Factors Involved in the Stability of Frozen Dough. II. The Effects of Yeast Type, Flour Type, and Dough Additives on Frozen-Dough Stability[1]

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ABSTRACT

Shelf-life stability studies were conducted to evaluate the effects of yeast type, flour type, and various dough additives on the ability of frozen bread dough to proof in an acceptable period of time and to bake into a loaf with normal volume and bread characteristics. In this study, fresh compressed yeast performed slightly better than active dry yeast and instant active dry yeast in proof-time stability over a storage period of 20 weeks. The surfactants sodium stearoyl lactylate (SSL) and diacetyl tartaric acid decreased the effects of frozen storage on rheological properties, but they were not effective in reducing the time to proof doughs to a specific height. Frozen doughs with SSL had greater loaf volume after baking than did doughs with no SSL, because of greater oven spring. The use of diacetyl tartaric acid was less effective than SSL in counteracting rheological changes and in maintaining loaf volume. Flour type was found to be an important variable in the proof-time stability of doughs. Based on flours used in this study, the data indicate that protein content is not a reliable indicator of a flour's performance in frozen dough. Starch characteristics in bread crumbs produced from frozen dough were found to change with frozen storage.

Some workers have suggested that dry yeast may be superior to compressed yeast in maintaining shelf life in frozen dough (Merritt 1960, Zaehringer et al 1951). Theoretically, the longer lag period with dry yeast should minimize fermentation before freezing and thus give a more stable frozen dough. Kline and Sugihara (1968), however, found that doughs made with dried yeast had somewhat longer proof times than doughs made with compressed yeast (CY). These workers suggest that the release of reducing agents from active dry yeast (ADY) could be the cause of the longer proofing time.

Oszlanyi (1980) reported data on the amount of thiol compound released by various types of yeast in mixed and in fully proofed doughs. On a usage basis (0.33 g of instant active dry yeast [IDY] = 1.0 g of CY and 0.45 g of ADY), ADY released the greatest amount of thiol compounds in mixed doughs, and instant active dry yeast released a similar amount. Although thiol compounds are not normally leached from fresh CY (Ponte 1960), osmotic pressure within a dough system might result in some cellular damage and the subsequent release of these compounds.

In this study CY, ADY, and IDY were compared in frozen-dough shelf-life stability tests. Shelf-life stability is defined as the ability of a thawed dough to proof in an acceptable period of time and to bake into a loaf with normal volume and bread characteristics.

Little work has been reported on the effect of flour type on frozen-dough stability. A medium to strong patent flour is recommended for frozen doughs (Marston 1978, Tressler et al 1968). Tressler suggests that a high-quality protein flour is important for frozen dough but that the amount of protein is not critical. Lorenz and Bechtel (1965) compared the stability of frozen doughs made from spring and winter wheat flours at various levels of oxidation. These workers found that at optimum levels of oxidation for each flour, proof-time stability did not differ. In this study, four flours varying in protein quantity and quality were evaluated in frozen-dough stability studies.

The surfactants sodium stearoyl lactylate (SSL) and diacetyl tartaric acid ester of monoglyceride (DATA) have been shown to be effective in maintaining both volume and crumb softness in bread produced from dough subjected to extended storage (Davis 1981, Marston 1978, Varriano-Marston et al 1980). Davis reported data showing that SSL provides longer shelf-life stability in terms of loaf volume; however, the study did not include information on proof-time stability, which is critical to the overall shelf-life of the product.

In this study the effect of SSL and DATA on proof-time and loaf-volume stability were analyzed over 20 weeks of frozen storage. Data on the role of SSL and DATA in counteracting rheological changes that occur with frozen storage were obtained with the extensigraph. Starch characteristics of bread crumbs produced from dough frozen up to 16 weeks were also analyzed.

MATERIALS AND METHODS

Yeast Samples

ADY and CY samples were obtained from the Universal Foods Corporation, Milwaukee, WI. Compressed yeast samples of similar gassing power were received by air express directly from the factory. All CY samples were stored under refrigeration and used within one week of their arrival. IDY was supplied by GB Fermentation Industries, Inc., Des Plaines, IL.

