Preparation of Frozen French Bread Dough with Improved Stability

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ABSTRACT

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Optimizing the properties of French bread dough through prolonged frozen storage is difficult because the dough is prepared from a simple recipe to which few additives are permitted. We analyzed the parameters that directly influence the properties of such doughs. At the formulation stage, a specific compressed yeast with "reduced activity" was found to contribute greatly to dough stability. This benefit was largely lost when this yeast was converted to different instant-dry forms. An adequate protein content in the bread flour and a carefully formulated bread improver were shown to be important in optimizing the gas retention properties of frozen doughs. At the mixing stage, conditions that gave full dough development without inducing the start of gas production by the yeast improved dough stability. The addition of prefermented doughs was contraindicated, whereas delayed incorporation of the yeast and a relatively low dough temperature were shown to be advantageous. An outline production process incorporating the positive findings is presented.

In the current practice of deep-freezing bread doughs, extending the storage life of yeast-leavened, unbaked doughs is difficult, giving inconsistent product quality. As distinct from standard foodstuffs, frozen bread dough once defrosted is not the end product. It must undergo the proofing process to allow proper rising before baking. Therefore, in addition to optimizing the usual factors involved in the quality of frozen foodstuffs (International Institute of Refrigeration 1986), the baking industry must succeed in freezing and thawing unbaked doughs without killing the cells of *Saccharomyces cerevisiae* (Lamb and Bender 1977).

Yeast cells in bulk can be considered cryoresistant (Bruinsma and Giesenschlag 1984). Their ability to produce CO_2 is little affected by successive freeze-thaw cycles (Table I). This resistance is not maintained, however, when the cells are dispersed in a dough, particularly when unfavorable processes intervene before freezing. In such cases, the rate of gas production decreases throughout frozen storage (Fig. 1). Consequently, prolonged proofing times are required, and after baking, much smaller loaf volumes are obtained (Fig. 2). The difficulty is that freezing yeast dispersed within a dough mass is different from direct freezing of yeast (Hsu et al 1979, Wolt and D'Appolonia 1984a).

Over the past forty years, many investigations have shown clearly that the gas production capacity of yeast was the specific factor that limited the useful life of frozen bread dough. Numerous studies have suggested various formulations and processing conditions to improve freeze-thaw resistance and viability of yeast cells. Because most of the work was done in the United States, applied research was to a large extent undertaken on American bread doughs, which are rich in fat and sugar. Standard French bread dough, which yields the celebrated baguette, is produced from an extremely lean formulation. Only a few additives are permitted (Table II). Because fats are not allowed, they cannot contribute to cryoprotection in the freezer or to specific rise in the oven. Sugars are not allowed and cannot promote starting of yeast before freezing.

It is predicted that, by 1995, 10% of ordinary French bread will be produced from frozen dough. The objectives of this study were to examine parameters that directly influence French lean doughs destined to be frozen and to compare results with those obtained elsewhere with rich recipes. The production process proposed should improve dough stability through prolonged storage (three months or longer).

MATERIALS AND METHODS

Flour

Ordinary Type 55 French flour was used for most experiments. Protein content, falling number, and commonly used factors of the Chopin alveograph (Chopin Tripette et Renaud, Paris, France) were measured according to AACC methods (1983). Damaged starch was determined according to the method of Audidier et al (1966). Throughout our study, average values for these analyses were: protein (N × 5.7) ~12%; Chopin parameters $W = 220–230$ and $P/L \sim 0.65$; falling number near 280; damaged starch < 8%. In a specific part of the study, flours differing in protein level (11.1%, 12.8%) and falling number (218) were assessed with regard to frozen dough stability.

Yeast

A compressed yeast (about 32% dry matter, 46% protein [N × 6.25], 2.25% total P_2O_5, 17.2% trehalose; Gist-brocades, Paris, France) was used throughout the experiments as a control. After the frozen dough performance of this yeast had been compared with that of other yeasts, compressed products from Spain and Germany (both about 32% dry matter, 46% protein) and England (about 28% dry matter, 55% protein) were selected for testing. To evaluate the influence of yeast type, porous cylindrical yeast particles were produced. A crumbled cake of Gist-brocades yeast (30.85% dry matter content) was extruded into cylindrical pellets. A carefully controlled "fluidized bed drying process" afterwards yielded semidried (75.65% dry matter) and dried (93.90% dry matter) particles with instant dry yeast properties.

Bread Improver

A commercially available product appropriately formulated to conform with the current French legislation regarding "standard bread" (Table II) was used in all experiments. After the specific function of the improver was examined, two other French products (B and C) were compared for performance with our reference product (A). All three improvers had similar qualitative composition (wheat flour, vital wheat gluten, soya lecithin, ascorbic acid, alpha amylases).

