Frozen Dough. I. Factors Affecting Stability of Yeasted Doughs[1]

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ABSTRACT

Doughs frozen after fermentation gave poorer quality bread than did doughs frozen without fermentation. A liquid ferment system was used to study the effect of fermentation on frozen-yeast stability. Activated yeast was somewhat more susceptible than nonactivated yeast to freeze damage; however, the severest damage was caused by the fermentation products. Quality of yeast greatly affected the stability of the frozen doughs. Good yeast performance after freezing was associated only with yeasts with protein contents higher than 57%. A short-time dough method, developed to study frozen doughs, worked better than the sponge-and-dough method for preparing frozen doughs. The damaging feature of the sponge-and-dough method was believed to be the mixing step at the dough stage.

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Frozen dough has been gaining acceptance in the baking industry. The frozen doughs produced today, however, perform satisfactorily for only a few weeks. As the storage period increases, the breadmaking potential of frozen doughs decreases substantially.

Compressed yeast (~ 70% water) can be stored at subfreezing temperatures without losing its baking properties (Bailey et al 1940, Cook and Malloch 1930, Thiessen 1942). But problems arise if the yeast is incorporated into a dough system before freezing. Dough fermentation before freezing may be the most important factor affecting the stability of frozen doughs (Godkin and Cathcart 1949, Kline and Sugihara 1968, Merritt 1960, Meyer et al 1956, Sugihara and Kline 1968). Many workers believe that fermentation before freezing is detrimental to the viability of yeast; they attribute the greater stability of the unfermented dough to the relatively dormant condition of the yeast (Kline and Sugihara 1968, Merritt 1960, Sugihara and Kline 1968). Lorenz and Bechtel (1964, 1965), however, showed that, at least with short storage periods, doughs with full fermentation produced better bread than those without fermentation before freezing.

The purpose of this study was to investigate the damaging factors associated with the instability of frozen bread doughs, especially those caused by fermentation before freezing, and to devise a short-time dough system for production of frozen doughs with improved stability.

MATERIALS AND METHODS

Liquid Ferment

Each liter of liquid ferment (Ling and Hoseney 1977) contained 20 g of yeast, 60 g of sucrose, and 200 ml of nutrient solution. Each

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liter of nutrient solution contained 10 g of diammonium phosphaste, 7 g of magnesium sulfate, 3 g of potassium chloride, 0.015 g of thiamine hydrochloride, 0.015 g of pyridoxine hydrochloride, and 500 ml of citrate buffer. The citrate buffer, pH 5.4, 0.264 *M*, was made with 55.5 g of citric acid and 27.0 g of sodium hydroxide diluted to 1 L.

Straight-Dough Baking Method

The formula contained 100 g of flour (14% moisture basis), 6 g of sucrose, 1.5 g of salt, 4 g of NFDM, 3 g of shortening, 2 g of yeast, 1 g of malt syrup (60° L), 100 ppm of ascorbic acid, 10 ppm of potassium bromate, and an optimum amount of water. Each dough was mixed to optimum development in a pin mixer (National Mfg. Co., Lincoln, NE). Fermentation was for 180 min, with punching at 105 and 155 min. Sheeting rolls were set with a 3/16 in. opening. Fermentation was in a cabinet maintained at 30° C and 90–95% rh. At the end of fermentation, the dough was sheeted through the sheeting rolls set at 5/16 in. and molded with a dough molder. The dough was then panned and proofed at 30° C and 90–95% rh for 55 min. Baking was at 218° C for 24 min. Loaf weight and volume were measured immediately after baking. Volume was determined by rapeseed displacement.

