

# Evaluation of Various Baking Methods for Polished Wheat Flours

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## ABSTRACT

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Flour qualities of polished wheat flours of three fractions, C-1 (100–90%), C-5 (60–50%), and C-8 (30–0%), obtained from hard-type wheat grain were used for the evaluation of four kinds of baking methods: optimized straight (OSM), long fermentation (LFM), sponge-dough (SDM) and no-time (NTM) methods. The dough stability of C-5 in farinograph mixing was excellent and the maturity of polished flour doughs during storage in extensigraph was more improved than those of the commercial wheat flour (CW). There were no significant differences in the viscoelastic properties of CW dough after mixing, regardless of the baking method, while those of polished flour doughs were changed by the baking method; this tendency became clear after fermentation. The polished flours could make a better gluten structure in the dough samples after

mixing or fermentation using LFM and SDM, as compared with other baking methods. Baking qualities such as specific volume and storage properties of breads from all polished flours made with SDM increased more than with other methods. In addition, viscoelastic properties of C-5 and C-8 doughs fermented by SDM were similar to those of CW, and the C-5 breadcrumb showed softness similar to that of the CW. Also, SDM could make C-5 bread with significantly higher elasticity and cohesiveness after storage for five days when compared with CW bread. Therefore, SDM with long fermentation, as compared with other baking methods, was considered suitable for use with polished flours to give better effects on dough properties during fermentation, resulting in more favorable bread qualities.

Recently, whole wheat grain flours have been the focus of new food materials from the viewpoint of high nutritional and functional values including dietary fibers, minerals, and antioxidants. However, the practical utilization of whole wheat flour is not as common in our daily diet in Japan as it is in the United States or Europe, and whole wheat flour could not be used for daily meals. Wheat flour is normally considered white because of the removal of bran or germ. Therefore, milling companies have made a great effort to remove the bran or germ from wheat grain. However, the pericarp (13%), endosperm (85%), and embryo (2%) in whole grains are good sources for vitamins, minerals, and dietary fibers (Pomeranz 1988a). The conventional milling method recovers only 70% of the flour from whole grains. However, the bran and germ contain various functional and nutritional components that are good for our health. The removal of these materials is considered a problem because of environmental pollution and high production costs. To resolve these problems, a new wheat flour was prepared from the whole wheat grain by gradually polishing from the outer layer to the inner layer using 10% of the total wheat weight as reported previously (Maeda and Morita 2001, 2003). Eight fractions of the whole wheat grains could be obtained by the polishing method without waste of bran or germ: C-1 (100–90%) 10% layer graded from outer part of whole grains; C-2 (90–80%) 10% layer graded from outer part of C-1; C-3 (80–70%); C-4 (70–60%); C-5 (60–50%); C-6 (50–40%); C-7 (40–30%); and C-8 (30–0%) 30% layer graded from the remaining core of the whole grain.

Generally, commercial whole wheat grain flours are prepared by the conventional milling method which includes conditioning, breaking, grading, purification, and reduction processes, and all milled fractions are combined to resemble the composition of the original grain. The present polishing method did not include any of these processes; it is quite easy, with no side production; and the resultant polished flours from the whole grain have nutritional value similar to that of commercial whole grain flours. In the present study, we focused on practical uses of polished wheat flours

in processed foods. To find the optimum baking method of polished flours, we used rheological studies of mixed and fermented doughs and baked breads.

## MATERIALS AND METHODS

### Flours and Chemicals

Polished flours were prepared from a hard-type wheat grain 1CW (No. 1 Canada Western Red Spring) using a rice polisher in the same polishing-grading method reported previously (Maeda et al 2001; Tang et al 2000, 2001). Eight fractions of polished flours were prepared: C-1 (100–90%), C-2 (90–80%), C-3 (80–70%), C-4 (70–60%), C-5 (60–50%), C-6 (50–40%), C-7 (40–30%), and C-8 (30–0%) were prepared from 1CW, as described above. C-1, C-5, and C-8 were used for breadmaking in the present study. The conventionally milled flour prepared from 1CW (CW) was used for the control sample. L-Ascorbic acid and L-cysteine were purchased from Wako Pure Chemical Industries (Osaka, Japan) and dry baker's yeast was donated by J. T. Foods (Shizuoka, Japan). All chemicals were reagent-grade and the materials did not need purification for the present examination.

