Studies on Frozen Dough Baking. I. Effects of Egg Yolk and Sugar Ester

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ABSTRACT

Improvements in the baking properties of frozen dough with egg yolk and sugar ester were studied by test baking, estimations of the gassing power and dough expansion, dough expansion test under decreased pressure, and surface membrane tension of thawed doughs after frozen storage for up to three weeks. The observed effects of the additives were assumed to be brought about both by protection of yeast cells from damage and by prevention of dough proteins from denaturation by freezing, frozen storage, and thawing.

In the currently popular frozen-dough baking process, frozen dough is thawed, proofed, and baked to serve customers with oven-fresh bread (Allenson 1982). In spite of attractive sensory features of freshly baked bread, storage of frozen dough for several weeks causes problems such as decreased gassing power and weakened dough.

Studies of a possible solution to these problems can be classified into three approaches. The first approach concerns the improvement of the gassing power of dough after thawing. Noteworthy developments in this area were reported by Hino et al (1987) regarding commercial production of new yeast strains resistant to freeze damage. The second approach involves the use of prefermentation before freezing (Lorenz and Bechtel 1964; Lorenz 1974; Hsu et al 1979a,b; Kline and Sugihara 1968). The third approach concerns the use of dough ingredients and additives to prevent loss of dough quality during frozen storage. Surface-active agents such sodium stearoyl-2-lactylate, diacetyl tartaric acid esters of monoglycerides (Marston 1978, Varriano-Marston et al 1980, Davis 1981, Wolt and D'Appolonia 1984b), and oxidizing agents (Lorenz and Bechtel 1965, Varriano-Marston et al 1980, Wolt and D'Appolonia 1984a) were used in these studies. Nonfat dry milk had no improving effect in frozen dough (Sugihara and Kline 1968). On the other hand, Nonami et al (1984) found that egg yolk improved the overall quality of the bread from nonfrozen dough.

Wakamatu et al (1983) reported that gelation of a low-density lipoprotein (LDL) solution with 1–10% NaCl was inhibited during storage at −20°C. They suggested that formation of an LDL-water-NaCl complex increases the proportion of unfrozen water. Following this report, the present article reports on studies carried out to examine the effect of egg yolk combined with sugar ester on the quality of bread baked from frozen dough. We investigated the characteristics that are affected by sugar ester and egg yolk during fermentation and baking of bread.

MATERIALS AND METHODS

The flour was a commercially milled strong bread flour provided by Nisshin Flour Milling Co. (Tokyo) with 12.1% protein content and 0.33% ash content (14% mb). A commercial compressed yeast was provided by Nitten Yeast Co. Salt and cane sugar were commercial products of reagent grade.

Table I shows the ingredients for sample doughs as parts per 100 parts of flour. Egg yolk was separated from fresh eggs just prior to use. Water absorption (65%) was equal to farinograph absorption for a consistency of 500 BU. The farinograph test indicated that egg yolk at the level used in this study did not decrease dough consistency. The sugar ester was sucrose stearate ester, which has a hydrophil-lipophil balance value of 15 (S-1570, Mitsubishi-Kasei, Tokyo). For surface tension and expansion under decreased pressure tests, the yeast was decreased to 0.5% and 0, respectively.

Doughs were mixed (1,000 g of flour) in a vertical screw pin mixer (SS Type 151, Kanto Mixer Co. Ltd.) for 5 min at low speed (100 rpm) and for an additional 7 min at medium speed (190 rpm). The temperature of the dough from the mixer was controlled at 25°C.

After fermentation at 30°C for 60 min, the dough was subdivided as follows: 1) 160 g for baking test, 2) 100 g for gassing power and expansion test, 3) 40 g for test of physical properties, and 4) 30 g for expansion under decreased pressure test. Three dough pieces were prepared for each of the tests, which were conducted before freezing and after three weeks frozen storage at −28°C. All test pieces were sheeted into 6-mm slabs. For the control experiment, the slabs were used directly. For the tests on frozen doughs, they were placed on aluminum plates, covered with a plastic film, and stored. After the frozen storage period, the doughs were thawed at 30°C for 60 min and tested the same way as the control.

Baking Tests

Baking tests were carried out according to the AACC test-baking method (AACC 1983). Thawed doughs were rounded, sheeted, and molded according to the method and placed into the pans. Proofing time was defined as the time required for the dough to expand to the top of the baking pan at 35°C. The loaves were baked at 200°C for 20 min. Oven spring was taken as the height in millimeters to which the dough rose in the oven during baking. It was calculated as the height of bread minus the depth of the pan. Loaf volume was estimated by displacement of sesame seeds.

