Frozen Doughs: Freezing and Thawing Rates and the Potential of Using a Combination of Yeast and Chemical Leavening[1]

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ABSTRACT

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A major problem of frozen doughs is the reduced viability of yeast after thawing. To avoid this problem, combinations of yeast and chemical leavening agents in frozen doughs were studied. A short-time dough fermentation process was used to prepare frozen doughs. Nonfat dry milk was eliminated from the formula to lower the oxidant requirement; however, without it, a lower salt level (0.5% based on flour weight) was required for the short-time doughs. Thawing for 1 hr at 38°C, 90–95% rh, and proofing to a constant height at 32°C, 90–95% rh, were determined to be the optimum conditions for frozen doughs. In the systems tested, there appear to be no benefits of using chemical leavening in frozen doughs.

Frozen doughs are gaining acceptance in the baking industry despite the fact that they generally suffer from variable performance. As reported by many investigators (Merritt 1960; Kline and Sugihara 1968; Hsu et al 1979a,b) the major problem of frozen doughs is the performance of the yeast. Yeast is necessary to provide proper gas production for dough leavening. In any yeast-leavened dough, the aroma, taste, and texture of the final product are dependent on yeast fermentation and its development action (Merritt 1960). When dough is frozen and thawed, yeast's viability and capacity to produce gas is decreased, resulting in bread with lower loaf volume and inferior quality.

Studies show that frozen dough stability is related to yeast quality, dough formulation and process, and freezing and thawing conditions (Merritt 1960; Kline and Sugihara 1968; Lorenz 1974; Hsu et al 1979a,b; Davis 1981). Because of its importance, yeast is the single most studied ingredient in frozen dough (Bruinsma and Giesenschlag 1984). Kline and Sugihara (1968) reported that the first problem that must be solved with frozen unbaked doughs is the retention of sufficient yeast viability and gassing power during frozen storage to avoid excessive proofing times or even a virtual loss of proofing power after thawing. Minor improvements in quality of the thawed product can be achieved by formulation changes, type of yeast, dough conditioners, decreasing absorption, oxidizing agents, or reworking the dough after thawing (Lorenz and Bechtel 1964, 1965; Davis 1981; Bruinsma and Giesenschlag 1984). A detailed review of these improvements is given by Pizzinatto (1979). However, these are of little consequence if the yeast activity is not maintained at or near a prefreezing level.

There appears to be a consensus that to achieve yeast stability during frozen storage, one must minimize or eliminate yeast activity before molding and freezing of the dough (McPherson and Lamb 1948, Godkin and Cathcart 1949, Meyer et al 1956, Merritt 1960).

The rate of freezing and thawing also has an effect on yeast viability. Results show that freezing rate should be slow and thawing rate rapid (Pizzinatto 1979, Lorenz 1974). Slow freezing is generally believed to allow cells to adjust to the frozen environment by transferring intracellular water to external ice. Fast freezing, on the other hand, causes intracellular freezing, because temperature changes are faster than the transport of water to the external environment. The small ice crystals formed during intracellular freezing are likely to recrystallize into larger crystals during warming and, hence, become lethal to the cells (Lorenz 1974). Another view proposed by Hsu and co-workers (1979b) is that the lowest temperature reached has a greater effect on yeast survival than the freezing rate.

Kline and Sugihara (1968) noted that dough rheology was altered when doughs were stored for long periods in the freezer or when subjected to freeze-thaw cycles. Frozen doughs, after thawing, are often slack and sticky and retain gas poorly. The defect is possibly associated with the release of reducing substances from yeast cells that died during frozen storage (Kline and Sugihara 1968). Wolt and D'Appolonia (1984) refuted that idea with data showing that reducing compounds are not a factor in the gas retention of frozen doughs. Varriano-Marston et al (1980) stated that the phenomenon of ice recrystallization contributed to the weakening of the three-dimensional protein network responsible for gas retention in doughs.

Carbon dioxide produced either by yeast fermentation or chemical reaction is a major leavening gas. Chemical and yeast leavening sources are rarely used together in the same product. Their combination apparently has not been studied in detail. The objective of this study was to examine the feasibility of using a combination of chemical and yeast leavening to produce a frozen dough product that was comparable to a freshly baked, yeast-leavened bread. The effects of freezing rate and thawing temperature were also studied.

