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Firming Properties of White Pan Breads Made by Different Baking Methods

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<Abstract>

It is generally believed through baker's experiences that a bread made with longer fermentation time exibits better quality in softness and firming rate. This is explained due to variable organic acids and alcohols produced during dough fermentation. The firming rate of bread is considered to be affected also by the dough mixing method, not only by fermentation time. That is, a dough developed slowly with sufficient time gives loaves of slower firming rate, compared with a dough mixed up in a second with a high speed mixer. But the most suitable baking formula may be fairly different for each baking method and also for an individual baker according to his/her targeting quality and preference. Therefore the relation between baking method and firming rate that is generally perceived through a baker's experience is not simply reflecting fermentation time and mixing method. Then in this report the effect of dough fermentation time and mixing method on firming rate is examined. Three factors (baking formula, specific loaf volume, residual loaf sugar) affecting bread firming rate were taken into consideration in this study. As a result, there was only, very small difference observed in firming rate between sponge dough process of the longest fermentation time and short-time dough process of the shortest fermentation time among various baking methods. Conventional dough mixing also showed little difference in bread firming from high speed mixing. This fact suggests that firming properties of bread are largely affected by baking formulas rather than by fermentation time or dough mixing methods.

Key words: Bread, Firming, Baking method

INTRODUCTION

Sponge dough process, straight dough process and short-time dough process are the major baking methods widely used over the world for the baking of white pan breads[1]. Sponge dough process is suitable for machinery automated baking since the dough has moderately extensible characteristics for machinery handling. But this method is fairy time consuming due to the hours of sponge fermentation required. Straight dough process is popular in Japanese retail bakers since it gives better flavor and texture to breads and it can reduce baking time. The method is not preferred by large whole sale bakers since the dough is intolerable for machinery handling. Short-time dough process is utilized in the U.S. retail bakers since it has the shortest fermentation time. In the U.S. and England, high-speed mixer is widely used for short-time dough process in order to shorten the baking time as much as possible.

Generally, it is said that sponge dough bread gives much longer shelf life on crumb softness compared with short-time dough bread[1)2)]. The difference in firming between these two baking processes is due to following features. Longer

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fermentation gives enough time to the dough for maturation and water hydration, which improves moisture retention of the bread causing late staling characteristic. Gluten network is well developed by the double mixing causing very extensible dough, as the result, gas retention power of the dough is improved to give better oven-spring to the bread. The high-speed mixing bread is believed much inferior than the conventional mixing bread.

When bread staling characteristics and shelf-life are discussed in relation to various baking methods, crumb firming property is regarded as the most significant marker. Firming rate of the bread made by sponge dough process is said to be slower than that made by the short-time dough process. Also, when we talk about the difference between the conventional mixing and the high-speed mixing method, the firming of the latter mixing bread is perceived to be much faster than the other. However, these observations are learned by experience and little scientific studies have apparently been done so far to obtain conclusive data in this area. The most suitable baking formula established for each baking method is fairly different. Furthermore, an individual baker has its own targeting quality and preference. Therefore the relation between baking method and firming rate that is generally perceived through baker`s experience is not simply reflecting fermentation time and mixing method.

A question is that in what degree the baking method itself, that is, fermentation time and mixing method affect the bread firming property, when the factors (baking formula, specific loaf volume, residual loaf sugar) affecting to firming rate are eliminated. So in this research, two different baking methods, that is, sponge dough process which has the longest fermentation time and short-time dough process which has the shortest fermentation time among various baking methods, are compared. And two mixing methods were compared for short-time dough process: the conventional mixing and the high-speed mixing.

The difficulty in this study is that the crumb grain structure is very hard to control to obtain same structure for three different baking methods. It is obvious that grain pore size and thickness of cell wall affects crumb firmness significantly. There is no standard analytical method established for examining bread grain structure so far. The most standard way for that is eye observation by baking experts. So in this study, the grain structure was examined by three baking experts and the result was taking into account for results and discussion.