Laboratory Determinations

To assess the effects of freeze-thaw cycles on yeast cells, 500 g of compressed fresh yeast was frozen at −34°C after initial gassing power was determined. After different periods of storage (Table I), the sample was allowed to thaw (16 hr at 5°C) before being tested and frozen again. To determine gassing power, flour (200 g), water (114 ml), salt (4 g), and yeast (4.4 g) were mixed 10 min in the Chopin alveograph mixer; then gas production of the prepared dough (200 g) was analyzed in the SJA fermentograph (AB Nassjo Metallverkstad, Nassjo, Sweden) at 30°C for 165 min. For rheofermentometer analyses, doughs were formulated as follows: 250 g of flour, 7 g of yeast, 5 g of salt,

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and hydration according to flour moisture content to achieve constant consistency. Each dough was prepared in the Chopin mixer (8-min mixing time). To evaluate initial fermentative ability of the yeast, each dough was transferred to the airtight chamber of the Chopin rheofermentometer. Direct gas production and gas-retaining capacity of doughs then were recorded at 28.5°C for 3 hr. To assess yeast cryoresistance, doughs were frozen immediately at −34°C until the core temperature reached −7°C and stored at −20°C. The cooling rate thus obtained (1°C/1 min) closely matched the optimal dessication rate of the yeast cells (Mazur 1961). After periods of storage of zero, one, two, and three months, frozen dough pieces were withdrawn from the freezer for testing. Defrosting took place at 28°C for 1 hr; then the same rheofermentometer determination was made.

Breadmaking Procedure

The basic recipe was as follows: flour, 100%; water, 59%; bread improver, 1%; compressed yeast, 6% (2.4% for semidried and instant dried yeasts); and salt, 2.25%.

Dough Processing

Mixing. An inclined-arm mixer was used for kneading. Dough was mixed 3 min at low speed (40 × *g*), then 17 min at high speed (80 × *g*). Improver was added directly to the flour. Yeast and salt were added at 5 and 2 min, respectively, before the end of mixing. Final dough temperature was 20°C.

Scaling and molding. Doughs immediately were divided mechanically (with a hydraulic box divider) and hand balled to give 70 dough pieces of 350 g. After resting up to 15 min (intermediate proof), dough pieces were machine molded into 32-cm French "bâtards" using a French stick molder. Samples then were placed on perforated trays for immediate freezing. In all tests, a 30-g portion of the dough was frozen as a reference, which was allowed to proof to a constant height during the recovery process.

TABLE I
Gassing Power of Yeast Cells Subjected to Successive Freeze-Thaw Cycles

Storage Time (days)	Yeast	ml of CO_2
0	Fresh	895
1	1st freezing	905
2	2nd freezing	885
3	3rd freezing	895
8	4th freezing	880
9	5th freezing	875
10	6th freezing	870
11	7th freezing	880
130	8th freezing	880

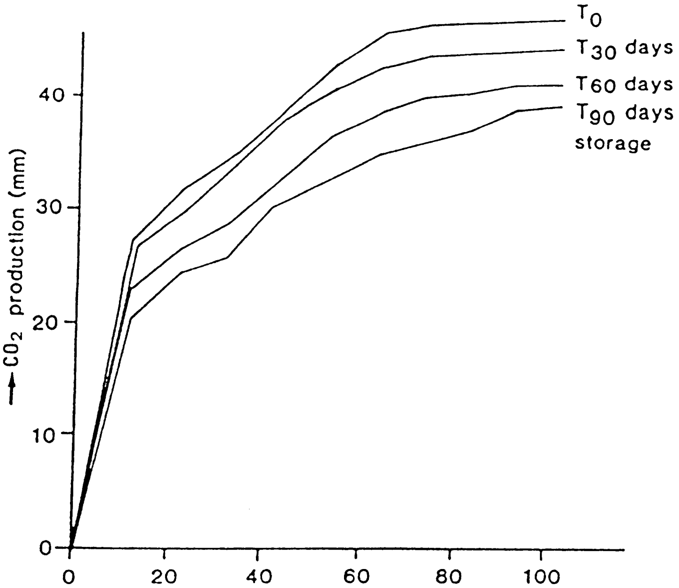

Fig. 1. Yeast activity in a nonoptimal frozen dough. Influence of storage time (T) on the CO_2 production (Chopin rheofermentometer).

Freezing and storage. Freezing took place at −34°C in a blast freezer within 20 min after mixing. Judging from the freezing curve (Fig. 3), the decrease of the dough temperature was 1°C/min throughout the "refrigeration" and "under cooling" zones. Freezing rates within the "freezing zone" and storage temperature (−20°C) were appropriate to describe the doughs as "deep frozen." Dough pieces were stored in sealed plastic bags once a core temperature of −7°C was reached. Maximum storage time was three months.

Recovery process (defrosting and proofing). Dough was defrosted slowly overnight in a dough retarder (12 hr at 0°C), and final proof was about 4 hr at 25°C in 85% relative humidity (70-mm height for the 30-g reference dough pieces). To obtain the initial loaf volume at time = 0 (T_0), 10 dough pieces were thawed immediately when their core temperature reached −7°C during freezing. For the other volume determinations (T_{15}, etc.), frozen dough pieces stored at −20°C were defrosted in identical conditions every two weeks thereafter (10 dough pieces per experiment).