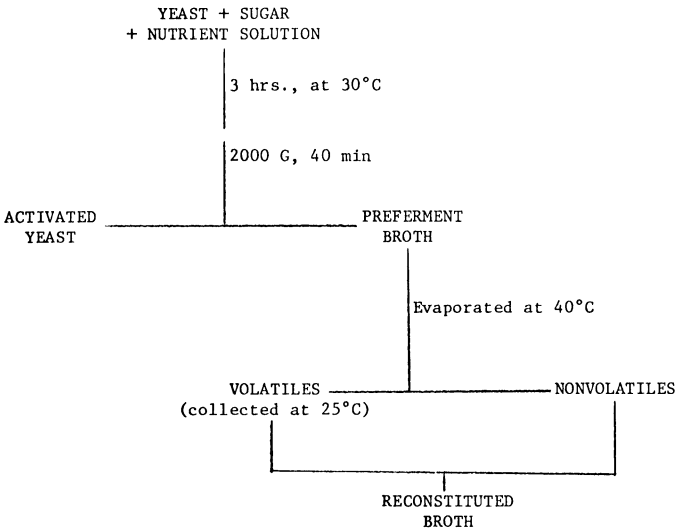

Fig. 1. Fractionation scheme for fermentation products.

Short-Time Method

The formula was the same as for the straight dough procedure except the yeast was increased to 3 g, the sucrose reduced to 3 g, and the NFDM eliminated. The dough was mixed in the pin mixer and, unless specified otherwise, the fermentation time was 40 min. After makeup, the dough was proofed to 7.5 cm and the proof time recorded. All other treatment was as given for the straight dough procedure.

Sponge and Dough Method

The sponge contained 65 g of flour (14% moisture basis), 2 g of yeast, 1 g malt of syrup (60° L), 40 g of water, 10 ppm of potassium bromate, 100 ppm of ascorbic acid, and 4 g of NFDM. The ingredients added at the dough stage were 35 g of flour, 22 g of water, 3 g of sucrose, 3 g of shortening, and 1.5 g of salt. The sponge was mixed for 1 min in the pin mixer and fermented at 30° C, 90–95% rh. After the desired fermentation time, the sponge was mixed with the rest of the ingredients to optimum development. The mixed dough was given a 30-min floor time (30° C, 90–95% rh) before molding and panning. The dough was proofed to 7.5 cm and the proof time recorded. All other treatment was as given for the straight dough procedure.

Freezing

Doughs were frozen in rectangular slabs (approximately 7½ × 3 × ½ in.) obtained by passing the dough through sheeter rolls (5/16-in. opening). The dough was wrapped in aluminum foil and placed directly on the freezer shelf at −18° C.

Thawing

The dough pieces were transferred from the freezer to a fermentation cabinet, maintained at 30° C and 90% rh, and held for 1 hr. Because the dough was still wrapped, there was no

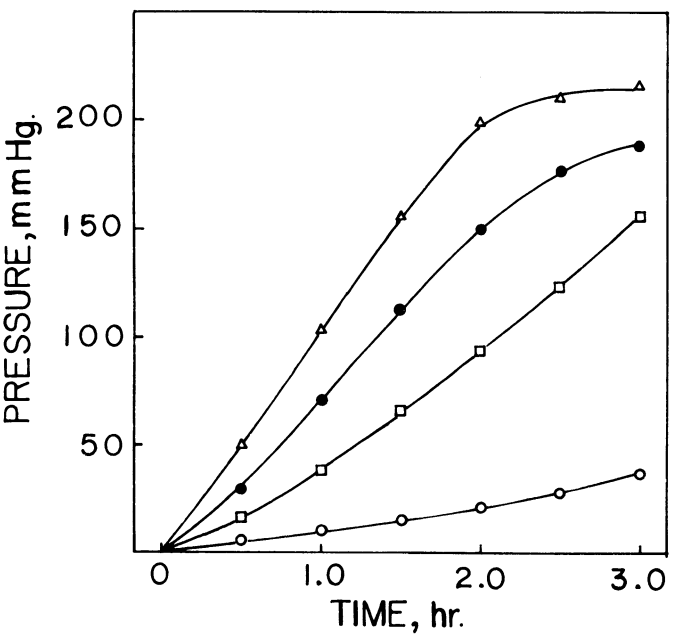

Fig. 2. Gassing power of frozen slurries containing various fractions of the liquid ferment. △ = Fresh yeast + 1 ml of nutrient solution + 0.3 g of sugar; -• = activated yeast + 1 ml of nutrient solution + 0.3 g of sugar; □ = fresh yeast + preferment broth; o = activated yeast + preferment broth.