Formulation for different baking methods was identical, except for the yeast and oxidation level. To achieve the purpose of this study, strong attention has to be paid to eliminate or minimize such factors that would affect the crumb firming and the crumb starch retrogradation, that is for example, the specific volume of loaves, ingredients (wheat flour[3], shortening and emulsifier[4]), moisture redistribution during storage[5], dough-forming technique[6], baking temperature[7] and so on. Especially the care was taken as described in the following section of materials and methods to be sure that specific volume for all the breads were essentially identical to remove this variable as a factor in firming studies. Also the type and the amount of the fat and the yeast food are very critical for the bread staling[8]. Several commercial shortening contains an emulsifier that affects significantly the bread staling. Several yeast foods contain a crumb softener which also affect the bead staling significantly. Therefore the choice of ingredients is carefully considered.

Though early studies suggested that the sugar content in the formula does not affect the firmness of the bread[9),10),11)], recent studies showed the sugars affects the starch retrogradation to some extent[12),13),14)]. Therefore we tried to minimize the effect of the residual sugar on bread staling, selecting adequate sucrose level in formula. In former days, several studies have been done to trace fermentable sugars throughout sponge dough process[15)] and liquid pre-ferment process[16)]. And unfortunately there is little information concerning residual sugars in breads baked by short-time

dough process with the use of conventional mixer and high-speed mixer. So in order to collect the information in this area aiming to find out a way to adjust the residual sugar balance of final loaf of breads baked by different baking method, major residual sugars of white pan bread baked by no-time dough process had to be compared to those baked by sponge dough process, with the variation of formula sucrose level at the initial stage of this study. High performance liquid chromatography (HPLC) was used for sugar qualification at the experimental condition modified from previous workers[17),18)].

MATERIALS AND METHOD

Flour

Bromated (10ppm) bread flour was obtained from Ross Milling Co. (Kansas City Kansas). Lot of wheat flour is different between residual sugar analysis and firming analysis. Laboratory analysis for the flour used for residual sugar analysis showed 13.7% moisture, 11.9% protein and 0.48% ash on dry basis. Farinograph showed 61.4% water absorption and 6.5min peak time. Amylograph peak viscosity was 580B.U. Falling number was 206, indicating a typical commercial malt level. Laboratory analysis for the flour used for firming analysis showed 12.9% moisture, 11.1% protein and 0.45% ash on dry basis. Farinograph showed 60.4% water absorption and 5.5min peak time. Amylograph peak viscosity was 615B.U. Falling number was 220, indicating a typical commercial malt level.

Sponge Dough Process

A Hobart mixer, Model A-200 was used for mixing sponge and dough. Sponge was mixed for 3min at speed 1 to achieve 24-25℃ sponge temperature and fermented for 4hrs at 29℃ and 86% humidity to reach proper ripeness. Dough ingredients were pre-mixed and were mixed for 5min at speed 2 to optimum development achieving 27-28℃ dough temperature. After 30min dough rest at 29℃ and 86% humidity, dough was scaled into 539g pieces and rounded. Intermediate proof period of 20min was taken at 24℃ and 75% humidity. Oshikiri Moulder Model MS was used for moulding, then proofed to height (1.5cm above pan) at 41℃ and 92% humidity for about 1hr. Dough was baked at 218℃ for 20min in Reed Reel Oven (Bakers Engineering & Equipment Co.), then cooled on the steel rack for 1hr at 24℃ and 75% humidity. Loaf was wrapped by twice in a moisture-proof plastic bag with sucking the internal air without deforming the loaf shape. Loaves were placed on the steel rack at 24℃ and 75% humidity for following experimental work.

Short-time Dough Process

Conventional mixing and high-speed mixing were performed. A Hobart mixer, model A-200 was used for conventional mixing and dough was mixed for 6min at speed 2 to get optimum development. Mono high-speed mixer, model 35F with a rotation speed of 475rpm and a propeller length of 33.0cm was used for high speed mixing. Dough was mixed for 30sec at first, then after scraping down the ingredients, mixed again for another 3min to obtain optimum development. Dough temperature after mixing was 27-28℃ for both mixing methods. Dough was rested for 15min in a fermentation cabinet at 29℃ and 86% humidity, then scaled into 539g pieces. After rounded, the dough had an intermediate proof period of 10min at 24℃ and 75% humidity. Oshikiri Moulder, Model MS was used for moulding the dough and the dough was proofed to height (1.5cm above pan) at 41℃ and 92% humidity (approximately 70min for the conventional mixing dough and 75min for the high-speed mixing dough). Following steps were the same as sponge dough process mentioned previously.