Baking. A gas-fired, two-deck oven equipped for steam injection (Pavailler, Valence, France) was used for baking (25 min at 225°C). Before introducing the bread, steam was injected and three incisions were made with a sharp blade across the width of the dough pieces. Loaf volumes were measured in pairs by seed displacement after the bread had cooled for 30 min.

Dough-processing variations. Changes in the standard method were studied to determine the best conditions for optimizing frozen dough stability. Several yeast levels were tested (4, 5, and 7%, instead of 6%). Different times for the addition of yeast to the mixer were compared (immediately and after 3 min, instead of 15 min after start of mixing). The influence of adding prefermented doughs was analyzed. (Prefermented doughs were made with 50% flour, 50% water, yeast levels of 2, 3, 4, 5, and 6%, and a 1-

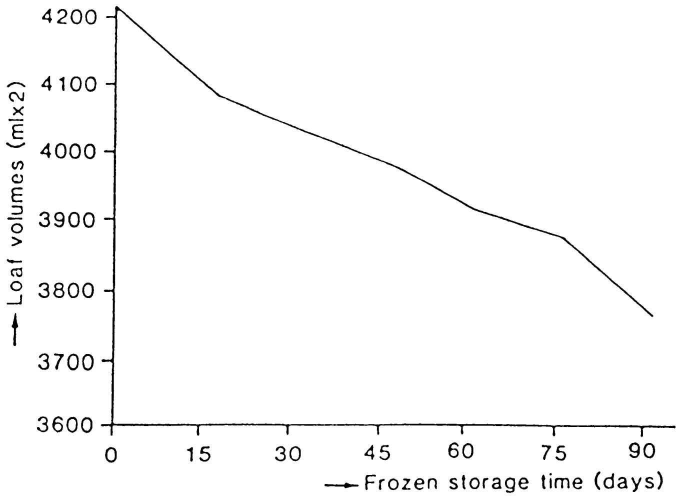

Fig. 2. Yeast activity in a nonoptimal frozen dough. Influence of storage time on the baking performance.

TABLE II
Dough Additives Permitted in French Standard Bread Production

Additive	Function	Maximum Percentage Allowed (on flour weight)
Vital wheat gluten	Texture improver	Unlimited
Ascorbic acid	Oxidation	0.03
Bean flour	Oxidation	2
Soya flour	Oxidation	0.5
Soya lecithin	Emulsifier	0.3
Wheat malt flour	Fermentation corrector	0.3
Fungal alpha amylases	Fermentation corrector	Unlimited

hr sponge stage, with one third of the total flour quantity being used at this step.)

RESULTS AND DISCUSSION

Effect of Dough Composition on Stability in Frozen Storage

Influence of yeast characteristics. In the past, dry yeasts were said to be as efficient as compressed yeasts in frozen doughs (Lorenz and Bechtel 1964, Marston 1978). It also was suggested that dry products at a high conversion ratio performed better (Zaehringer et al 1951, Merrit 1960, Reed 1966). In our work, an attempt was made to verify these views by fluid bed-drying a known effective compressed yeast. The results presented in Figure 4 demonstrate that dried yeasts give poorer results than the original compressed yeast. Drying conditions most probably affect the structure and functional integrity of the cytoplasmic membrane (van Dam 1986) and increase the sensitivity of dry yeasts to freezing (Kline and Sugihara 1968, Javes 1971, Wolt and D'Appolonia 1984b).

Figure 5 shows the different efficiencies of yeasts with different gassing rates in maintaining a normal loaf volume. The initial rheofermentometer analysis (Fig. 6) showed that the rapid yeast from England was immediately active and much faster than the reference product of reduced activity. Hsu et al (1979) asserted that high yeast performance after freezing was obtainable only with high-protein yeasts (>57%). Our opinion is different because the English yeast (protein content of 55%) gave a high rate of fermentation before freezing, which was detrimental to later performance. Figure 7 illustrates the frozen dough performance of two other European yeasts whose protein content (46%) and initial gassing power are comparable to those of the reference product. Selecting a "reduced activity" yeast is not in itself sufficient to achieve stability, as the German and Spanish products show. Throughout our work, doughs yeasted with the reference product always presented the same behavior after freezing and storage: an initial drop in activity evidenced by a slight decrease

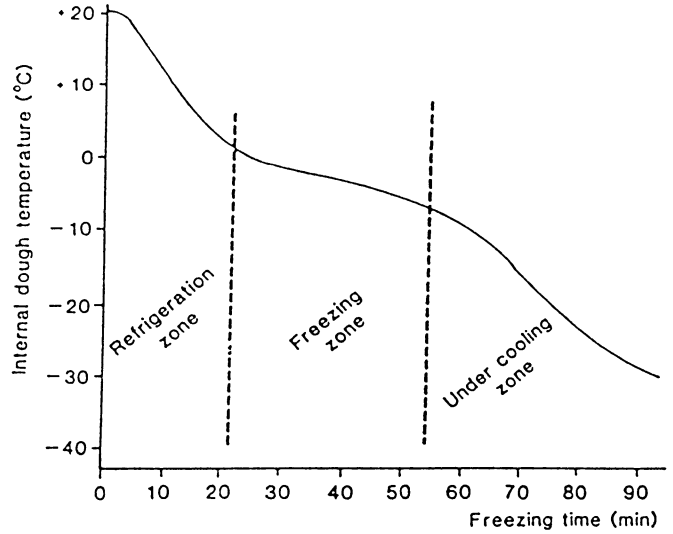

Fig. 3. Freezing curve of a 350-g French "bâtard" dough piece (air blast freezer set at −34°C).