### Breadmaking

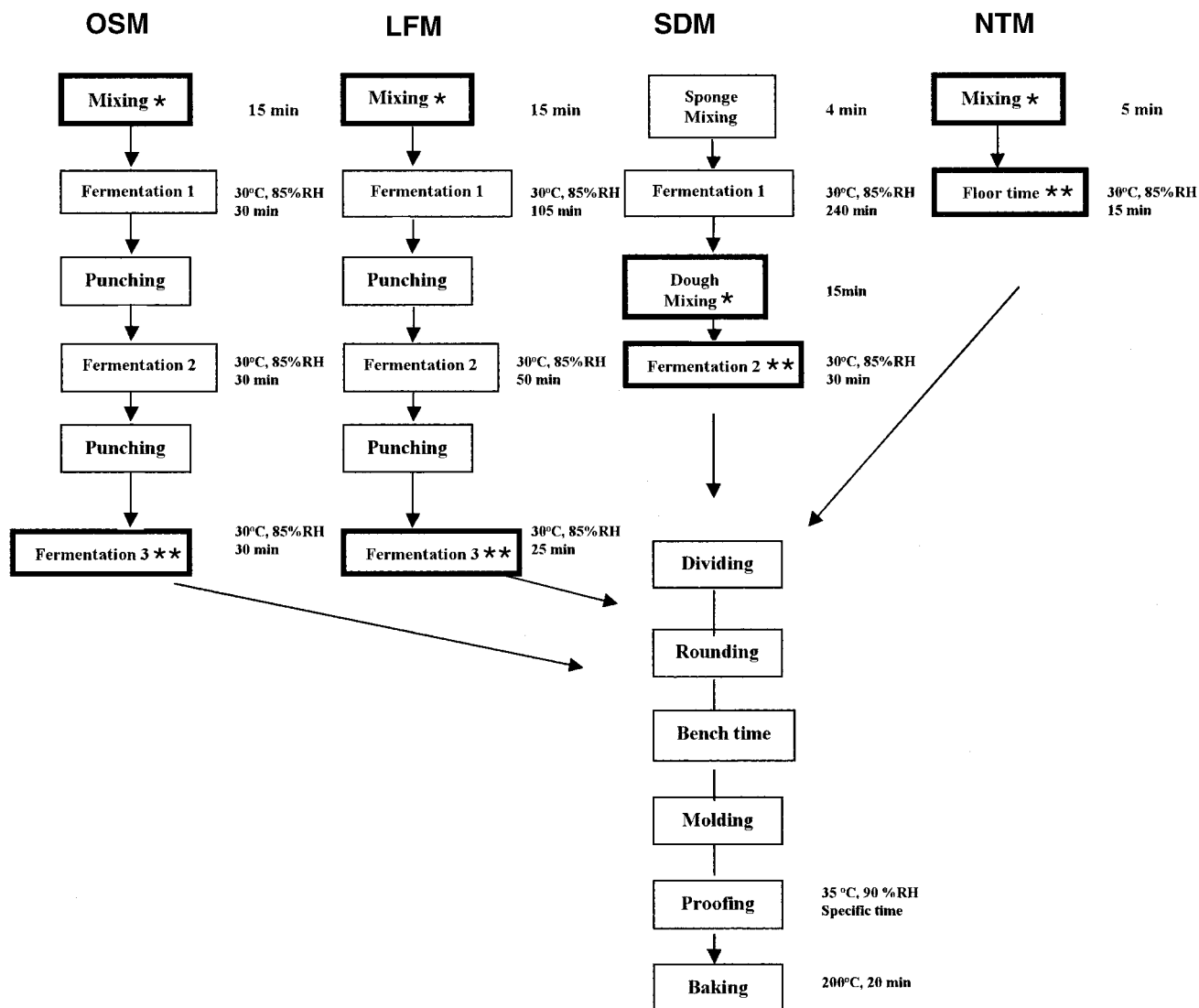
In the present study, four different baking methods were used for finding the optimum baking conditions for polished flours. Optimized straight method (OSM) (Approved Method 10-10B, AACC 2000), long fermentation method (LFM, Approved Method 10-09), sponge-dough method (SDM, Approved Method 10-11) and no-time method (NTM) (Baker et al 1988) were used for the present study. Ingredients for these baking methods are summarized in Table I; for each case, the dough was made from 300 g of flour.