Baking Formula

Typical baking formula described by Dubois[19)], Kulp and Dubois[20)] was used with little modifications to permit more accurate comparison of the baking methods. For residual sugar analysis, sucrose level in formula varied from 1% to 8% as shown on Table 1. The formula

shown on Table 2 was used in the firming analysis and gave similar residual fructose and glucose levels in all experimental loaves. The estimated residual sugars in loaves are: Fructose 1.5% and Glucose 1.0%, w/w.

Bread Crumb Moisture Determination

Bread moisture was determined according to AACC method 44-15A. There was no significant difference at α=0.05 level of statistical LSD test among bread moisture derived from different formula sucrose level for residual sugar analysis.

Extraction of Residual Sugars from Bread Crumb

The ethanol-water solvent was applied for sugar extraction from bread crumb as by Birch and Green[18] with some modifications. 50g of bread crumb was placed in a 500ml flask and 250ml of 80% ethanol was added. After shaking the flask intensely for 3min, it was placed in a water bath at 60℃ with vacuum moderate shaking for 60min. After the mixture was filtered roughly with vacuum through a Whatman No.2 filter paper, it was filtered again carefully through Whatman No.5 filter paper and washed several times with a small amount of 80% ethanol with vacuum. The filtrate was evaporated to about 15ml in a rotary vacuum evaporator at a bath temperature of 50℃, then placed in a centrifuge tube, and evaporation flask was washed several times with a small amount of distilled water, then taken into the same centrifuge tube. Since fat mostly stuck to evaporation flask, defatting process was eliminated. The solution was centrifuged at 10,000rpm for 5min. After carefully taken without disturbing the bread crumb residue on the bottom of the centrifuge tube, the supernatant was diluted up to accurately 25ml with a volumetric flask. The frozen sample was thawed at room temperature (c.a. 25℃) just before chromatographic analysis.

HPLC

HPLC equipment was: Varian (Pala Alto, CA) high performance liquid chromatograph (Model 5000), Varian Aerograph refractive index detector (cell volume, 6 ml), Houston Instrument (Austen, Texas) Omniscribe TM Recorder (100mV full scale, chart speed variable), Alltech (Arlington Heights, IL) analytical column (length 30cm, 4.6mm I.D.) packed with Alltech Bondapack NH_2, particle size 10μm Universal Guard Column, length 4cm, 4mm I.D., packed with Alltech pellicular (40μ) amino packing material. Sugar standards (Fructose, Glucose, Sucrose, Maltose, Lactose) were the highest purity grade from Fisher Scientific Co. (Fairlawn, NJ). Peak area was calculated in concern to sugar quantity, because peak height did not gave satisfactory correlation to sugar quantity. The correlation factors of regression lines between peak area and sugar quantity were more than 0.9990 for all sugar standards, indicating excellency of standard curve obtained in this study. Following two different conditions were undertaken to acquire the best analytical result for each sugar. Experimental conditions were: eluant; 85/15, acetonytolyle/water; flow rate; 1.0ml/min for qualification of glucose and fructose, and 1.5ml/min for quantification of sucrose and maltose, temperature; 25℃, injection; 10μl, refractometer; ×2, chart speed of recorder; 0.5cm/min.

Firmness Measurement

Firmness measurements were undertaken at day 0 (2hours after baking), and from day 1 (24hours) to day 8 (192hrs), after every 24hrs, using the Voland Stevens LFRA Analyzer (Voland Corporation, Hawthrone, NY) adjusted as follows: penetration speed; 2.0mm/sec, penetration distance by thumb wheel; 4mm, mode selection; normal, load choice 1-1000g in 1g increments. A cut slice of loaf was placed on the table of the texture analyzer and adjusted to the height ensuring that the probe was placed 5mm apart from the surface of a loaf slice. Load was displayed digitally in gram and the unit of maximum load was measured as the crumb firmness for each loaf slices. Six of 2.5cm thick slices were taken from each loaf (two slices from each end were discarded) for firmness measurements and average firmness values of six slices were used as the representative crumb firmness of the loaf. Measurements were made

on the center of each slices. The direction of applied force was from ends towards the center. Two loaves from two different doughs were used for each measurement and those values were averaged to represent the crumb firmness of the loaf for each experimental condition. After measuring the firmness of loaves, loaves were discarded and new loaves were taken for firmness measurement on the next measurement.