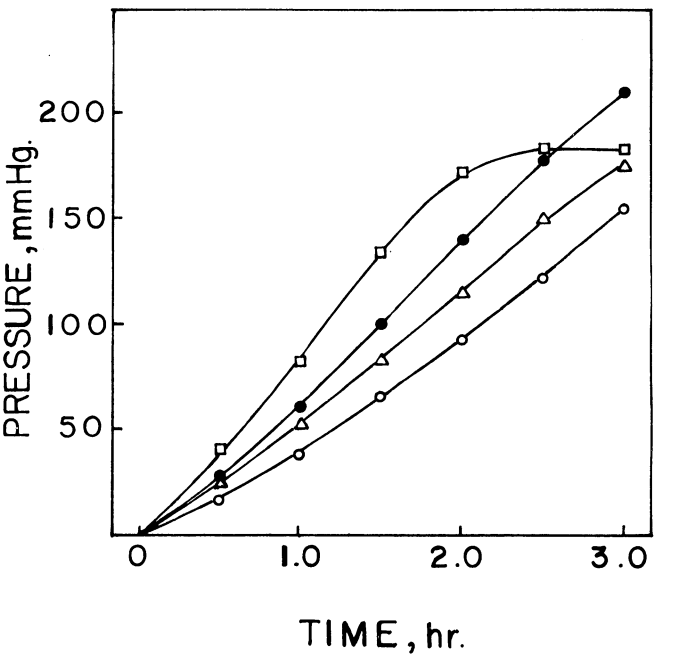

Fig. 3. Effect of freezing on gassing power of samples containing various fractions of the preferment broth. □ = fresh yeast + nonvolatiles; • = fresh yeast + volatiles + 1 ml of nutrient solution + 0.3 g of sugar; △ = fresh yeast + reconstituted broth; o = fresh yeast + preferment broth.

condensation on the dough. The dough temperature after thawing was about 26 ± 1.5° C. The thawed dough was then processed as described previously (starting at the molder).

Gassing Power

Pressuremeters were used in all gassing power determinations (AACC 1962).

Liquid ferment system. Each fraction separated from the preferment was diluted with water to its starting volume, so that its concentration would be equivalent to that found in the original fermentation broth. Each solution used for gassing power determination contained 0.2 g of yeast and 10 ml of the desired fraction; the final volume was 12 ml. Gassing was conducted in a 30° C water bath equipped with a shaker to minimize sedimentation of yeast.

Flour system. Each sample contained 0.2 g of yeast, 10 g of flour, 0.6 g of sugar and 10 ml of water. All ingredients were mixed thoroughly with a stirring rod and placed into the pressuremeter jar. Gassing was also conducted at 30° C.

Protein Analysis

Protein content was determined by the Kjeldahl method (AACC 1962).

Reproducibility

Duplicate samples or more were run for each treatment. Standard deviations were calculated to be 10.9 mm Hg, 11.6 cc, and 3.93 min for gassing power, loaf volume, and proof time, respectively.

RESULTS AND DISCUSSION

Liquid Ferment

Preliminary results with frozen doughs showed that fermentation before freezing was detrimental to yeast activity. Were the damaging effects due to the freezing of activated yeast or to the effect of fermentation products? To answer that question, a liquid ferment system (Ling and Hoseney 1977) was employed.

The yeast slurry was first combined with the buffered liquid nutrients and incubated in a water bath for 3 hr at 30° C. At the end of fermentation, the mixture was centrifuged to remove the yeast (Fig. 1). Each separated fraction was used in the freezing study.

The activated yeast was slightly more susceptible to freezing damage than was the nonactivated yeast (Fig. 2). When no fermentation products were present, however, there was no extreme damage to either the activated or the nonactivated yeast upon freezing. When the yeast was frozen together with the fermentation products, damage was major and was particularly severe if the yeast had been activated. That could explain why frozen fermented dough performed poorly after thawing.