Gassing Power and Expansion Tests

Gassing power and dough expansion were determined by the classic method (Fig. 1) by measuring dough volume in a glass cylinder (i.d., 50 mm; height, 350 mm). Frozen dough pieces were thawed, rounded, sheeted, and molded as in the baking test. The cylindrical pieces were folded into a "U" shape and inserted into the glass cylinder. First, the rounded end was inserted and pushed up by a rubber stopper from the bottom. The apparatus was

TABLE I
Ingredients in Test Dough[a,b]

Dough	Control	Sugar Ester	Egg Yolk	Sugar Ester + Egg Yolk
Flour	100	100	100	100
Cane sugar	5	5	5	5
Salt	2	2	2	2
Water	65	65	65	65
Sugar ester (S-1570)	···	0.5	···	0.5
Egg yolk	···	···	3	3

[a] Expressed in parts per 100 parts of flour.
[b] Amounts of yeast used in the following tests (parts per 100 parts of flour): baking, gassing power, and expansion, 3; surface membrane tension, 0.5; expansion under decreased pressure, 0.

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placed in a cabinet controlled at 35°C. The increasing height of dough in the cylinder was measured with a cathetometer every 10 min during fermentation. The volume of expansion was obtained from the height increment of the dough and the inside area of the horizontal section of the cylinder, assuming that the shape of top of the dough did not change. Air displaced by the expanding dough and released carbon dioxide was collected (Fig. 1), recorded every 10 min, and used to determine the gassing power.

Surface Membrane Tension of Dough

Surface membrane tension was estimated with a ring plunger as described by Matsumoto (1986), with a slight modification. The plunger was forced into the dough at a speed of 10 mm/sec to a depth of 6 mm. Resistance to the plunger was determined and recorded with a rheoner (RE-3305, Yamaden Co., Tokyo). Surface membrane tension was derived from the total resistance divided by the ring circumference (total of inner and outer circumferences) (Fig. 2).

Expansion Test under Decreased Pressure

A 30-g piece of dough, before freezing or thawed after frozen storage for three weeks, was molded in a similar way to that used in the expansion test and inserted into a test tube (i.d., 25 mm; length, 200 mm). A plastic tube (diameter, 3 mm) was fixed along the inside wall of the test tube (Fig. 3) to allow for equilibration of pressure below and above the dough piece.

The test tube was rested for 5 min at 35°C and evacuated by a vacuum pump to a pressure of 30 mm Hg in 10 min. The expansion under decreased pressure, expressed as the ratio L_2:L_1, was calculated from the length of dough in a test tube before (L_1) and after (L_2) evacuation, measured with a cathetometer.

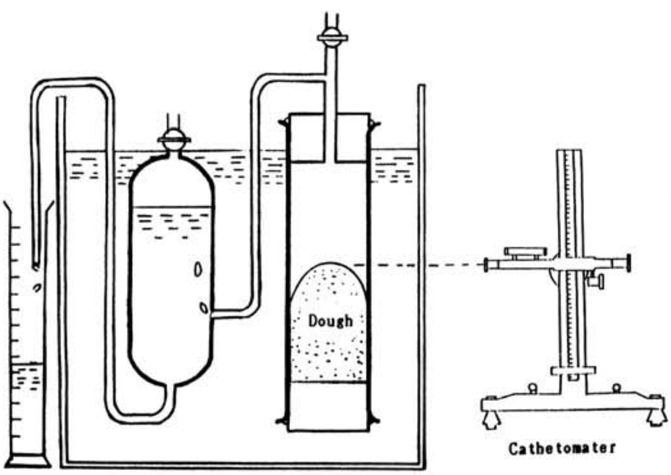


Fig. 1. Apparatus for the estimation of gassing power and expansion of dough.

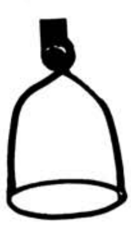
wire ring

Circumference

inner 63.1mm

outer 69.1mm

Total 132.2mm



The membrane tension dyne/cm

$$= \frac{\text{Total stress to the ring (dyne)}}{\text{Total circumference (cm)}}$$

Fig. 2. Ring plunger and process to obtain surface membrane tension of dough.

RESULTS

Baking

The results of test baking are shown in Figure 4 and Table II. Addition of sugar ester improved the oven spring and the volume of the test loaves before freezing and after three weeks frozen storage. Egg yolk showed an additional improving effect.

Proofing times to constant dough height (Table III) showed that the additives offered the yeast cells some protection from freeze damage. The increase in proofing time resulting from frozen storage was significantly less in the treated than in the control doughs.