Water Activity Measurement

Water activity was measured with a Beckman Water Activity Meter (Beckman Instruments, Inc., Cedar Grove, NJ) Model VFB, using a 75-100% R.H. module. For the measurements at 24℃, the sensor was covered with a cardboard box to prevent air flow from changing the temperature of the sensor rapidly. For each measurement, at least one hour was elapsed before the sensor equilibrated, then readings were taken. The central portion of the loaf, with 5mm thickness, was sliced and placed into the plastic sample cap. Two loaves were used for each measurement and the readings were averaged.

Amylograph

Amylogram on bread crumb was measured as described by Yasunaga *et al.*[21] with some modifications. The loaf of bread was taken out of the plastic bag, then was cut into 2cm-thick slices. The outer 2 slices from each end were discarded and the remained five slices were used for the analysis. About 1cm-thick portion of crust-containing layer of each slices were discarded and 95g crumb was weighed accurately. 95g bread crumb was soaked in 300ml distilled water at 25℃ for 1 hr and dispersed with a Waring Blender (15sec at low and 60sec at high-speed) to form smooth slurry. This slurry was transferred into an Amylograph bowl and further 150ml of distilled water was added. Amylogram was determined with a pin cartridge at normal heating cycle.

Statistical Method

Analysis of variance (Least Significant Difference Test)[22] was applied for analyzing the data statistically for crumb firmness, Amylograph peak viscosity, moisture and water activity of bread crumb, and bread crumb color, using the SAS computer program.

Table 1. Baking formula used for residual sugar analysis

Ingredients[a]	Sponge Dough Process			Short-Time Dough Process
	Sponge	Dough	Total	
Flour[b]	70	30	100	100
Water	40	23	63	63
Yeast[c]	2.5	—	2.5	3.5
Yeast Food[d]	0.5	—	0.5	0.5
Salt	—	2.0	2.0	2.0
NFDM[e]	—	2.0	2.0	2.0
Shortening[f]	—	2.5	2.5	2.5
SSL[g]	—	0.5	0.5	0.5
Sucrose	—	1~8	1~8	1~8

[a] Ingredients, % based on total flour weight.
[b] Bromated to 10 ppm.
[c] Though yeast % is expressed as fresh yeast, Instant Active Dry Yeast (IADY) was used in the actual experiment in the followin manner: IADY % = 0.4 × Fresh Yeast %.
[d] Arkady, components are calcium sulfate, ammonium sulfate, azo-dicarbon amide, Archer Daniels Midland Co., Decatur, IL.
[e] Non Fat Dry Milk.
[f] Non emulsified shortening, Archer Daniels Midland Co., Decatur, IL.
[g] Sodium Stearoy 1-2-Lactylate, C.J.Patterson Co., Kansas City, MO.

RESULTS AND DISCUSSION

Residual Sugar Analysis

In this research, the most attention was paid to minimize the effect of ingredients on the bread staling between two different baking methods. So as shown on Table 1, the content of each ingredients in the formula is set to be equal between sponge dough process and short-time dough process except yeast content. The reason why the yeast content can not be set at the same amount is that yeast content is a critical key factor to decide the baking method as far as the fermentation time is essentially different from the each baking method. That is, in other word, the balance between the yeast content and fermentation time is very crucial to avoid over- and under-fermentation of the dough to get the favorable quality in the final loaves.

Residual fructose, glucose, sucrose and maltose in loaves were quantified. Lactose is derived from formula NFDM (Non Fat Dry Milk) and is not fermented by Baker's yeast as described by Ponte[1]. Thus, lactose may be neglected as far as same amount of formula NFDM is used for all the experimental baking, since the residual lactose content in final loaves should be at the same level. At the HPLC analysis, two different flow rates were performed for the accurate determination of each sugar. That is, for the quantification of fructose and glucose, the flow rate of 1.0ml/min was adopted. Here, referring to the HPLC analysis, the correlation factor of regression lines between peak area and fructose quantity was 0.9998. The correlation factor for glucose was 0.9999. For maltose, the flow rate of 1.5ml/min was adopted, and the correlation factor was 0.9999. These correlation factors are very satisfactory for the accurate quantification. No trace of sucrose was identified through all the analysis, since sucrose added in formula is mostly inverted