To study the substances that were detrimental to yeast survival, the fermentation broth was further fractionated into volatile and nonvolatile fractions by means of rotary evaporation (Fig. 1). Gassing power determinations showed that the volatile fraction was more damaging than was the nonvolatile fraction when both were added back at the level recovered (Fig. 3).

Reconstituting the volatile and the nonvolatile fractions revealed that part of the damaging substance was lost in the evaporation step. Because the volatile fraction was collected under reduced pressure at 25° C, some of the volatile materials could have been lost reconstituted broth, perhaps because more sugar was present in the solution. Sugar protected yeast against freezing damage (Fig. 4).

During 3-hr fermentation, an estimated 2.5% ethanol was produced. Freezing experiments with that amount of ethanol present showed a damaging effect (Fig. 5). The effect of 2.5% ethanol on the gassing rate of the frozen yeast was similar to that of the volatile fraction (Fig. 3). In the reconstitution scheme, some highly volatile materials were lost during evaporation. We concluded that ethanol, although present in fairly large amounts (compared with other volatile materials), was responsible for only a part of the frozen yeast damage. A part of damage probably was caused by the highly volatile substances lost during evaporation.

TABLE I
Effects of Ascorbic Acid on the Quality of Frozen, Fermented Straight Doughs[a]

Oxidant	Proof Time to 7.5 cm (min)	Loaf Volume (cc)
20 ppm bromate	130	810
10 ppm bromate + 100 ppm ascorbic acid	124	867

[a]Frozen and stored at −18° C for five days.

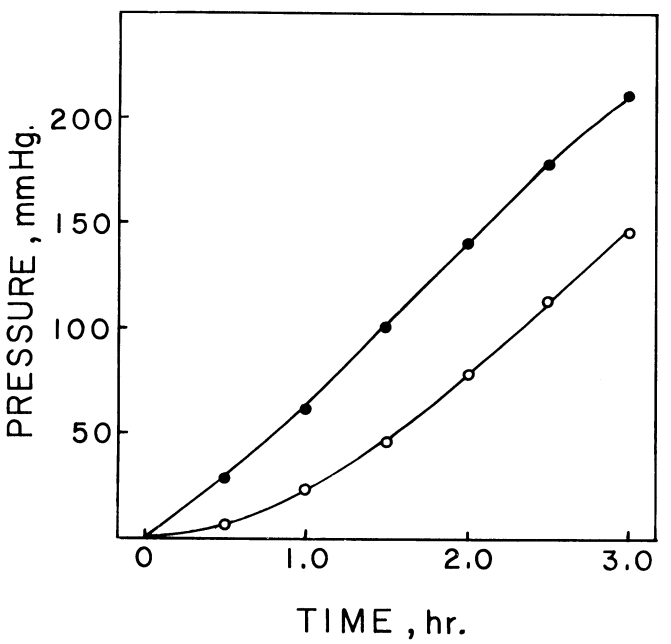

Fig. 4. Effect of sugar on yeast survival. Freezing solutions contained yeast, volatiles, and nutrient solution. • = 0.3 g of sugar added before freezing; o = 0.3 g of sugar added after thawing.