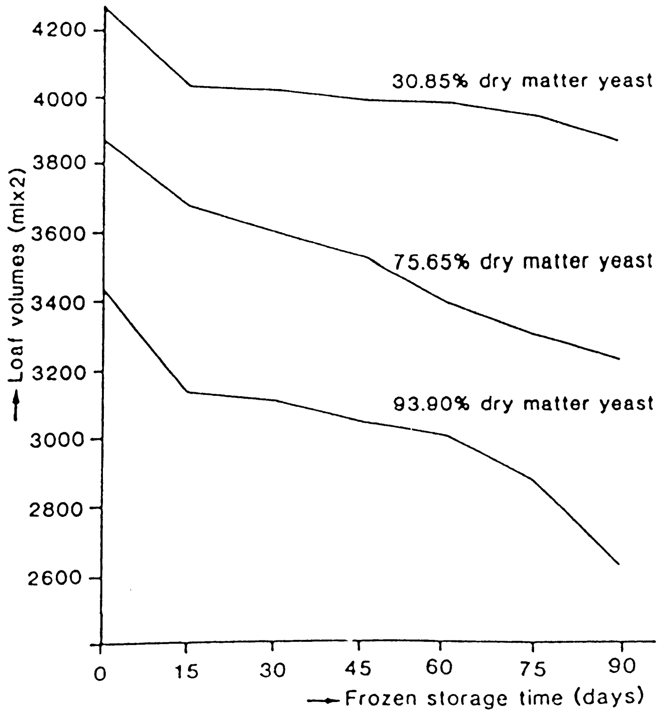

Fig. 4. Conversion of a compressed yeast to instant dry forms. Effect on the frozen dough performance.

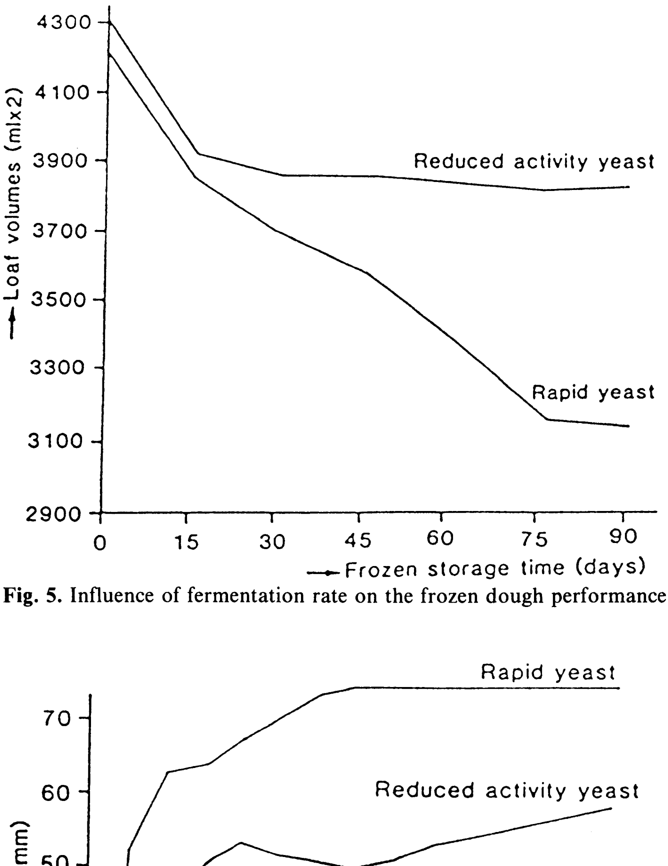

Fig. 5. Influence of fermentation rate on the frozen dough performance.