Fig. 1 graphically summarizes the three kinds of residual sugar (fructose, glucose, maltose) content when formula sucrose level was varied from 1 to 8% as a baker's percentage. The pattern of increase in residual fructose and glucose of final breads seems to be similar among three different baking experiments. These two residual sugars are derived from formula sucrose. The reason why the glucose level is lower in amount than fructose is that yeast ferments glucose faster than fructose as described by Tang *et al.*[23] and Ponte[1]. Difference in residual fructose and glucose between sponge dough bread and short-

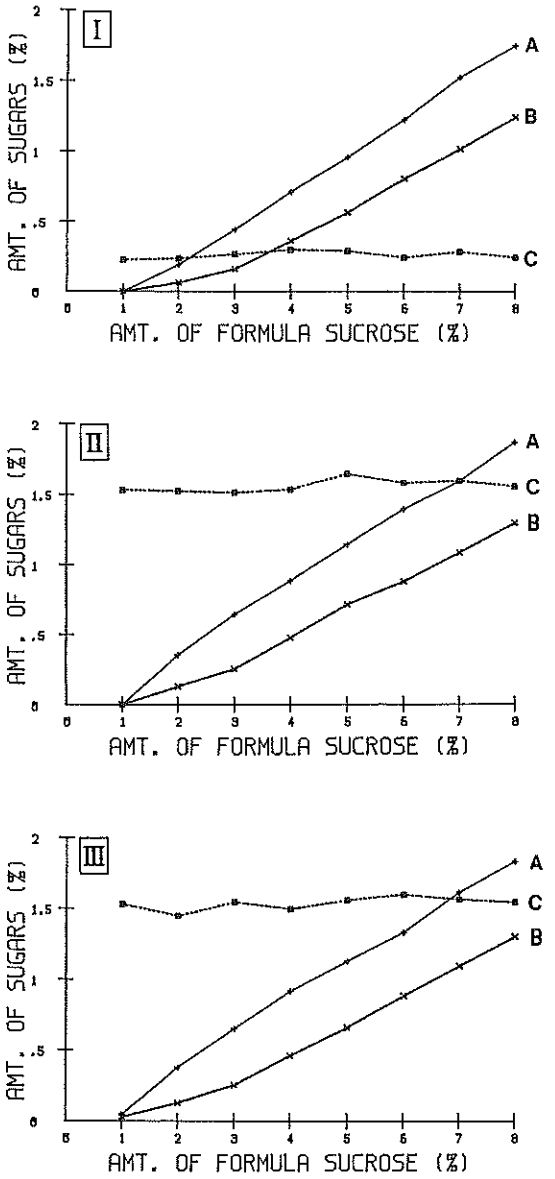

Fig. 1 The amount of residual sugars in loaves baked with different baking methods and with various formula sucrose. I. Sponge dough bread, II. Conventional mixing bread, III. High-speed mixing bread. A: Fructose, B: Glucose, C: Maltose.

time dough bread is much more slight at the higher formula sucrose levels probably because of a balance between fermentation time and yeast level. There was no significant difference observed between conventional mixing bread and high-speed mixing bread for short-time dough process.

Residual maltose showed obvious difference between two different baking methods. Maltose appears in final loaves by the digestive action of starch with α- and ß-amylase. Thus longer fermentation gives more time for starch degradation by amylases. Residual maltose showed similar level even if the amount of sucrose in formula varied for each baking method. Sponge dough bread showed lower level than short-time dough bread, probably because yeast does not have enough time to metabolize maltose for short-time dough process. The increase of glucose was slightly slower at lower formula sucrose levels presumably because yeast requires that amount of sugar to satisfy metabolism requirements. This result agrees with previous works[1),11),15),16),23)].

According to this study, we found that the content of the residual fructose and glucose in the final loaves can be control to be similar level by adjusting the sucrose amount in formula. Though the residual maltose is difficult to regulate to be similar level at the two different baking methods, as far as we have the precise information on the residual maltose in the final loaves shown in this result, it would be very possible to discuss and to clarify the difference of the effect of baking methods on the bread firming properties.