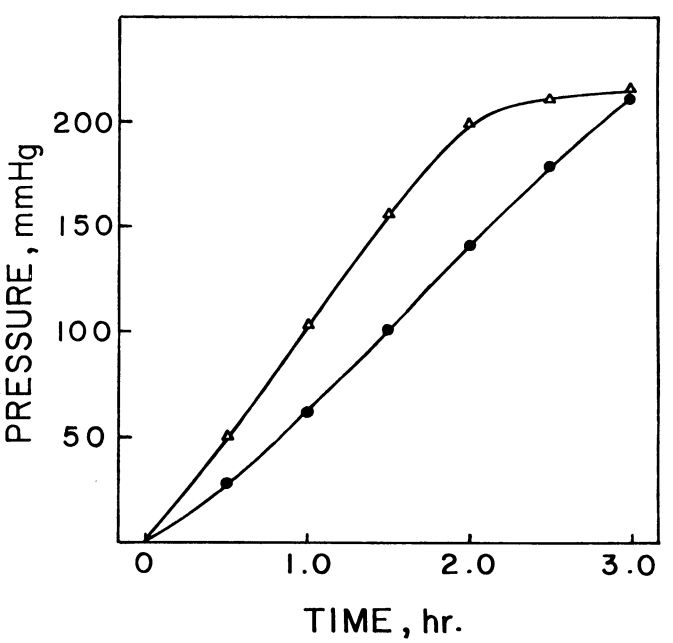

Fig. 5. Effect of ethanol on yeast viability. Freezing solutions contained yeast, sugar, and nutrient solution. △ = no ethanol added; • = 2.5% ethanol added before freezing.

The finding that volatile substances cause major damage to yeast is interesting. Organic solvents such as ethanol, toluene, and ethyl acetate induce autolysis in yeast, which in turn brings about the leaching of cell constituents (Ichimasa 1978, Lenney 1956). The damage to yeast caused by fermentation before freezing may well follow the same mechanism.

Effect of Ascorbic Acid

In a study of frozen dough by the straight dough method (Table I), an oxidant system consisting of 10 ppm of potassium bromate and 100 ppm of ascorbic acid performed better than did 20 ppm of bromate alone; proof times were 6 min shorter, and bread volumes increased 7%. The shorter proof time was surprising; however, Kline and Sugihara reported (1968) that, although a higher level of bromate improved bread quality and volume, it also had a definite deleterious effect on frozen yeast activity. That could explain our results.

Yeast Performance

Yeast from different batches and sources responded differently to freezing. If the cause of those differences in performance could be determined, it would certainly be a step toward improving the stability of frozen doughs. Yeast performance after freezing was correlated with protein content (Kjeldahl method), fermentation ability, and osmosensibility (gassing power with 6 and 12% of sugar, respectively). Weekly shipments of three commercial yeasts were received, and tests were conducted for eight weeks. The straight dough method with full fermentation was employed and the doughs frozen and stored at −18° C for 60 hr, the time during which differences in yeast performance were most apparent.

Proof time (88–240 min) of a thawed dough (height 7.5 cm) was used as a measure of yeast performance. No meaningful correlations were found between yeast performance after freezing and its gassing abilities with 6 or 12% sugar or the proof height of the nonfrozen control at constant proof time.

Protein content was the only factor studied that appeared to affect the performance of the yeast after freezing (Fig. 6). Even though the correlation was low, good yeast performance after freezing was associated with high protein yeast (57% or higher). With yeast protein lower than 55%, performance after freezing was always poor.

In another experiment, one commercial yeast was stored at 4° C, and baking and freezing tests were conducted weekly for eight weeks to study the effect of refrigerated storage on yeast performance after freezing. The activity of yeast that had been frozen and thawed improved during the first four weeks of refrigerated storage; the proof time of the thawed dough decreased from 116 to 88 min. After the first four weeks, performance dropped gradually; proof time of the thawed dough increased from 88 to 99 min by the end of eight weeks (Fig. 7). Protein content of the yeast decreased during the eight weeks, from 59.6 to 57%. The gassing power of the yeast fluctuated during the first four weeks of storage and then consistently dropped. No meaningful correlation was found between the frozen yeast activity and its protein content or gassing ability.

The results of the storage study seemed to indicate that refrigerated storage protects yeast from freezing damage. However, the fermentation activity of the yeast decreased consistently after a short storage period. Those two factors worked against each other over the storage period and thus gave an optimum storage period. This storage phenomenon also was observed by Kline and Sugihara (1968); they attributed the improved stability to the increased lag time of the yeast during the refrigerated storage.