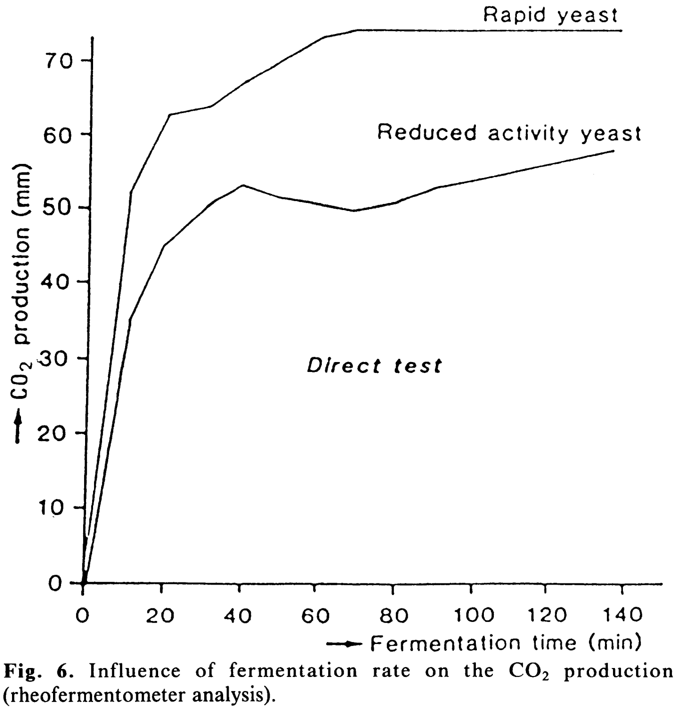

Fig. 6. Influence of fermentation rate on the CO_2 production (rheofermentometer analysis).

in loaf volumes, followed by constant proofing times and bread volumes. If "direct chilling injury" can partly explain the initial decline in efficiency (Morris 1981), the subsequent evolution of the frozen doughs gives evidence of a shelf life stability as defined by Wolt and D'Appolonia (1984b).

In the last decade, research focused on better understanding the factors involved in yeast cryoresistance. Response of yeast cells to freezing injury was shown to depend on their stage in the cell cycle (Cottrel 1981) and on growth conditions (Hino et al 1987, Gelinas 1988, Morris et al 1988). Freeze-thaw resistance of yeast was demonstrated as being partly related to the presence of trehalose, a cryoprotective agent (Oda et al 1986, Uno 1986, Dunas 1988, Gelinas 1988, van der Plaat 1988). Throughout our work, closely controlled growth conditions were used to produce the reference yeast. The rather low protein level (46%) gave a yeast with reduced activity. The high trehalose content (17%) imparted a resistance to freezing.

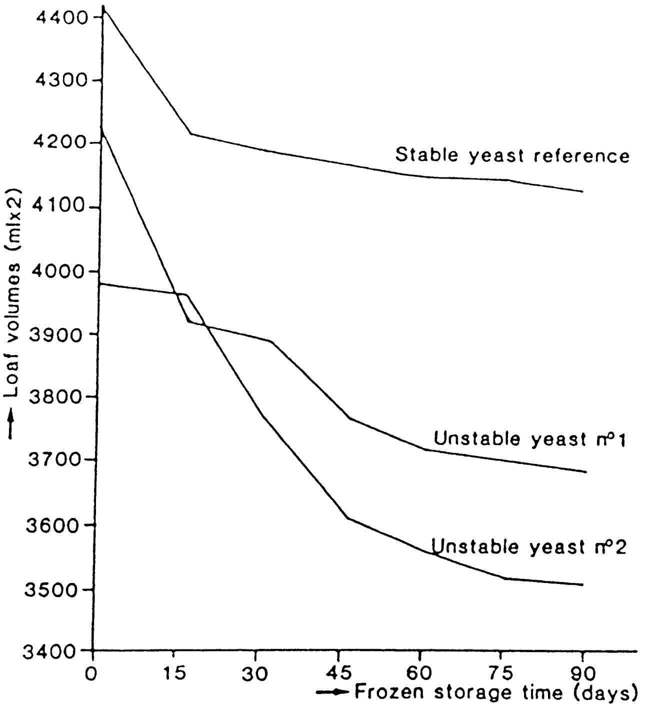

Fig. 7. Difference in frozen dough stability between yeasts with "reduced activity" (yeast No. 1 from Spain, yeast No. 2 from Germany).

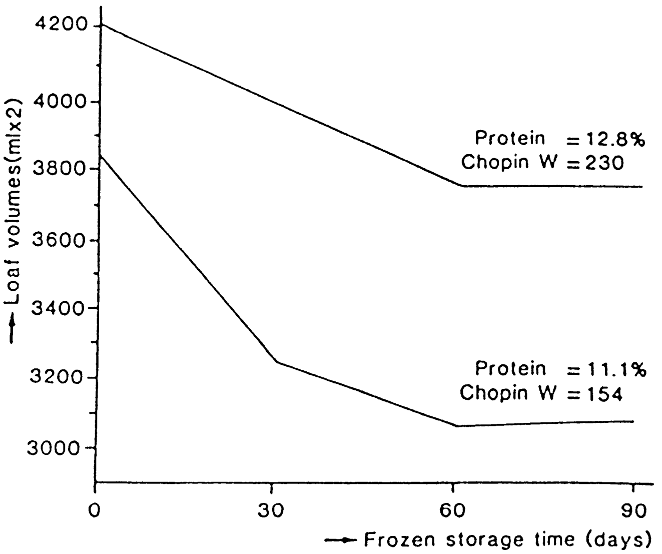

Fig. 8. Effect of baking quality of flours on frozen dough performance.