Firming Analysis

The physical critical factors to affect crumb firmness of fresh bread are the specific volume of loaves[6)] and the crumb grain structure. Since grain structure is hard to control for different baking methods, we have to take the result into account for discussion. But the specific volume of loaves can be controlled by the use of an oxidant. Potassium bromate ($KBrO_3$) was used as an oxidant in this study to adjust the specific volumes of white pan breads baked by sponge dough and short-time dough processes to similar

Table 2. Baking formula used for firming analysis

Ingredients[a]	Sponge Dough Process			Short-Time Dough Process
	Sponge	Dough	Total	
Flour[b]	70	30	100	100
Water	40	23	63	63
Yeast[c]	2.5	—	2.5	3.5
Yeast Food[d]	0.5	—	0.5	0.5
Sucrose	7.0		7.0	7.0
Salt	—	2.0	2.0	2.0
NFDM[e]	—	2.0	2.0	2.0
Shortening[f]	—	2.5	2.5	2.5
SSL[g]	—	0.5	0.5	0.5
Bromate Soln.[h]	Variable	—	Variable	Variable

[a] Ingredients, % based on total flour weight.
[b] Bromated to 10 ppm.
[c] Though yeast % is expressed as fresh yeast, Instant Active Dry Yeast (IADY) was used in the actual experiment in the followin manner: IADY % = 0.4 × Fresh Yeast %.
[d] Arkady, components are calcium sulfate, ammonium sulfate, azo-dicarbon amide, Archer Daniels Midland Co., Decatur, IL.
[e] Non Fat Dry Milk.
[f] Non emulsified shortening, Archer Daniels Midland Co., Decatur, IL.
[g] Sodium Stearoy 1-2-Lactylate, C.J.Patterson Co., Kansas City, MO.
[h] 1% of Potassium bromate solution was prepared with water just before baking.

levels such that the effect of specific volume on crumb firmness was minimized (Table 2). Fig. 2 shows the effect of potassium bromate on the specific volume of white pan bread made by each different baking method. Four loaves from two different doughs were taken at each bromate level to average the obtained data. This result indicates that the commercial flour used in this study was already oxidized by bromate to the optimum level for sponge dough process. An interesting observation is that high-speed mixing enhances oxidation. According to this result, the bromate dose was decided differently for each baking process as follows: 0ppm for sponge dough process, 80ppm for short-time dough process with conventional mixing, 50ppm for short-time dough process with high-speed mixing. Here, though the significant difference in crumb grain structure was not observed between sponge dough bread and short-time dough bread with conventional mixing, there was obvious difference observed between two mixing methods. High speed mixing yielded more coarse crumb grain with uneven pore size and with thick cell wall compared with other methods. The more elastic gluten net work is formed by gradual mixing of the dough. Probably the gluten network obtained from high speed mixing must be comparatively crumble or may be fragile, therefore fermentation gas produced by yeast can not be retained uniformly. This is also the reason for the thick cell wall of the bread crumb. Also it is possible that the harsh aeration gives uneven size of air bubbles into the dough causing uneven crumb grain. The firmness of the bread baked by high-speed mixing method will be affected by the coarse grain structure.

Fig. 3 graphically summarizes the daily changes in crumb firmness of stored white-pan bread baked by different baking methods over an eight-day period. Statistical ANOVA analysis showed that the crumb firmness of short-time dough bread with conventional mixing is not different from other two baking methods until 7 days period, but significantly different at day 8 at α=0.05 level. The crumb firmness of sponge dough bread is significantly different from that of short-time dough bread with high speed mixing over more than 4 days period at α=0.05 level. The moisture content (mean=37.5 %) and the water activity (mean=0.967) of all the experimental loaves served in this study were equal at α=0.05 level, indicating these two factors are not affecting the purpose of this study.

Because bread is served as fresh food, shelf life of bread should be discussed within five days stock period. On that point, the result in this study seems not to agree with general observations experienced by baking industry. These firming differences are relatively smaller than the perceived experience in the industry. Actually,

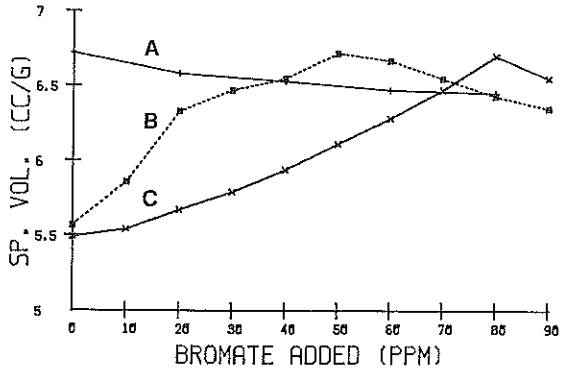

Fig.2 The effect of potassium bromate on the specific volume of white pan bread made by different baking methods, A: Sponge dough process, B: Short-time dough process with high speed mixing, C: Short-time dough process with conventional mixing