For all baking methods, the water absorption that was indicated at 500 BU in farinograph mixing of the dough samples was used (Table II). The farinogram of the C-1 sample was quite unstable because C-1 contained a large amount of bran, therefore the exact value of water absorption could not be obtained. As a result, the water absorption of C-5 was used for the breadmaking. The procedures for the mixing and fermentation conditions are shown in Fig. 1. The ingredients and optimum amount of water were mixed at a low speed (380 rpm) using a KN-200 mixer (Taisho Denki Co., Tokyo, Japan) for a specified time. For NTM, premixing was performed to advance the oxidation of additives. Flour, L-ascorbic acid, and L-cysteine were mixed and then held for 5 min at room temperature to produce the additional oxidative reaction of additives, followed by mixing with other ingredients. After completing the

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**Fig. 1.** Flow diagram of various baking methods. OSM, optimized straight method; LFM, long fermentation method; SDM, sponge-dough method; NTM, no-time method. Stages of mixing and fermentation are indicated as \* and \*\*, respectively.

**TABLE I**  
Ingredients (%) of Breadmaking for Various Baking Methods

Ingredient	Optimized Straight Method	Long Fermentation Method	Sponge-Dough Method		No-Time Method
			Sponge	Dough	
Flour	100	100	60	40	100
Water	Water absorption	Water absorption	60 Water absorption	40 Water absorption	Water absorption
Dry yeast	2.0	2.0	2.0	0	2.0
Sodium chloride	1.5	1.5	0	2.0	1.5
Sugar	6.0	6.0	0	5.0	6.0
L-Ascorbic acid	0	0	0	0	100 ppm
L-Cysteine	0	0	0	0	40 ppm

**TABLE II**  
Farinograph Data of Various Polished Wheat Flours

Sample <sup>a</sup>	Water Absorption (%)	Arrival Time (min)	Development Time (min)	Stability Time (min)	Weakness Value (BU)	Valorimeter Value (BU)
CW	67.0a <sup>b</sup>	2.5c	19.5b	26.0b	12.5a	94.5b
C-1	—	—	—	—	—	—
C-5	105.0c	1.5a	23.5c	31.0c	30.0b	98.0c
C-8	86.0b	2.0b	14.0a	20.0a	40.0c	88.0a

<sup>a</sup> CW, common hard-type wheat flour; polished flours C-1 (100–90%), C-5 (60–50%); C-8 (30–0%) of wheat grain.

<sup>b</sup> Values followed by the same letter in the same column are not significantly different ( $P < 0.05$ ).

mixing and fermentation under the specific conditions for each baking method (Fig. 1), the dough was divided into three pieces (130 g/piece), rounded, and benched for 15 min covered with cotton cloths, followed by molding using a mechanical molder (SM-230, Baker's Production Co., Osaka, Japan), and then it was placed in a baking pan. The dough was subjected to a final proof in a cabinet at 35°C and 90% relative humidity (rh), followed by baking at 200°C for 20 min using an electric oven (POF-1, Baker's Production Co., Osaka, Japan). The final proof times for OSM, LFM, SDM, and NTM were controlled for 33, 50, 50, and 50 min, respectively. Regardless of baking methods, the recommended pan size was the same for all breadmaking methods: upper size, 105 i.w. × 60 i.d. × 69 i.h.; lower size, 91 i.w. × 55 i.d. × 62 i.h. (Approved Method 10-11, AACC 2000).

After baking, the bread was removed from the oven and the loaf was weighed immediately; the specific loaf volume was measured by rapeseed displacement after standing for 40 min at room temperature. The loaves were sliced in half and then the appearance of the inside of the loaf was examined visually, and the surface of the crumb was photocopied to determine the gas cell distribution.

### Evaluation of Qualities of Polished Flours

Farinograph mixing of various doughs was conducted using Brabender apparatus (Approved Method 54-21, AACC 2000). The 50-g bowl maintained temperature at 30°C, and the blender was controlled at 63 rpm (regular speed). For extensigraph measurements, doughs were prepared by mixing 300 g of flour with water containing 2% (w/w) of NaCl at 30°C using a farinograph according to Approved Method 54-10 (AACC 2000).