Short-Time Dough Process

Results of the liquid-ferment study showed that freezing activated yeast and fermentation products together was detrimental to yeast viability. Thus, if dough fermentation before freezing could be reduced or eliminated, yeast survival might be improved. However, we had to be sure that the improved yeast viability after freezing was not at the expense of bread quality. Thus a short-time dough process was developed that gave reasonably good quality frozen dough. Preliminary results of a short-time dough process in which the regular straight-dough formula was used suggested that some formulation changes were needed to overcome the excessively weak structure and dark crust color of the bread. The following corrections were made in the straight-dough formula: (a) NFDM was eliminated, (b) sugar content was reduced from 6 to 3%, (c) yeast concentration was increased from 2 to 3%, and (d) the oxidant system was changed from 20 to 10 ppm of bromate plus 100 ppm of ascorbic acid. Eliminating NFDM improved the system by lowering the oxidant requirement. Lowering the sugar content had a twofold effect: (a) the dough became more elastic (sugar competes with gluten and other dough components for the available water), and the more sugar in the dough, the more the system will flow (Hoseney et al 1979); and (b)

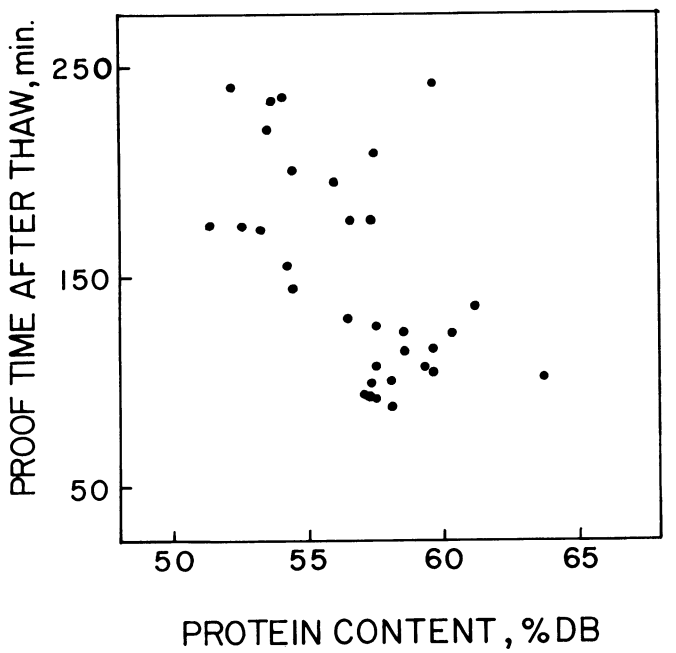

Fig. 6. Yeast performance after freezing vs. protein content of the yeast.

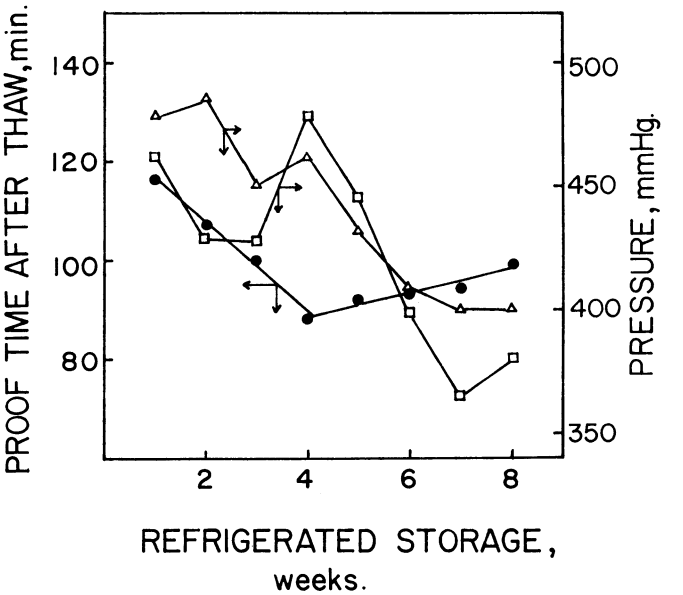

Fig. 7. Effect of refrigerated storage of yeast on the yeast performance after freezing. • = Proof time after thaw; △ = gassing power with 6% sugar; □ = gassing power with 12% sugar.

