarinograph stability, ^eGassing power, ^fVacuum expansion volume, ^gSpecific loaf volume, ^p<0.05, ^pp<0.01.
Haruyokoi was bred from a cross of Haruyutaka and Stoal (spring wheat cultivar of U.S.A.) (Ikeguchi et al., 2002). The reason for the similar change in water absorption, breaking deformation and breaking force for Haruyutaka and Haruyokoi is believed to be the greater similarity of their genetical background. Kitanokaori, in contrast, was bred from a cross of Horoshirikomugi (winter wheat cultivar of Japan) and GK Szemes (winter wheat cultivar of Hungary). However, it is necessary to investigate more cultivars to clarify the relationship between the increase in the specific loaf volume and the dough properties, and the difference of the aging process in spring and winter wheat.

In conclusion, this report has elucidated the changes in properties of flour during aging that improve the bread-making quality using Japanese domestic wheat cultivars. The relationship between the dough properties and changes in chemical components should be investigated in further study to clarify the mechanism of different aging processes in wheat cultivars. These findings will provide useful information about the flour aging characteristics of wheat cultivars and would be an accurate indicator of flour maturity.

Acknowledgment This work has been partially supported by a Research and Development Program for New Bio-industry Initiatives of the Bio-oriented Technology Research Advancement Institution.

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