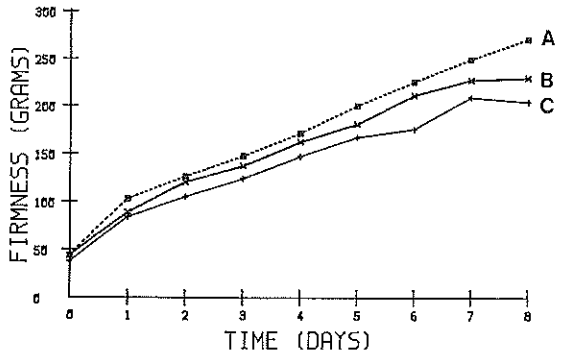

Fig.3 The firmness of bread crumb made by different baking methods over an eight-day period. A: Short-time dough process with high speed mixing, B: Short-time dough process with conventional mixing, C: Sponge dough process

these small differences can be easily overcome by some adjustment of formula ingredients such as shortening content or the choice of kinds and amount of emulsifiers. Similar indication was pointed previously by Ponte[22] such that short-time dough bread containing a commercial dough conditioner was softer than sponge dough bread when stored for more than two days. In this study, the small difference in firming between sponge dough bread and short-time dough bread is caused by the difference in fermentation time, since other baking conditions are carefully adjusted not to affect the bread staling. The difference between sponge dough bread and short-time bread must be affected largely by the difference in crumb grain structure. But the difference is considered to be small as easily overcome by the use of a crumb softener or an anti-staling agent. On the experiment of short-time dough process, unexpectedly, different mixing methods yielded small differences in firming. This observation doesn't agree with the experience perceived in the baking industry.

Amylograms were obtained for each experimental loaves used for the crumb firming analysis. Fig. 4 shows an example of Amylograms obtained from stored breads crumb made by sponge dough method. As stored day passes, the Amylogram viscosity becomes higher. Other Amylograms obtained from different baking methods showed similar Amylogram patterns (data not shown). Fig.5 graphically summarizes the change in Amylogram peak viscosity (P.V.). The statistical ANOVA analysis showed that P.V. was significantly different by three baking experiments at α=0.05 level over more than 3 days period. This means the difference in P.V. appears earlier than crumb firmness. The peak viscosity of sponge dough bread was higher than that of short-time dough bread, while conventional mixing bread showed somewhat higher value than that of high-speed mixing bread. Though the crumb firmness showed very little difference among different baking methods, it is possible that this result in Amylograms is directly related to crumb firming change. It is indicated that the bread crumb which has higher firmness shows lower Amylograph P.V.

Starch forms a continuous phase in bread crumb and the starch granules swollen and elongated. During baking the dough, starch gelatinizes and the immiscibility of amylose and amylopectin forms two distinguishable, that is, amylose-rich and amylopectin-rich zones[24)25)]. This phase separation promotes leaching of amylose into intra- and intergranular regions. The

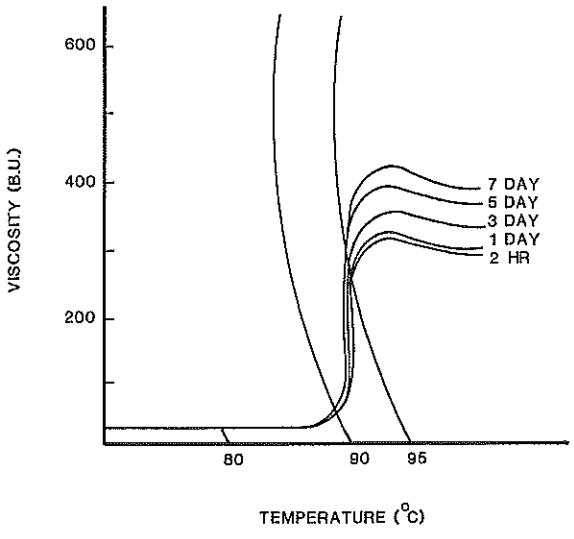

Fig.4 An example of Amylogram of bread crumb which was stored over a seven-day period.