Fresh yeast samples (CY, ADY, and IDY) were analyzed for moisture, protein, and gassing power according to AACC (1962) methods 44-32, 46-10, and 22-13, respectively. For the gassing power test, conversion factors of 0.45 and 0.33 were used to convert the compressed yeast weight (0.3 g) to equivalent weights for ADY and IDY, respectively.

The percentage of dead cells was determined by the procedure previously outlined (Wolt and D'Appolonia 1984). For the ADY and IDY samples, 0.5 g of yeast was suspended in 9.5 ml of tap water at 40°C and agitated gently for 10 min. A 5.0 ml aliquot of this suspension was diluted to 100 ml, and the analysis was conducted as indicated for compressed yeast.

Flour Samples

Flours A and B were commercial patent flours that were bleached and bromated at the mill. Flour B was produced from 100% hard red spring wheat. Two additional flours (C and D) were obtained from hard red spring wheat samples milled on a Miag pilot mill according to the method of Shuey and Gilles (1968). Flour C was produced from a lot of hard red spring wheat obtained from a commercial mill. Flour D was produced from the hard red spring wheat variety Coteau. Flours C and D were straight-grade flours that were bleached but had received no additional treatment.

Moisture, ash, and protein contents in the flour samples were measured according to AACC (1962) methods 44-11, 08-01, and 46-10, respectively. Protein and ash content were reported on a 14.0% moisture basis. Dough-mixing properties of the flours were

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TABLE I
Formulation of Doughs in Stability Study I

Dough Series	Flour	Yeast Type[a]	Oxidation[b]	Dough Additive[c]
1 (control)	B	5.0% CY	100 ppm AA/30 ppm $KBrO_3$	···
2	A	5.0% CY	100 ppm AA/30 ppm $KBrO_3$	···
3	B	5.0% CY	100 ppm AA/30 ppm $KBrO_3$	0.5% SSL
4	B	5.0% CY	100 ppm AA/30 ppm $KBrO_3$	0.5% DATA
5	B	2.25% ADY	100 ppm AA/30 ppm $KBrO_3$	···
6	B	1.65% IDY	100 ppm AA/30 ppm $KBrO_3$	···

[a]CY = compressed yeast, ADY = active dry yeast, IDY = instant active dry yeast.
[b]AA = ascorbic acid.
[c]SSL = sodium stearoyl lactylate. DATA = diacetyl tartaric acid.

TABLE II
Formulation of Doughs in Stability Study II

Dough Series	Flour	Yeast Type[a]	Oxidation[b]	Dough Additive[c]
1 (control)	A	5% CY	100 ppm AA/30 ppm $KBrO_3$	···
2	B	5% CY	100 ppm AA/30 ppm $KBrO_3$	···
3	C	5% CY	100 ppm AA/30 ppm $KBrO_3$	···
4	D	5% CY	100 ppm AA/30 ppm $KBrO_3$	···
5	A	5% CY	100 ppm AA/30 ppm $KBrO_3$	0.5% SSL
6	A	5% CY	100 ppm AA/30 ppm $KBrO_3$	0.5% DATA
7	A	5% CY	100 ppm AA/30 ppm $KBrO_3$	0.25% CMC

[b]AA = ascorbic acid.
[c]SSL = sodium stearoyl lactylate, DATA = diacetyl tartaric acid, CMC = carboxymethyl cellulose.

TABLE III
Pertinent Information on Yeast Samples

	Samples[a]		
	CY	ADY	IDY
Moisture content, %	69.0	8.7	4.0
Protein content (dry basis), %	51.5	38.7	52.0
Gassing power (dry basis), mm Hg at 5 hr	470.0	455.0	465.0
Dead cells, %	4.9	13.0	18.6
Glutathione leached, mg/g of dry yeast	0.0	2.56	4.06

[a]CY = compressed yeast, ADY = active dry yeast, IDY = instant active dry yeast.