### Evaluation of Rheological Properties of Dough

*Preparation of dough samples.* To determine the effects of various baking methods on properties of dough from polished flours, after mixing or fermentation, dough samples were prepared by the various baking methods. The specified stages for mixed dough samples were OSM and LFM, after mixing for 15 min; SDM, after the second mixing for 15 min with fermented sponge-dough (30°C, 85% rh for 4 hr); NTM, after mixing for 5 min with additives. The specified stages for fermented doughs were OSM, after fermentation for 90 min; LFM, after fermentation for 3 hr; SDM, after the second fermentation for 30 min; NTM, after floor time for 15 min. The stages of mixing and fermentation are indicated in Fig. 1 by asterisks (\*) and (\*\*), respectively.

*Viscoelastic properties.* The mixed or fermented dough samples using various baking procedures were tested for viscoelastic properties using a rheometer (Rheotech Co., Tokyo, Japan) as reported previously (Maeda and Morita 2001). After holding the dough samples for 10 min at 30°C, compression stress, modulus of elasticity, and viscosity coefficient were measured at 30°C. Data were processed using a computer program (TR-06, Rheotech Co., Tokyo, Japan).

*Scanning electron microscopy (SEM).* For SEM observation, a small portion was obtained from mixed or fermented doughs using the method reported above. A small portion of dough sample was frozen and lyophilized by methods used previously (Nihei et al 1990). SEM samples were coated with Pt-Pd for 4 min before observation, and SEM apparatus (Hitachi Model S-800) was operated at 10 kV according to the procedure reported previously (Maeda and Morita 2000).

### Evaluation of Baking Qualities

*Baking properties.* The bread qualities were measured using a Fudoh rheometer (Rheotec Co., Tokyo, Japan) with the method reported previously (Morita et al 2002a,b). After storage for 0, 2, and 5 days, the bread was cut into two slices 3 cm thick from the central portion before analyses. Rheological and textural tests used one sample 4 cm<sup>3</sup> long × 4 cm<sup>3</sup> wide × 3 cm<sup>3</sup> high cut from

one slice with the crust removed. The information obtained from the curve included hardness, adhesiveness, cohesiveness, elasticity, chewing property, brittleness, and gumminess of breadcrumb. All data were processed using the Rheosoft TR-06 computer program.

*Image analysis of crumb grain.* The features of crumb grain were analyzed by the Image Hyper II v. 4.8 system. After baking, the breads were sliced in half from the central top portion of the loaf with an electric cutter, and the inner area of the cut sample was copied on a Canon 5020 copier and scanned with a CanoScan 676U/N1240U scanner (Canon, Tokyo, Japan). The images of the crumb grain of scanned areas were analyzed according to the instructions for the Image Hyper II v. 4.8 system.

### Statistical Analysis

Breadmaking, farinograph, and extensigraph tests were conducted five times for each sample. The dough or bread samples were prepared 5× for rheological measurements. The analysis of variance (ANOVA) results and significant differences among samples were evaluated by Duncan's multiple-range test ( $P < 0.05$ ) using SPSS statistical methods (v. 11.0, SPSS, Chicago, IL).

## RESULTS AND DISCUSSION

### Characteristics of Polished Wheat Flours

Farinograph data of various wheat flours are summarized in Table II. The farinograph curve of C-1 was quite unstable because of the presence of a large amount of bran (Maeda and Morita 2001), so it was impossible to determine the mixing properties of C-1. The water absorption of polished flours C-5 and C-8 were significantly higher by 38 and 19%, respectively, than the CW. Polished flours contain large amounts of pentosan (CW, 1.33%; C-1, 11.30%; C-5, 3.31%; C-8, 2.29%), damaged starch (CW, 15.47%; C-1, 16.54%; C-5, 39.06%; C-8, 27.95%), maltose value (CW, 267 mg/10 g of flour; C-1, 486 mg/10 g of flour; C-5, 618 mg/10 g of flour; C-8, 618 mg/10 g of flour), and dietary fiber (CW, 2.1%; C-1, 32.8%; C-5, 5.7%; C-8, 3.8%) (Maeda and Morita 2001). Therefore, this result might be caused by larger amounts of dietary fiber and damaged starch, as compared with CW. In addition, the larger amount of water-soluble pentosans in polished flours has a higher water-holding capacity than CW, retaining more water than protein. Although C-5 had the highest water absorption among all samples, the dough stability was quite excellent with the significantly largest valorimeter value and smallest weakness among all samples tested, indicating that the mixing properties of C-5 were similar to those of CW rather than C-8.