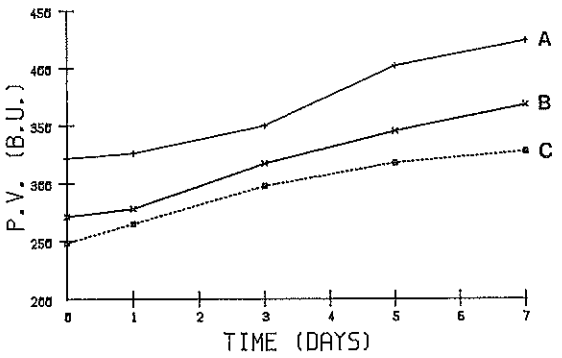

Fig.5 Amylograph peak viscosity (P.V.) of bread crumb made by different baking methods over a seven-day period. A: Sponge dough process, B: Short-time dough process with conventional mixing, C: Short-time dough process with high speed mixing

leached intergranular amylose is considered to be an essential structuring element of fresh bread crumb[26] and it directly decides the Amylograph P.V. Thus, as the content of the leached amylose increases, the Amylograph P.V. increases. The Amylogram obtained in this study indicates that leached amylose content differs by three different baking processes. That is, leached amylose content is highest in the bread baked by short-time dough process with high speed mixing, and the content is least in bread baked by sponge dough process. Why the difference in leached amylose content has caused? The amount of fermentation products may explain the difference between sponge dough process and short-time dough process. But there is also significant difference observed between two mixing methods. One of the possible reason to explain that is the association between starch molecules and gluten net work, since firming of bread involves cross-links between starch and protein by hydrogen bonds[27]. Yeast secrets β-amylase that reduces crumb firming[28]. Thus, as longer fermentation time is taken, more β-amylase is secreted into the dough by yeast. β-amylase does not act to raw starch, but it is assumed that only a small portion of leached amylose was degraded during the initial phase of starch gelatinization[28]. This may contribute to the softer crumb firmness of sponge dough bread.

Staled breads showed higher Amylograph peak viscosity. Reorganization of amylopectin is the primary cause for bread firming during aging[29]. During aging, amylopectin wchich is located inside the swollen starch granules, acts as physical cross-links in the continuous starch net work, resulting in increased rigidity. On the other hand, reorganization of amylose during aging result in clearly detectable birefringent zones by the observation with polarized microscopy[24]. This means that reorganization of amylose is also important for firmness. It is speculated[28] that both amylose and amylopectin form crystalline zones. The formation of cross-links by hydrogen bonds and entanglements between amylose and amylopectin have an impact on the mechanical strength of the interfaces between the amylose-rich and amylopectin-rich zones, which in turn influence the mechanical properties of bread. Therefore the increased Amylograph P.V. as aging can be explained by reorganization of amylopectin and amylose.

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製パン法の違いによる食パンの硬化特性

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＜要　旨＞

パンは発酵時間が長いほど柔らかく硬化速度も遅くて良いということが経験的に信じられてきた。これは発酵生産物である有機酸やアルコール類がパン骨格を適度に潤滑させるためと説明されている。またパンの硬化速度には、発酵時間だけでなく生地のミキシング方法も影響すると考えられている。つまり、緩やかに時間をかけて生地を捏ね上げて作ったパンは、高速ミキサーで一気に捏ね上げたものよりも硬化速度が遅い。しかしながら製パン法の違いによって適する基本配合は大きく異なり、さらに加工者の品質目標や好みによって用いる原材料や使用量が異なる。従って一般に経験的に認識されている製パン方法とパンの硬化速度の関係は、発酵時間やミキシング方法の影響だけを純粋に反映しているわけではない。そこで本報では、生地発酵時間の長短とミキシング法の違いがどの程度パンの硬化速度に影響を与えるのかを検証した。ここではパンの硬化速度に影響を与える３つの因子（製パン配合、パンの比容積、パンの残糖）を考慮して実験を行った。その結果、発酵時間の最も長い中種法と最も短い短時間法との間には僅かな差しか見られなかった。通常のミキシング法と高速ミキシング法の差も僅かであった。この事実はパンの硬化特性は配合による影響が大きいことを示唆するものである。

キーワード：パン、硬化、製パン法