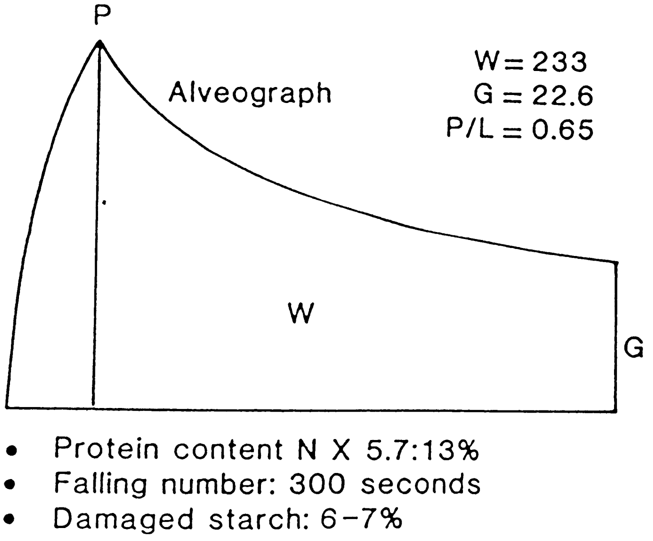

Fig. 9. Characteristics of a flour selected for frozen dough production. *W*, *G*, *P*, and *L* are parameters of the Chopin alveograph.

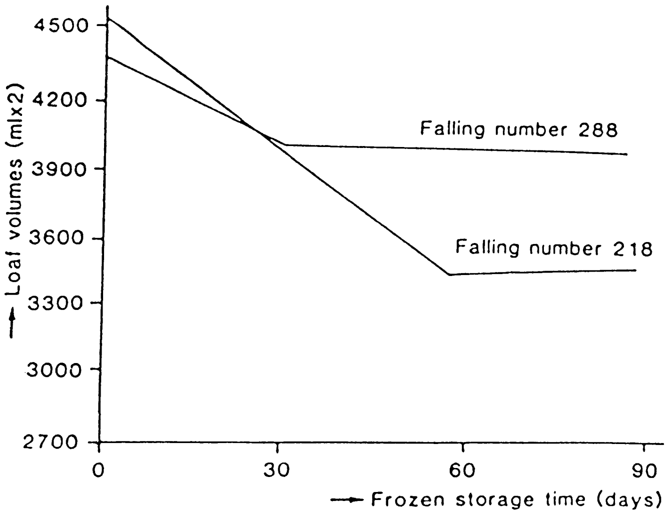

Fig. 10. Effect of the diastatic activity of flours on frozen dough performance.

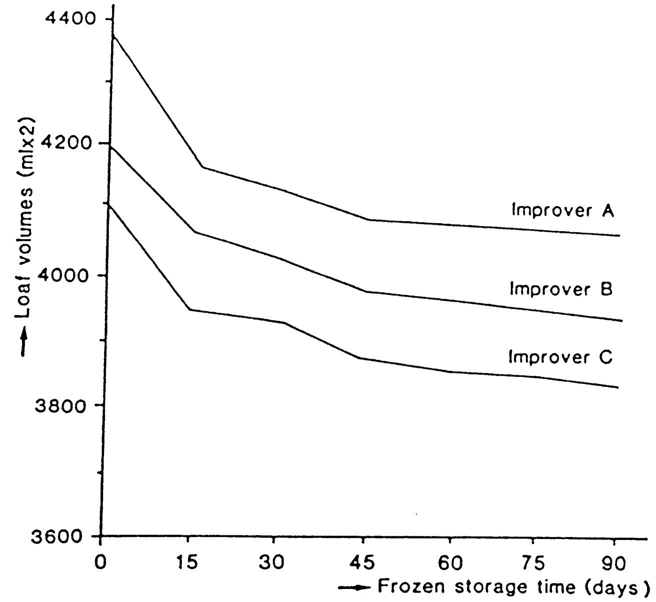

Fig. 11. Effect of bread improvers on frozen dough performance.

Influence of Flour Specifications

For French bread doughs to be frozen, Maitre (1985) advised a protein level between 12 and 13%. For other types of bread, American and European reports recommended the use of medium-strong flours. From our work, protein content of a French flour can be considered a reliable indicator of frozen dough stability however lean the recipe is. Figure 8 illustrates that an 11.1% protein flour is unable to optimize initial and subsequent bread volumes and that a 12.8% protein flour better fulfills these necessary requirements. Figure 9 presents the characteristics of a French flour intended for use in frozen dough production. Protein content should not exceed 13% so as not to restrict the volume of baked loaves (Roussel 1985).

The diastatic activity of flours to be frozen is important. Maitre (1985) quoted a minimum of 280 as the falling number; Sideleau (1987) insisted on avoiding a low amylograph reading. Figure 10 demonstrates that a falling number in the region of 300 is desirable. A low Hagberg value may lead to serious problems in frozen dough technology (Neyreneuf 1988) because the naturally occurring amylases in wheat can have significant activity at low temperatures.