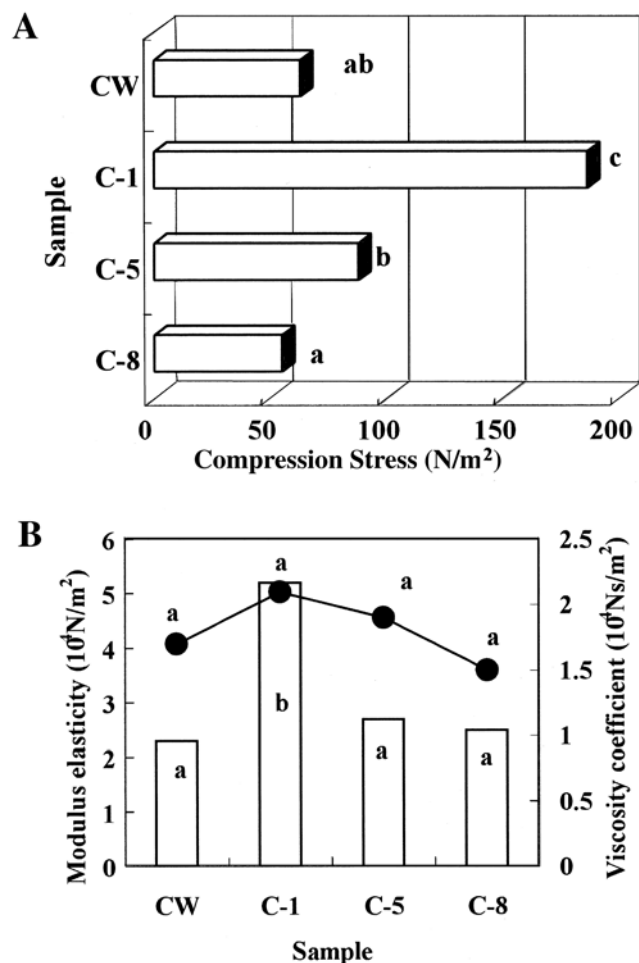
Table III shows dough properties of various wheat flours obtained from extensigraph curves. Resistance ( $R$ ) and extensibility ( $E$ ) of doughs made from polished flours clearly decreased compared with the CW. The dough properties of polished flours from these parameters were inferior to those of CW; however, the  $R/E$  ratio of polished flours was significantly larger than that of CW. The  $R/E$  values for C-5 and C-8 were significantly (1.2× to 2.2×) greater than those of CW during aging from 45 min to 135 min. The larger amounts of water-soluble pentosans and damaged starch in polished flours would be associated with the larger increasing ratio of  $R/E$ , as compared with CW. Therefore, the dough maturity of polished flour was increased in the ratio of  $R/E$  during aging. The maturation of polished flours contributed to good bread quality.

### Effects of Baking Methods on Dough Properties

*Viscoelastic properties.* CW doughs made from various baking methods showed similar viscoelastic parameters, and there were no significant differences among the four baking methods (data not shown). Therefore, the viscoelastic properties of dough mixed with CW could not be affected by baking method. In contrast, the parameters of doughs mixed with polished flours by SDM were the lowest among all baking methods, and the viscoelastic prop-