Gassing Power and Expansion

Gassing power (Fig. 5) was virtually unaffected by sugar ester, egg yolk, or sugar ester plus egg yolk before freezing (results are shown only for untreated doughs). After three weeks of frozen storage, the doughs with yolk alone and with sugar ester plus egg yolk showed less decrease in gassing power than that of the

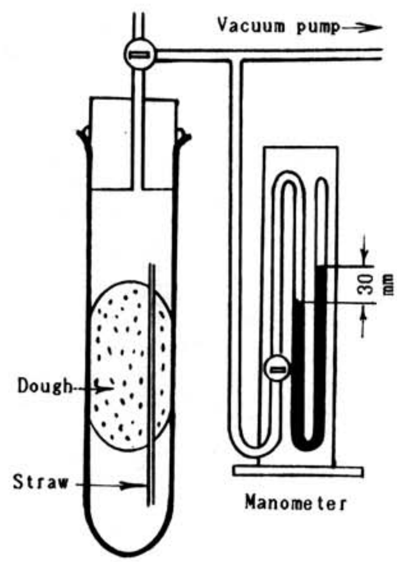


Fig. 3. Expansion test under decreased pressure.

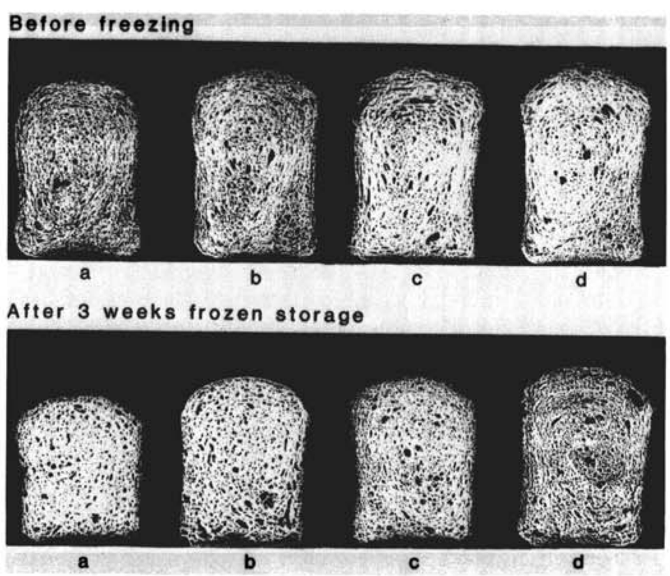


Fig. 4. Results of bread-baking test. Doughs and additives: a = control, b = sugar ester, c = egg yolk, d = sugar ester plus egg yolk.

control. The effect of sugar ester alone was negligible. These results indicate that egg yolk (alone or with sugar ester) partially protects yeast cells from damage during freezing and frozen storage.

The effect of additives on dough expansion and gassing power was generally similar (Fig. 6). The difference between expansion and gassing power curves is probably due to gas leakage from the dough. The leakage time of the onset of gas (detected as the separation of the two curves) are indicated by the arrow. Doughs with sugar ester, egg yolk, and sugar ester plus egg yolk seemed to improve gas-retention properties of dough before freezing and after frozen storage.

Surface Membrane Tension

The values for surface membrane tension (Table IV) were higher for the doughs with sugar ester, egg yolk, and sugar ester plus egg yolk than for those of the control. These results indicate that these additives make dough membranes stronger and thus prevent gas leakage as shown by Matsumoto (1986).

TABLE II
Oven Spring and Loaf Volume in Frozen Dough Baking (Mean ± SD)

	Before Freezing		After Three Weeks of Frozen Storage	
Dough	Oven Spring (mm)	Loaf Volume (ml)	Oven Spring (mm)	Loaf Volume (ml)
Control	29 ± 2	433 ± 19	3 ± 1	307 ± 7
Sugar ester[a]	31 ± 2	455 ± 14	8 ± 0	344 ± 19
Egg yolk[b]	34 ± 4	471 ± 15	12 ± 1	364 ± 2
Sugar ester + egg yolk	37 ± 2	482 ± 10	13 ± 0	372 ± 3

[a] Ryoto sugar ester (S-1570), 0.5% (wheat flour base).
[b] Fresh egg yolk, 3%.

TABLE III
Proofing Time in Dough Baking (Mean ± SD)

	Before Freezing	After Three Weeks of Frozen Storage	
Dough	Proofing Time (min:sec)	Proofing Time (min:sec)	Changing Proofing Time (min:sec)
Control	15:30 ± 2:00	71:50 ± 5:30	50:20
Sugar ester	16:00 ± 0:30	51:00 ± 1:40	35:20
Egg yolk	14:15 ± 0:20	48:50 ± 1:10	34:35
Sugar ester + egg yolk	14:00 ± 1:00	45:50 ± 2:10	31:50