TABLE IV
Analytical Data on Flour Samples[a]

	Flour Sample			
	A	B	C	D
Moisture, %	13.4	12.9	13.9	14.6
Ash, %	0.41	0.43	0.41	0.46
Protein, %	12.2	13.3	14.6	15.8

[a]On 14.0% moisture basis.

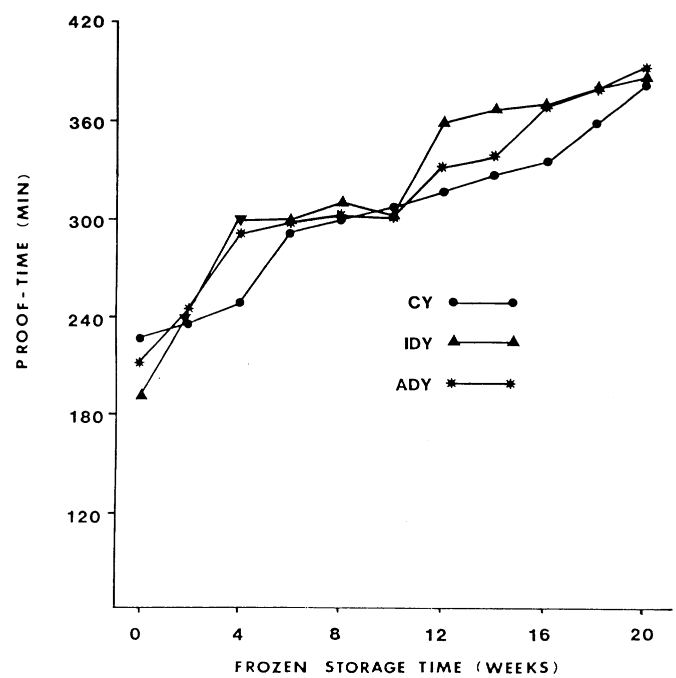

Fig. 1. Influence of yeast type on proof-time stability.

investigated using the farinograph according to AACC (1962) method 54-21. The 50-g bowl and the constant flour weight method were used. The extensigraph procedure previously outlined (Wolt and D'Appolonia 1984) was used to examine dough characteristics of the various flours.

Frozen-Dough Stability Studies

The following "no-time" dough formulation was used to prepare doughs for stability studies: 100% flour, 5% yeast, 4% shortening, 4% sugar, 1.5% salt, 100 ppm ascorbic acid, (flour basis), 30 ppm $KBrO_3$ (flour basis), and an optimum amount of water.

Study I. The doughs in Table I were evaluated to determine whether modifications in the basic formulation influenced frozen dough stability. ADY and IDY samples were rehydrated for 10 min at 40°C with enough water to give the yeast slurries a weight equivalent to 5% CY (flour basis). Three batches (3,000 g of flour) were prepared for studying each modification in the basic formulation. Each batch yielded eight 500-g frozen dough pieces. A total of 24 dough pieces were frozen for each series of formulation modification.

All ingredients were mixed to optimum development in a Hobart D-300T 30-quart mixer. Doughs were removed from the mixer, and the dough temperature was recorded. A dough temperature of 72 ± 2° F was maintained by using 50° F water in the formulation. Doughs were fermented 20 min in a cabinet maintained at 86° F and 80% rh and then divided into 500-g pieces and rounded. The rounded doughs were placed in stainless steel bowls and returned to the fermentation cabinet for a 10-min rest period. Doughs were then molded on a Nussex/straight-grain molder. The molded doughs were panned and then placed directly into a walk-in freezer at −10° F. After approximately 2 hr the dough pieces were removed from the pan and placed in polyethylene bags that were then sealed.

Two dough pieces of each dough type were not frozen but were placed directly into a proofing cabinet at 100° F, 98% rh. After 55 min, the height of the dough above the pan was measured. The average height of the two loaves was used as the proofing height for the frozen dough pieces for each respective dough type.