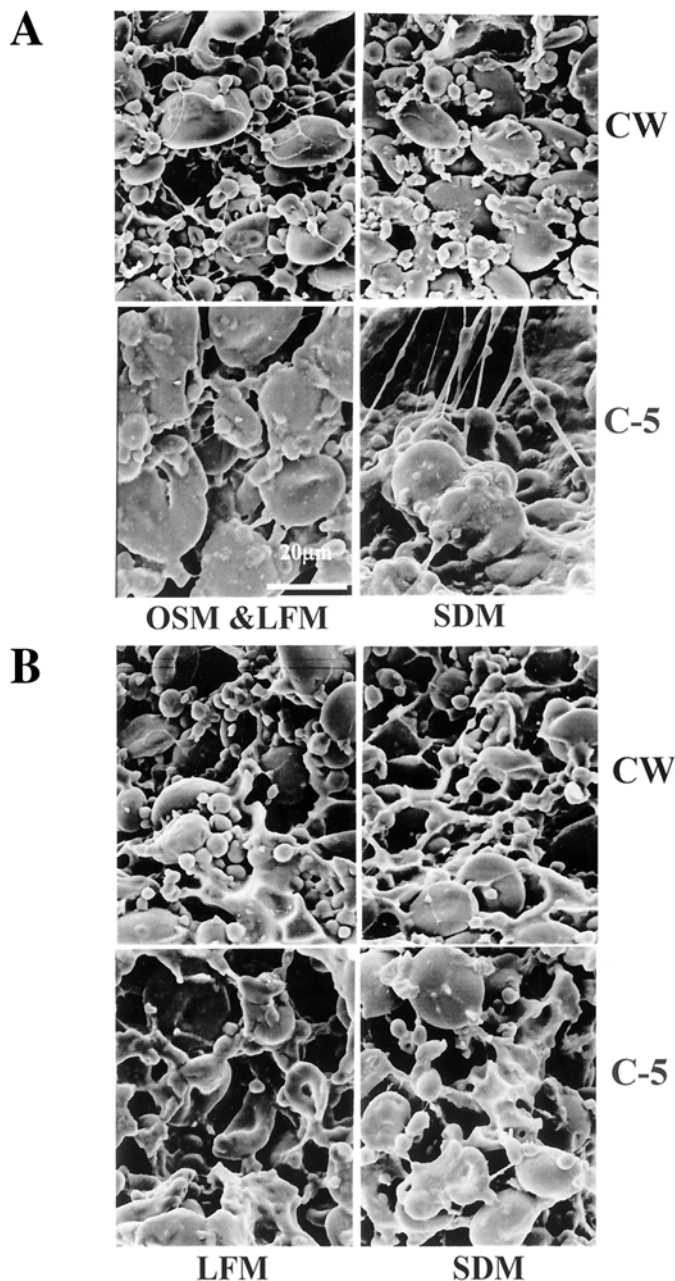
erties of polished flour doughs could be significantly changed, depending on the baking method.

For fermented dough samples, all parameters of polished flour doughs prepared by SDM decreased with some significant differences compared with OSM and NTM. C-5 showed similar viscoelastic properties for long fermentation of LFM and SDM. The compression stress, modulus elasticity, and viscosity coefficient of polished flour doughs prepared by SDM were not significantly different from those of CW, except for C-1 (Fig. 2). The differences in the water content among the dough samples might affect the dough properties. SDM significantly improved the dough properties of polished flours, but not those of CW after mixing. The polished flour doughs prepared by OSM, LFM, and NTM were still firm, but SDM softened the dough more than the other methods, and this method produced dough properties similar to those of CW after fermentation.



**Fig. 2.** Compression stress (A) and viscoelasticity (B) of wheat flour doughs fermented by sponge-dough method. Values indicated by the same letters in the same parameter are not significantly different ( $P < 0.05$ ).

**SEM results.** Figure 3 shows SEM images of dough made using OSM, LFM, and SDM after mixing and fermentation. The gluten matrix of CW dough made using OSM and LFM methods contained



**Fig. 3.** SEM images of mixed (A) or fermented (B) doughs by various baking methods. CW, common hard-type wheat flour; polished flours C-1 (100–90%), C-5 (60–50%); C-8 (30–0%) of wheat grain. Optimized straight (OSM), long fermentation (LFM), sponge dough (SDM) and no-time (NTM) methods.

**TABLE III**  
Extensigraph Data of Various Polished Wheat Flours<sup>a</sup>

Sample <sup>b</sup>	R (BU)			E (cm)			R/E (BU/cm)			Area (cm <sup>2</sup> )		
	45	90	135	45	90	135	45	90	135	45	90	135
CW	500b <sup>c</sup>	525b	541b	18.4b	17.5c	16.9c	27.3a	30.1a	32.0a	2,393b	2,655c	2,540c
C-1	—	—	—	—	—	—	—	—	—	—	—	—
C-5	322a	433a	473a	9.7a	9.4b	9.1b	33.4b	46.5b	52.0b	931a	1,104b	1,099b
C-8	307a	428a	498a	9.2a	7.7a	7.2a	33.4b	56.2b	69.7c	805a	821a	828a

<sup>a</sup> R, resistance to extension; E, extensibility; R/E, ratio between resistance and extensibility.