MATERIALS AND METHODS

Ingredients

A commercial bread flour from Ross Mills, Wichita, KS, was used in the preparation of the bread doughs. It contained 11.9% protein and 0.46% ash. A hydrogenated vegetable shortening (Crisco, Proctor & Gamble, Cincinnati, OH) was also used in the bread formula. Fermipan instant dry yeast (Gist-Brocades, Delft, The Netherlands) was used.

Sodium bicarbonate was obtained from the Church & Dwight Co., Princeton, NJ. The sodium aluminum sulfate was obtained from Allied Chemical, Morristown, NJ. All chemicals were reagent grade.

Doughs were mixed to optimum development in a National pin mixer, immediately sheeted through rolls set at 5/16-in. opening, molded, and panned. Baking was at 218°C for 24 min. The weight and volume of the loaves were measured immediately after baking. Volume was determined by rapeseed displacement.

Frozen Doughs

The procedure used for freezing was described by Hsu et al (1979a). The short-time dough procedure was employed (Fig. 1), with the same formula used for straight doughs (Finney 1984) except the sugar level was decreased to 3 g, nonfat dry milk (NFDM) was eliminated, and 100 ppm ascorbic acid was used as an additional oxidizing agent. Doughs were mixed to optimum in a National pin mixer and fermented for 40 min at 30°C, 90–95% rh, in a proof cabinet. Doughs were frozen either in rectangular slabs (approximately 7 ½ × 3 × ½ in.) or molded before freezing. The slab was obtained by passing the dough through sheeter rolls set at 5/16-in. opening. The doughs were molded on a drum molder. All doughs were wrapped in aluminum foil before being placed directly on the freezer shelf of a home-style, upright freezer (−15°C). Unless otherwise specified, the doughs were frozen for one week. After thawing, the doughs were molded if they had not been before freezing, and panned. Panned dough was proofed to constant proof height (73 mm) and the proof time recorded.

Thawing

The frozen doughs were thawed by one of four methods: 1) in a proof cabinet (30°C, 90–95% rh) for 1 hr; 2) at room temperature (25°C) for 1 hr; 3) in the refrigerator (10°C) for 12 hr; 4) in the refrigerator (10°C) for 24 hr. The thawed dough was then processed as described above.

In an additional study, frozen doughs were thawed and proofed at various temperatures. Thawing and proofing temperatures included 32, 38, 43°C and a combination of thawing at 38°C and proofing at 32°C.

Addition of Chemical Leavening to Frozen Doughs

The procedure used to incorporate leavening acids plus soda into frozen doughs was a combination of the remix and freezing procedures (Fig. 2). Doughs were mixed to optimum development in a National 100-g pin mixer and fermented for 40 min at 30°C, 90–95% rh. The fermented doughs were remixed for 1½ min to incorporate the chemical leaveners and fermented for an additional 30 min at 30°C, 90–95% rh, to relax the dough. Doughs were sheeted through rolls set at 5/16 in., and the resulting slab was wrapped in aluminum foil and frozen as previously described. Frozen doughs were thawed for 1 hr at 38°C, 90–95% rh, molded, panned, and proofed to constant height (73 mm) at 32°C, 90–95% rh. Baking and volume measurements were taken as previously described.

RESULTS AND DISCUSSION

Frozen Dough Freeze/Thaw Studies

Hsu et al (1979b) reported that freezing activated yeast and its fermentation products together was detrimental to yeast viability. Thus, if dough fermentation before freezing could be reduced or eliminated, yeast survival presumably would be improved. However, the improved yeast viability after freezing cannot be at the expense of bread quality.