Two frozen dough pieces of each dough type were thawed, proofed, and baked one day after freezing and then after every two weeks, for a total of 20 weeks. Doughs were thawed and proofed to height in a fermentation cabinet (30° C, 85% rh). Proofing time was

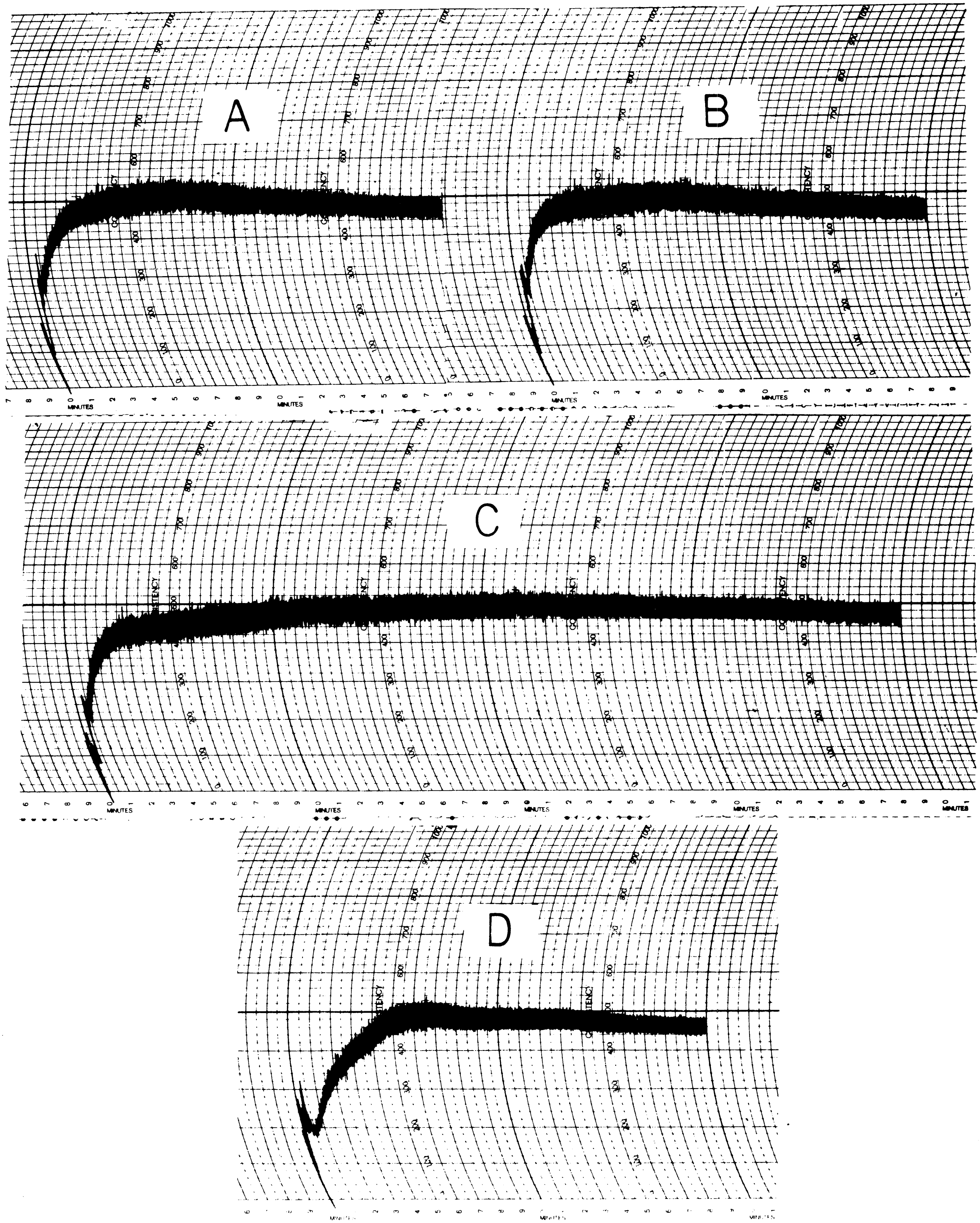

Fig. 2. Farinograph curves of flour samples.