<sup>b</sup> CW, common hard-type wheat flour; polished flours C-1 (100–90%), C-5 (60–50%), C-8 (30–0%) of wheat grain.

<sup>c</sup> Values followed by the same letter in the same column are not significantly different ( $P < 0.05$ ).

a thread-like substance covering starch granules after mixing, whereas CW dough made using SDM included a slightly thicker gluten substance than those made using OSM and LFM. Although polished flours contained large amounts of dietary fiber to suppress the satisfactory gluten structure for breadmaking, the C-5 dough mixed by SDM appeared to be more viscous than CW dough. In addition, the sticky substance was still observed in C-5 dough mixed by OSM or LFM. The SEM images of fermented C-5 dough samples were similar to those from CW dough, and polished flours could make a better gluten structure in the dough after mixing and fermentation using LFM and SDM. The unique appearance of polished flour doughs in SEM images coincided with the results of viscoelasticity of polished flours as described above.

### Effects of Baking Methods on Bread Qualities

**Specific loaf volume.** SDM increased the loaf volume of all bread samples (Table IV). The specific volume of bread made from polished flours was lower than that of CW, and the loaf volume of polished flours decreased in the order of C-8, C-5, and C-1. Although there was no significant difference in the results of CW bread among OSM, LFM, and SDM, the specific volume of polished flour breads was improved by using SDM compared with other baking methods. C-5 bread had significantly increased loaf volume. In addition, we noted that the NTM for C-8 significantly increased the specific volume of bread by  $\approx 40\%$  more than OSM, while CW bread was distinctly decreased by NTM. The SH residue derived from bran or germ in the innermost fraction of C-8 might be oxidized by L-ascorbic acid and L-cysteine during NTM, resulting in loaf volume larger than from OSM or LFM.

**Firmness of breadcrumb during storage.** The firmness of CW breadcrumb after storage for 2 or 5 days was not significantly different among various baking methods (Table V). Therefore, the storage property of CW bread was not affected by the baking method. In contrast, the bread made from polished flours using SDM suppressed the staling of breadcrumb more than other baking methods. In particular, the softness of breadcrumb made from C-5 was quite similar to that from CW, and there were no

significant differences in the results after storage for 5 days between the CW and C-5 breads (Fig. 4).

**Textural properties of breadcrumb after baking.** C-5 bread made using SDM showed significantly higher elasticity than other samples stored for 0 and 5 days, and also cohesiveness of the breadcrumb after storage for 2 or 5 days was significantly larger than that of CW breads (data not shown). Furthermore, the ratio of decrease in the cohesiveness for the polished flour breads during storage was lower than that of CW bread, and this result might be correlated to suppressing the staleness of breadcrumb.

**Image analysis of crumb grains.** CW bread gas cells had the largest size (1.21–1.66 mm) of all samples tested, and the bread baked using SDM had the largest size among all baking methods (data not shown). The C-5 breadcrumb made using SDM had larger gas cells than those from other baking methods, which might be due to the SDM improvement of softness of breadcrumb as described above. Although the larger water content in dough and bread would generally affect the bread qualities, the application of SDM using polished flours was important in improving the bread qualities.

Water-soluble pentosans improve the baking properties (Kim and D'Appolonia 1977) and water-soluble fractions have contributed to gas holding, gluten maturity, and extensibility (Matsumoto 1980; Grant and D'Appolonia 1991). In addition, pentosans influence the extent of retrogradation simply by forming hydrogen bonds with amylose and amylopectin (Pomeranz 1988b). From these results, the large amounts of damaged starch, pentosans, and dietary fiber or high maltose value in polished flours would produce poor dough properties (Pomeranz et al 1977; Tanaka and Matsumoto 1997; Maeda and Morita 2001). But the long fermentation process of SDM would cause these substances to be used effectively for improving maturity and gas holding properties of polished flours, producing the dough and baking properties similar to those of CW.