Based on the report of Hsu et al (1979a) a short-time dough process using the regular straight-dough formula was developed that gave reasonably good quality frozen dough. However, the bread had a weak structure and dark crust color that suggested that certain formulation changes were needed. NFDM was eliminated to lower the oxidant requirement and presumably strengthen the loaf structure. The sugar content was reduced to make the dough more elastic. This was necessary because sugar competes with the gluten and other dough components for available water (Hoseney et al 1979). The more sugar in the dough, the more the dough will flow. Also, less sugar results in decreased browning at the oven
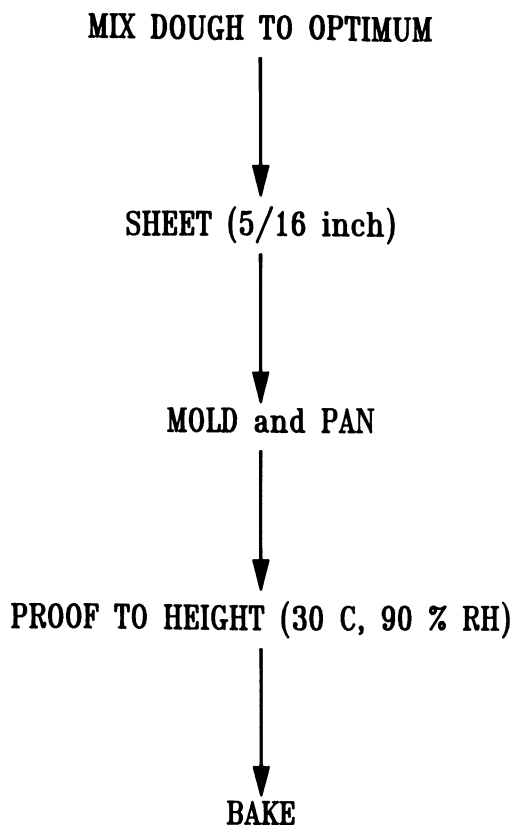
MIX DOUGH TO OPTIMUM

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SHEET (5/16 inch)

↓

MOLD and PAN

↓

PROOF TO HEIGHT (30 C, 90 % RH)

↓

BAKE

Fig. 1. Short-time fermentation scheme used for frozen doughs.

MIX DOUGHS TO OPTIMUM

↓

FERMENT FOR 60 min (30 C, 90 % RH)

↓

REMIX (1 1/2 min) ADD ACID AND SODA

↓

RELAX FOR 30 min (30 C, 90% RH)

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SHEET (5/16 inch)

↓

MOLD AND PAN
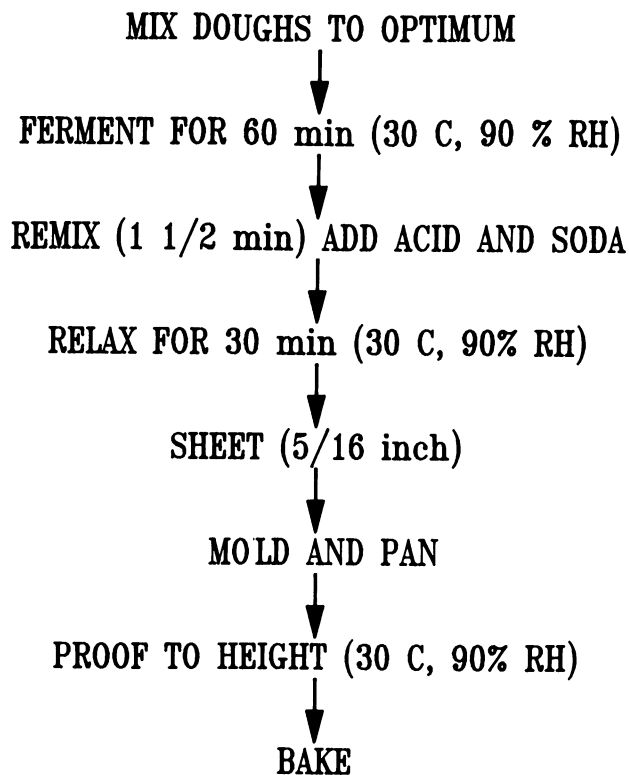
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PROOF TO HEIGHT (30 C, 90% RH)

↓

BAKE

Fig. 2. Procedure for the addition of leavening acids plus soda in frozen doughs.

stage (Hsu et al 1979a). The oxidant system, 10 ppm of bromate plus 100 ppm ascorbic acid, was used because of the increased oxidation requirement for a short-time dough system.

We attempted to optimize a method for freezing and thawing frozen dough using the revised formula and procedure. The dough was sheeted into a slab or molded before freezing. The slab produced a higher loaf volume and lower proof time than did the molded dough (Table I). This was expected because of the relationship between the geometry of the dough and heat transfer.