TABLE II
Effect of Rest Time on Fresh Dough Prepared by the Short-Time Dough Method

Rest Time (min)	Proof Time (min)	Volume (cc)
0	102	815
20	77	825
40	64	983
60	55	955
90	54	990
120	62	1012

TABLE III
Effect of Rest Time on Frozen Dough Prepared by the Short-Time Dough Method[a]

Rest Time (min)	Proof Time (min)	Volume (cc)
0	116	805
20	92	898
40	90	905
60	91	925
90	85	926
120	124	833

[a]Frozen and stored at −18°C for two weeks.

less sugar is available for browning at the oven stage. The higher concentration of yeast allowed for more gas production and shortened the proof time.

Test baking of nonfrozen dough prepared with this adjusted formula showed that reasonably good quality bread could be produced by the short-time process (Table II). The results also showed that some fermentation was required to produce bread of acceptable quality. Doughs with less than 40-min fermentation (floor time) produced bread with sharp corners and poor (cakelike) grain; with 40 or more min of fermentation, the final bread was acceptable. Loaf volume increased with fermentation time. The proof time, on the other hand, reached a minimum with 90 min of fermentation.

Results of frozen doughs (two weeks of frozen storage at −18°C) prepared by the short-time dough process are shown in Table III. The effect of fermentation time was observed. The proof time was generally lengthened and the loaf volume decreased as the result of freezing. Good quality bread was obtained from frozen doughs (two-week storage) for samples with fermentation times between 40 and 90 min.

Sugihara and Kline (1968) reported good quality frozen doughs prepared by a sponge and dough method (with reduced sponge times). We found that the quality of the bread improved with an increasing sponge time (Table IV). Frozen samples showed good yeast stability with sponge times up to 90 min. Sponge times longer than 90 min gave increased proof times. The quality of bread baked from frozen doughs prepared by the sponge and dough method was inferior to those prepared by the short-time dough method (Table IV). The poor quality apparently was not the result of yeast damage because the proof time was reasonably short and no differentiation in bread quality was observed between short and long sponge times. The problem was believed to be structural, the result of the remixing step at the dough stage.

That point was checked by using the short-time dough system to study the remixing effect. Dough samples mixed to optimum development were allowed to rest for 20 min, then were remixed to optimum development. Rest times of 20 and 40 min were provided after the remixing step and before the samples were molded or frozen. These samples were compared with the nonremixed controls (40 and 60 min of fermentation).

For the nonfrozen samples, the proof time correlated well with the total fermentation time, and the bread quality correlated well with the rest time provided after the last mixing step (Table V). The

TABLE IV
Effect of Sponge Time on Frozen Dough Prepared by the Sponge and Dough Methods

Sponge Time (hr)	Proof Time (min)	Volume (cc)
	Fresh	
0.5	65	755
1	60	888
1.5	58	920
2	52	955
3	51	963
4	52	990
	Two-Week Frozen Storage[a]	
0.5	88	723
1	82	763
1.5	86	770
2	107	730
3	122	728
4	130	738

[a]Frozen and stored at −18°C.

TABLE V
Effect of Remixing on the Quality of Frozen Dough Prepared by the Short-Time Dough Method

Treatment	Proof Time (min)	Volume (cc)
	Fresh	
40-min rest	65	895
60-min rest	60	948
20-min rest, remix, 20-min rest	64	810
20-min rest, remix, 40-min rest	58	895
	Two-Week Frozen Storage[a]	
40-min rest	80	910
60-min rest	80	870
20-min rest, remix, 20-min rest	81	770
20-min rest, remix, 40-min rest	88	785

[a]Frozen and stored at −18°C.

observation did not, however, hold for the frozen samples. Results indicated that frozen dough samples that had been remixed produced poor quality bread with low volumes, regardless of short proof times (Table V). The remixing effect was observed only for doughs put through the freeze-thaw cycle.

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