TABLE IV  
Effects of Various Baking Methods<sup>a</sup> on Specific Volume of Bread

Sample <sup>b</sup>	Specific Volume (cm <sup>3</sup> /g)			
	OSM	LFM	SDM	NTM
CW	4.72abc	5.27b	5.49b	4.23a
C-1	1.12a	1.35a	1.30a	1.27a
C-5	1.76a	1.88a	2.25b	1.83a
C-8	1.91a	2.03a	2.35b	2.35b

<sup>a</sup> Optimized straight (OSM), long fermentation (LFM), sponge-dough (SDM) and no-time (NTM) methods.

<sup>b</sup> CW, common hard-type wheat flour; polished flours C-1 (100–90%), C-5 (60–50%), C-8 (30–0%) of wheat grain.

<sup>c</sup> Values followed by the same letter in the same row are not significantly different ( $P < 0.05$ ).

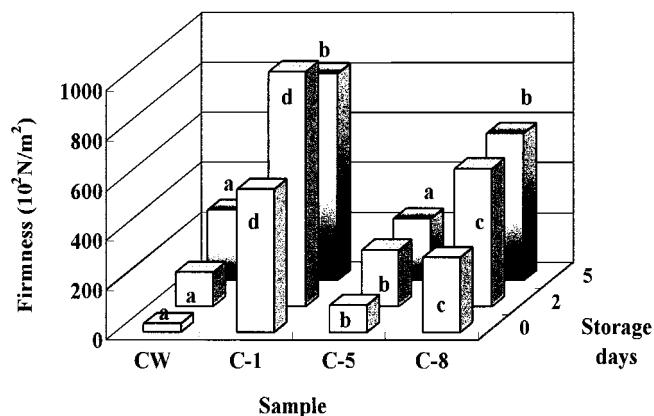


Fig. 4. Comparison of staleness during storage of breads baked by sponge-dough method. Values indicated by the same letters in the same day are not significantly different ( $P < 0.05$ ).

TABLE V  
Effects of Various Baking Methods<sup>a</sup> on Staleness of Breadcrumbs During Storage<sup>b</sup>

Sample <sup>c</sup>	0 days				2 days				5 days			
	OSM	LFM	SDM	NTM	OSM	LFM	SDM	NTM	OSM	LFM	SDM	NTM
CW	59.8bcd	47.0b	36.4a	73.0c	162.8a	140.4a	137.4a	226.0a	262.8a	265.6a	282.5a	284.2a
C-1	751.8a	814.2a	577.0a	699.0a	442.4a	764.0bc	944.0c	650.4b	1,154.2c	1,053.0bc	830.8ab	724.2a
C-5	300.8c	198.0b	111.0a	240.0b	897.6d	318.8b	228.0a	384.6c	415.0a-c	367.6b	249.0a	478.0c
C-8	364.4b	312.2ab	303.6ab	282.2a	706.6c	633.2bc	555.4ab	487.6a	940.2c	844.4bc	592.4a	787.8b

<sup>a</sup> Optimized straight (OSM), long fermentation (LFM), sponge-dough (SDM) and no-time methods (NTM).

<sup>b</sup> Firmness after storage (10<sup>2</sup> N/m<sup>2</sup>).

<sup>c</sup> CW, common hard-type wheat flour; polished flours C-1 (100–90%), C-5 (60–50%), C-8 (30–0%) of wheat grain.

<sup>d</sup> Values followed by the same letter in the same row are not significantly different ( $P < 0.05$ ).

## CONCLUSIONS

The mixing stability of C-5 dough was expected to be similar to that of CW dough, and C-5 and C-8 doughs had higher maturity than CW dough, as determined from extensogram curves. As for the effects of baking methods, viscoelastic properties of dough fermented by SDM were reported at levels similar to those of CW, and the viscoelasticities of C-5 and C-8 doughs prepared by SDM were improved during fermentation. The polished flours could make a more viscous dough structure with better gluten matrix after mixing or fermentation when using LFM and SDM. Compared with other methods, the use of SDM for polished flours suppressed the staleness of breadcrumb with even distribution and size of gas cells. SDM could make C-5 bread with the same storage properties as CW bread after storage for 5 days, and produce breadcrumb with significantly higher elasticity and cohesiveness when compared with the CW sample. From these results, SDM with long fermentation was considered suitable for improving the poor dough and baking properties of polished flours. The use of SDM with polished flours could produce bread with better qualities because of the high maturation and tolerance to various handling or mechanical processes during fermentation.

## ACKNOWLEDGMENTS

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