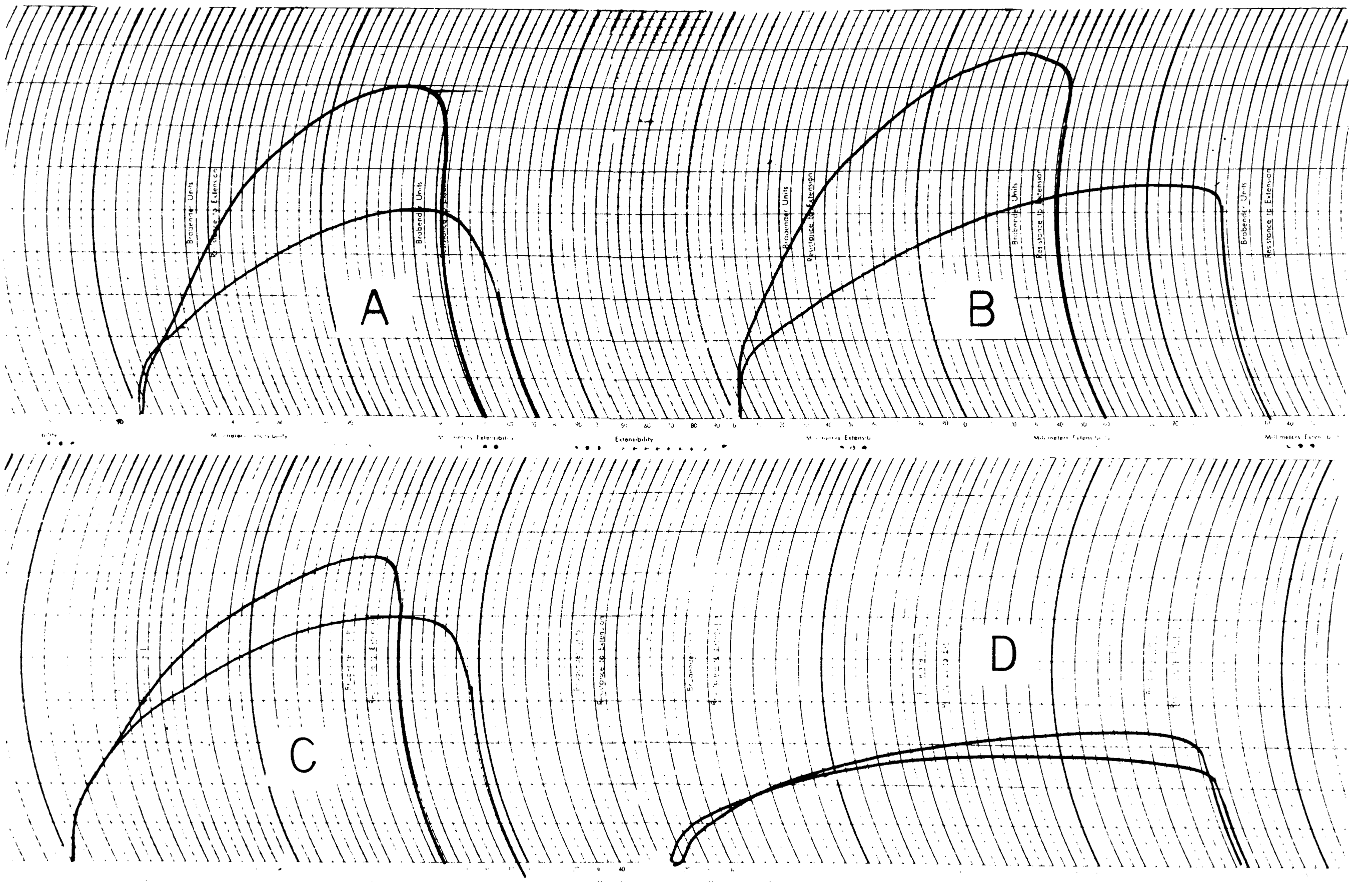

Fig. 3. Extensigraph curves of flour samples.

recorded to the nearest minute. Loaves were then baked at 400°C for 25 min. After cooling, loaf volume was determined by rapeseed displacement. The internal and external characteristics of the bread were noted.