The frozen doughs were subjected to one of four methods of thawing. As shown in Table I, the highest loaf volume and shortest proof times were achieved with the 1-hr thaw at 30°C. Furthermore, as shown in Table II, a storage study with thawing and proofing at 30°C, 90–95% rh, indicated that as storage time increased, the loaf volume decreased and proof time increased. This coincides with the findings of many investigators (Merritt 1960, Lorenz and Bechtel 1964, Hsu et al 1979a, Davis 1981).

When frozen doughs were thawed and proofed at 32, 38, and 43°C, the results (Table III) clearly show that as temperature increased proof time decreased. Loaf volume was comparable with the 32 and 38°C conditions; however, a 40-cm³ decrease in loaf volume occurred with the 43°C temperature. Thawing for 1 hr at 38°C, 90–95% rh, and proofing to constant height at 32°C, 90–95% rh, were determined to be the optimum conditions for frozen doughs. During freezing of dough, the yeast cells are dehydrated as water moves outside the cell and is frozen. The contents of the cell do not freeze. Therefore, during thawing the yeast is being rehydrated. It is well known that yeast is damaged less when rehydration is at higher temperatures. Perhaps the optimum rehydration temperature of 38°C for yeast explains the better results obtained with the higher thawing temperatures.

Study of Short-Time Fermentation Formula and Process

The reasons for changing the formula and procedure for the short-time fermentation system were logical; however, how those changes affected the system was not completely understood. The most extreme case of a short-time fermentation, no fermentation time, was used in this study. Because salt level was an important formula variable in the long-time fermentation, the effect of the salt level on loaf volume needed to be determined for the no-time fermentation. Figure 3 shows that the optimum level of salt in the no-time fermentation was 0.5% based on the flour weight. This was a decrease in salt level compared to the 1.5–2.0% optimum salt level for the long-time fermentation (Holmes and Hoseney 1987). The reason for the change was the elimination of the NFDM from the no-time fermentation formula (Fig. 4). This figure shows a 2% optimum salt level when NFDM was included in the no-time fermentation formula, which is comparable to the optimum salt level in the long-time fermentation.
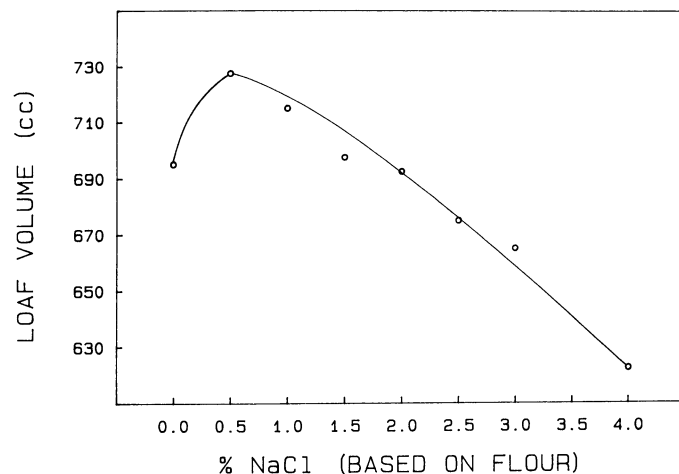
TABLE I
Optimizing Freeze-Thaw Conditions for Frozen Doughs[a]

Treatment	Proof Time (min)	Loaf Volume (cm³)
Slab, 1 hr proof box (30°C)	83 ± 2	867 ± 26
Molded, 1 hr proof box (30°C)	87 ± 5	826 ± 17
Slab, 1 hr room temp. (25°C)	143 ± 11	731 ± 25
Slab, 12 hr refrig. (10°C)	111 ± 9	789 ± 18
Slab, 24 hr refrig. (10°C)	118 ± 4	816 ± 16
Control	55 ± 0	904 ± 24

[a] Values are means ± standard deviations.

TABLE II
Storage Study for Frozen Doughs[a]

Storage Time (weeks)	Proof Time (min)	Loaf Volume (cc)
Control (0)	55 ± 0	935 ± 10
1	82 ± 1	905 ± 17
2	109 ± 5	877 ± 17
3	124 ± 2	835 ± 26
4	129 ± 7	833 ± 10

[a] Values are means ± standard deviations.

TABLE III
Higher Temperature Thawing and Proofing of Frozen Doughs[a]

Temperature[b]	Proof Time (min)	Loaf Volume (cm³)
32°C (control)	91 ± 5	882 ± 11
38°C	72 ± 6	878 ± 20
43°C	60 ± 2	843 ± 16
38°C thaw and 32°C proof	102 ± 5	913 ± 25

[a] Values are means ± standard deviations.
[b] All doughs thawed and proofed at 90–95% rh.

