Preparation of Frozen French Bread Dough with Improved Stability

O. NEYRENEUF\(^1\) and J. B. VAN DER PLAAT\(^2\)

\textbf{ABSTRACT}

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.

\textbf{MATERIALS AND METHODS}

\textbf{Flour}

Ordinary Type 55 French flour was used for most experiments. Protein content, falling number, and commonly used factors of the Chopin alveograph (Chopin Trippet 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 ~ 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.

\textbf{Yeast}

A compressed yeast (about 32% dry matter, 46% protein [N × 6.25], 2.25% total P₂O₅, 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 crumpled 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.

\textbf{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).

\textbf{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 Nasso Metallverkstad, Nasso, 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 rheometer. 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 desiccation 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 rheometer 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.

**Table I**

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

<table>
<thead>
<tr>
<th>Storage Time (days)</th>
<th>Yeast</th>
<th>ml of CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fresh</td>
<td>895</td>
</tr>
<tr>
<td>1</td>
<td>1st freezing</td>
<td>905</td>
</tr>
<tr>
<td>2</td>
<td>2nd freezing</td>
<td>885</td>
</tr>
<tr>
<td>3</td>
<td>3rd freezing</td>
<td>895</td>
</tr>
<tr>
<td>8</td>
<td>4th freezing</td>
<td>880</td>
</tr>
<tr>
<td>9</td>
<td>5th freezing</td>
<td>875</td>
</tr>
<tr>
<td>10</td>
<td>6th freezing</td>
<td>870</td>
</tr>
<tr>
<td>11</td>
<td>7th freezing</td>
<td>880</td>
</tr>
<tr>
<td>130</td>
<td>8th freezing</td>
<td>880</td>
</tr>
</tbody>
</table>

**Table II**

Dough Additives Permitted in French Standard Bread Production

<table>
<thead>
<tr>
<th>Additive</th>
<th>Function</th>
<th>Maximum Percentage Allowed (on flour weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital wheat gluten</td>
<td>Texture improver</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>Oxidation</td>
<td>0.03</td>
</tr>
<tr>
<td>Bean flour</td>
<td>Oxidation</td>
<td>2</td>
</tr>
<tr>
<td>Soya flour</td>
<td>Oxidation</td>
<td>0.5</td>
</tr>
<tr>
<td>Soya lecithin</td>
<td>Emulsifier</td>
<td>0.3</td>
</tr>
<tr>
<td>Wheat malt flour</td>
<td>Fermentation corrector</td>
<td>0.3</td>
</tr>
<tr>
<td>Fungal alpha amylases</td>
<td>Fermentation corrector</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

**Fig. 1.** Yeast activity in a nonoptimally frozen dough. Influence of storage time (T) on the CO₂ production (Chopin rheometer).

**Fig. 2.** Yeast activity in a nonoptimally frozen dough. Influence of storage time on the baking performance.
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 yeast with the reference product always presented the same behavior after freezing and storage: an initial drop in activity evidenced by a slight decrease

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**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 CO₂ 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 (Cottrell 1981) and on growth conditions (Hino et al. 1987, Gelinás 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, Gelinás 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.

![Graph showing difference in frozen dough stability between yeasts with reduced activity](image)

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

![Graph showing effect of baking quality of flours on frozen dough performance](image)

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

![Graph showing effect of bread improvers on frozen dough performance](image)

**Fig. 11.** Effect of bread improvers 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.

- Protein content N × 5.7: 13%
- Falling number: 300 seconds
- Damaged starch: 6–7%

**Fig. 10.** Effect of the diastatic activity of flours 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.

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 Blockcowsky 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
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 Stefani 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.

LITERATURE CITED


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