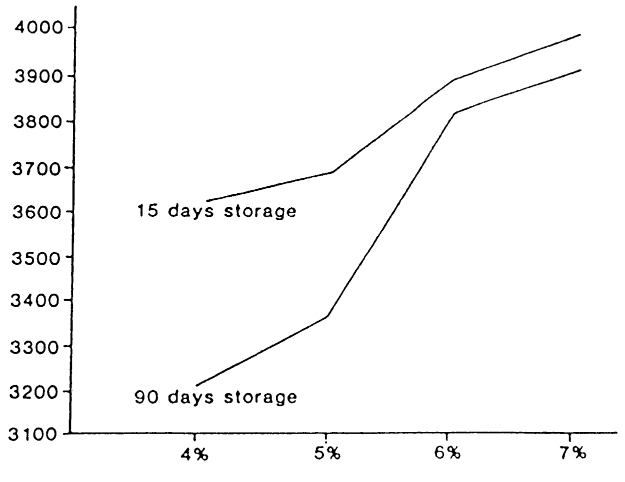

Fig. 12. Effect of yeast dose rate on loaf volume throughout frozen storage.

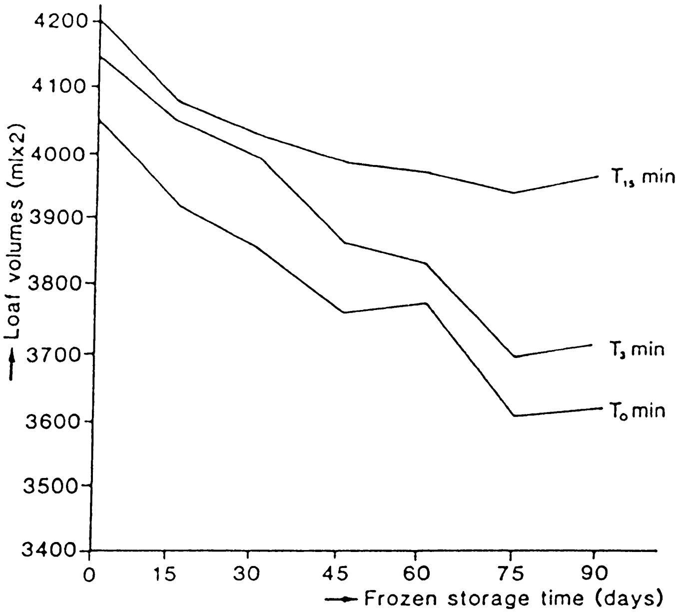

Fig. 13. Effect of the time (T) that yeast is added to the mixer on frozen dough performance.

Influence of Additives

In the past, various studies have suggested suitable additives for the correction of faults arising from the deep-freezing of unbaked doughs (potassium bromate, data esters, sodium stearoyl lactylate, gums, etc.). Such additives are not permitted for standard French bread, and Figure 11 shows the differences in efficiency among improvers whose components correspond with those in the additives listed in Table II. The initial superiority in performance of product A was confirmed throughout the experiment. From our experience, measuring loaf volumes at time = 0 provides a rapid test for predicting the performance of bread improvers in frozen dough production.

Effect of Dough Processing on Stability in Frozen Storage

Influence of yeast level. After dough is defrosted, ensuring development of dough volume in a proofing time consistent with high productivity is the target to reach. Figure 12 presents the results obtained using different levels of yeast (5, 6, and 7% on flour weight) instead of the standard 4% used for normal production. Adding 50% more yeast (6%) is sufficient to maintain satisfactory product volumes, particularly when prolonged storage times are envisaged. With French bread doughs to be frozen, 6% yeast on flour weight provides adequate stability and has no negative effects on taste and flavor. This increased yeast input is necessary because a substantial part of gassing takes place at reduced temperature (van der Plaat 1988).

Influence of mixing conditions. Previous American work advised delaying yeast and salt additions during mixing (Dubois and Blockcolsky 1986, Evenson 1987). Mixing time is long in French breadmaking (3 min at low speed, 17 min at high speed), and the moment when the ingredients are incorporated in the mixer can be important. In our work, influence of different timings for yeast addition was studied (at start of mixing [T = 0], at high speed [T = 3 min], and delayed in high speed [T = 15 min]). Figure 13 shows that the later the yeast is incorporated during mixing, the better the dough stability throughout frozen storage. Moreover, in addition to minimizing gas production before freezing, delayed yeast incorporation usually is considered to strengthen doughs (Calvel 1985).

Some American workers have considered it feasible to prepare frozen doughs using a sponge and dough process (with two mixing steps) (Sugihara and Kline 1968, Javes 1971, Hsu et al 1979). We evaluated the effect on stability of adding 1-hr prefermented doughs (with increased yeast levels up to 6% at the sponge stage). Our findings (Fig. 14) show that a liquid ferment process is not suitable in French frozen dough production. As previously