TABLE IV
Addition of Chemical Leavening in Frozen Doughs

Sample	Proof Time (min)	Loaf Volume (cm³)
Remix control (not frozen) (short-time ferm.)	72 ± 2	945 ± 7
Mix/remix frozen dough	92 ± 4	919 ± 9
Mix/remix frozen dough with chemical leavening	95 ± 3	842 ± 20
Mix/freeze frozen dough	94 ± 2	831 ± 25

[a] Values are means ± standard deviations.

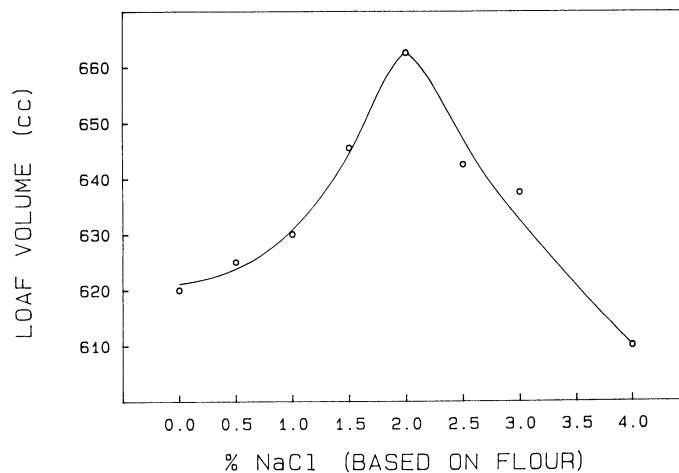Fig. 3. Effect of NaCl on loaf volume in a no-time fermentation system.

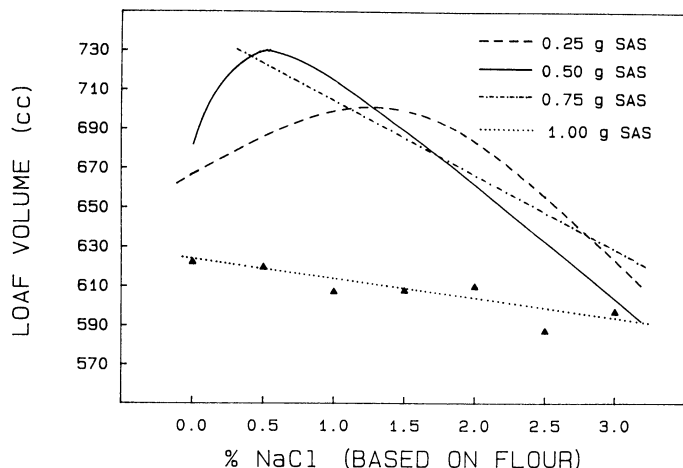Fig. 4. Addition of nonfat dry milk to no-time doughs.

Fig. 5. Addition of sodium aluminum sulfate in a no-time fermentation system. Nonfat dry milk was not added.

Addition of Chemical Leavening in Frozen Doughs

With the optimum salt level determined, the optimum level of chemical leavening (sodium aluminum sulfate and soda) needed to be established. Constant amounts of chemical leavening (0.25 g of sodium aluminum sulfate [SAS]: 0.25 g of soda, 0.5 g of SAS: 0.5 g of soda, 0.75 g of SAS: 0.75 g of soda, 1 g of SAS: 1 g of soda) were added to doughs that varied in salt from 0 to 4%. Figure 5 shows that the optimum bread was obtained with a combination of 0.5% NaCl and a 0.5 g SAS: 0.5 g soda ratio.

The question of the potential of chemical leavening in frozen doughs remains unanswered. The formula used was the same as the no-time fermentation formula except for the 0.5% salt level and the addition of the 0.5 g of SAS plus 0.5 g of soda. The formula did not contain NFDM. Table IV shows that the addition of chemical leavening to frozen dough did not decrease proof time and did not increase loaf volume when compared to the mix-remix control. Until the problems associated with the action of specific ions in bread doughs (Holmes and Hoseney 1987) are understood, there is no benefit in adding chemical leavening to frozen doughs.

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