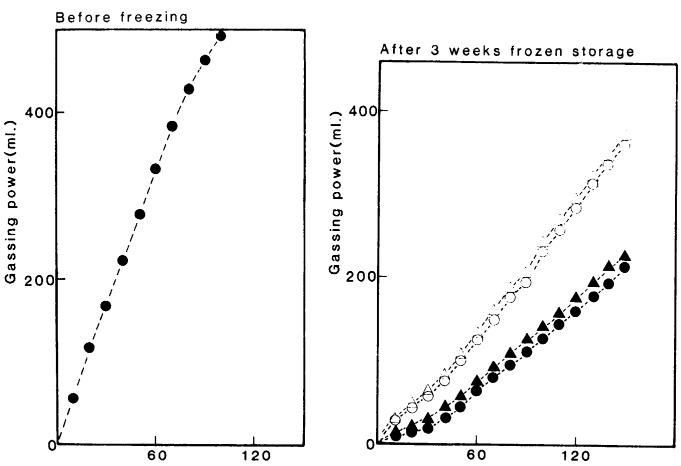


Fig. 5. Gassing power of 100 g of dough. Doughs and additives: ● = control, ○ = egg yolk, ▲ = sugar ester, △ = sugar ester plus egg yolk.

Expansion Under Decreased Pressure

The values for expansion ratio (Table V) were higher for the sugar ester, egg yolk, and sugar ester plus egg yolk doughs than for those of the control. These tests were also carried out with doughs heated to 70 and 75°C (results not shown). No differences were noted in the ratio values for treated and control doughs at these higher temperatures. These results indicate that sugar ester and egg yolk improved dough expansion before starch gelatinization. That is, the improvement is related not to the starch gelatinization but to the physical properties of dough at the lower temperature.

CONCLUSIONS

The baking properties of dough should be discussed from two aspects: gassing power and physical properties related to gas retention. Both of these aspects were investigated in the present study of frozen doughs.

Our results indicate that sugar ester, egg yolk, and sugar ester plus egg yolk decrease damage to gassing power during frozen storage. Results from tests of expansion, expansion under decreased pressure, and surface membrane tension suggest that the physical properties of dough in terms of dough expansion

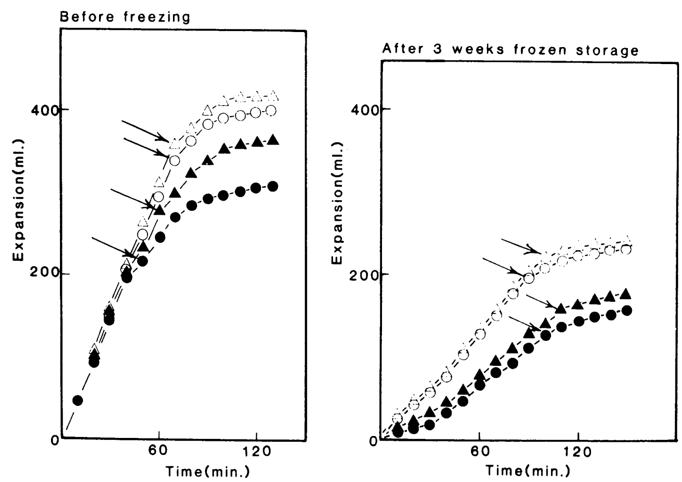


Fig. 6. Expansion of 100 g of dough. Doughs and additives: ● = control, ○ = egg yolk, ▲ = sugar ester, △ = sugar ester plus egg yolk.

TABLE IV
Surface Membrane Tension of Dough (Mean ± SD)

Dough	Before Freezing (dynes/cm) × 10^3	After Three Weeks of Frozen Storage (dynes/cm) × 10^3
Control	3.7 ± 0.1	1.8 ± 0.5
Sugar ester	3.8 ± 0.1	2.0 ± 0.1
Egg yolk	4.0 ± 0.4	2.1 ± 0.1
Sugar ester + egg yolk	5.1 ± 0.1	2.2 ± 0.5

TABLE V
Ratio of Dough Expansion Under Decreased Pressure (Mean ± SD)

Dough	Before Freezing	After Three Weeks of Frozen Storage
Control	1.79 ± 0.01	1.70 ± 0.02
Sugar ester	1.81 ± 0.01	1.71 ± 0.02
Egg yolk	1.83 ± 0.02	1.77 ± 0.03
Sugar ester + egg yolk	1.90 ± 0.02	1.85 ± 0.02

were improved by the addition of sugar ester and egg yolk when compared with the results for the control dough. Conditions that improve dough expansion under reduced pressure would lead to high loaf volume on baking (Matsumoto 1952, Bell et al 1981).

The results of test baking reflected the total effect of gassing power and physical properties related to gas retention. Improved oven spring and higher loaf volumes clearly indicated that the additives used in this study decreased overall freeze damage to dough.

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