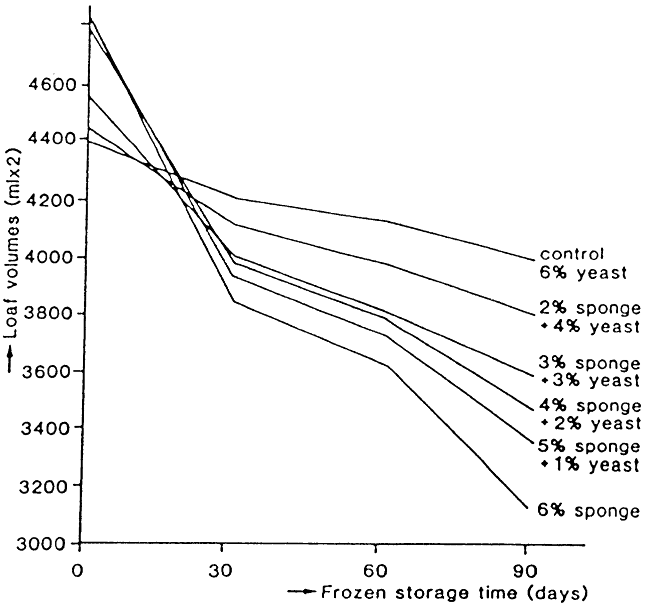

Fig. 14. Effect of prefermentation on frozen dough performance (yeast added at the mixing step).

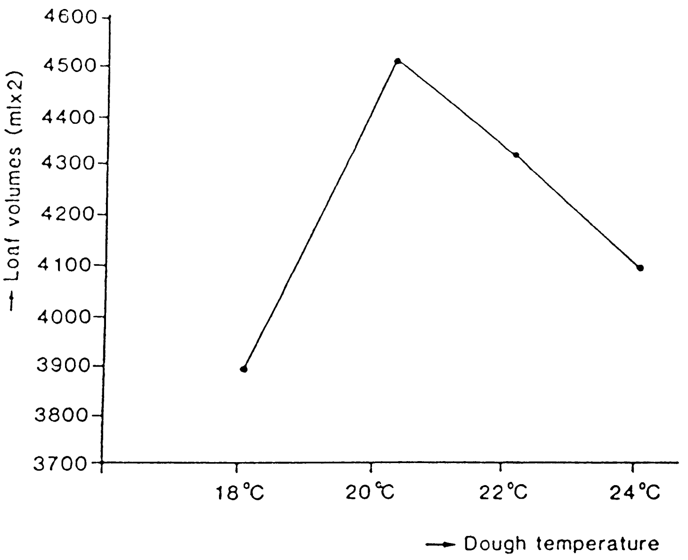

Fig. 15. Influence of dough temperature on frozen dough performance (90 days of storage).

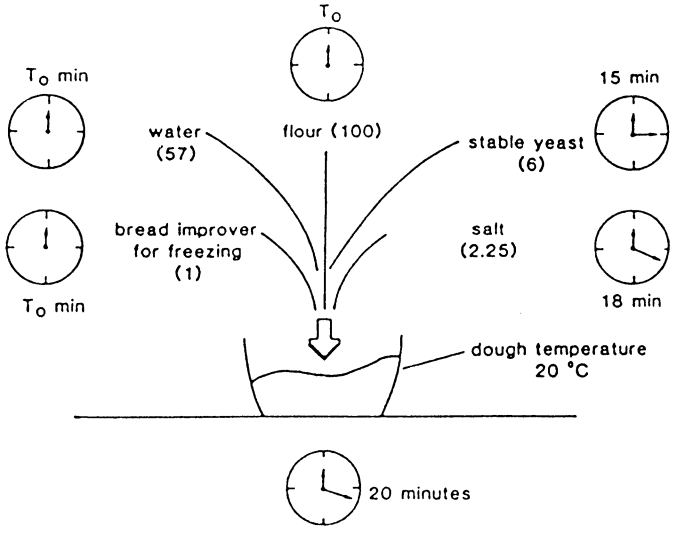

Fig. 16. Production process for optimizing stability of French frozen bread dough throughout extended storage. T = time.

reported (Lorenz and Bechtel 1965, Drake 1970), the method involves activating the yeast before preparing the dough itself. Thus, fermentation at the sponge stage greatly contributes to quality deterioration. Greater levels of yeast in the sponge result in smaller loaf volumes through storage.

It is widely accepted that a dough temperature in the range of 18–22°C is needed to achieve stability. From Figure 15, which shows the influence of different dough temperatures after the dough has been stored a long time, one can conclude that 20°C is the target to reach. Producing cold and highly oxidized doughs is important to achieving stability (De Stefanis et al 1986). A dough temperature of 18°C does not condition the gluten sufficiently in the available mixing time, and 24°C results in a dough with diminished performance. Once the yeast makes contact with the dough, the cell cycle starts almost immediately (van der Plaat 1988). Once the cells reach the S-phase, they are fully active and almost devoid of "cryoprotective" trehalose when freezing takes place. Using a cool dough (20°C) may prolong this transition to, at most, 30 min. Figure 16 illustrates the optimum sequence to be performed during mixing when using a French open-bowl mixer (single-arm type). When a spiral mixer is used, the yeast should be added at transition to high speed. Mixing with discipline is crucial to attaining optimum dough development and appropriate control of yeast cells. Such requirements must be met before freezing if dough stability is to be achieved through prolonged storage.

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