Study II. The doughs in Table II were evaluated in Study II. The procedure used was identical to that used in Stability Study I, with the following exceptions. Only one batch (4,500 g of flour) was prepared for each dough series, and doughs were evaluated after one day, two weeks, one month, three months, and four months of frozen storage. All doughs in Stability Study II were proofed to 4.0 cm above the pan. Additionally, the finished loaves were scored on a scale of 1–10 for external characteristics, grain/texture, crumb color, and crust color, respectively.

Extensigraph Studies

The extensigraph procedure (Wolt and D'Appolonia 1984) was used to evaluate the effectiveness of dough additives in counteracting rheological changes. Dough cylinders containing 0.5% SSL and 0.5% DATA were evaluated after one day and after 10 weeks of frozen storage.

Starch Characteristics

The crumb of the control loaves and of those containing the various dough additives from Stability Study II were freeze-dried 2 hr after baking. The freeze-dried crumb was ground on a Wiley mill to pass through a 60-mesh screen. The ground bread crumb was then evaluated for soluble starch and amylose content and for pasting properties.

The procedure outlined by Morad and D'Appolonia (1980b) was used for the isolation of soluble starch. Freeze-dried crumb was agitated with 80 ml of distilled water on a wrist-action shaker for 20 min. The slurry was centrifuged (2,000 × *g* for 5 min), and the supernatant was decanted. The procedure was repeated on the residue, and the combined supernatants were filtered through no. 4 filter paper. Three volumes of methanol were added to the filtrate,

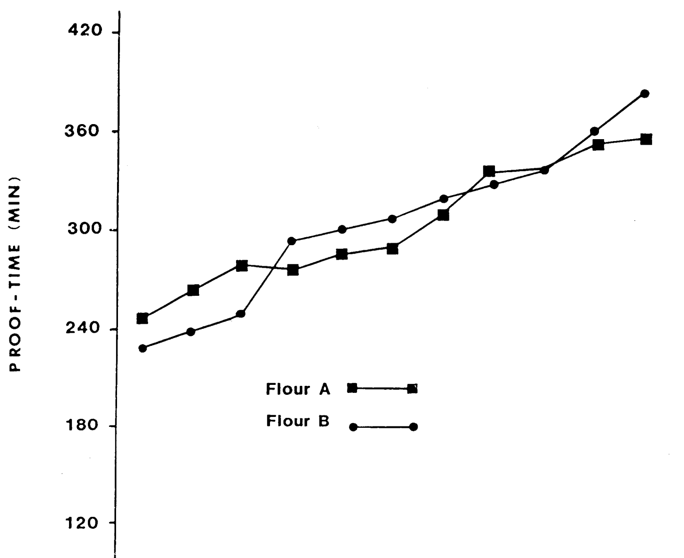

Fig. 4. Proof-time stability of frozen doughs made from flours A and B. Study I.

and the mixture was heated on a steam bath for 1 hr and left overnight at 4°C. Soluble starch was then collected after centrifugation (16,300 × *g* for 20 min). The collected material was dispersed in 25 ml of distilled water, freeze-dried, and the weight of dry soluble starch recorded.

Amylose content in the soluble starch was determined by the colorimetric iodine procedure of Williams et al (1970). A standard curve for amylose was prepared by using amylose isolated from the control flour by the method of Montgomery and Senti (1958). The soluble starch isolated from the freeze-dried bread-crumb samples was extracted for 16 hr with methanol before the amylose determination. The Brabender Amylograph was used to examine the pasting properties of the freeze-dried bread crumb (Morad and D'Appolonia 1980a). The sample (60 g) was suspended in 350 ml of distilled water and agitated for 1 min in a Waring blendor. The suspension was poured into the amylograph bowl, and the blender was rinsed with 100 ml of additional water. The crumb suspension was heated uniformly from 25 to 95°C, held at 95°C for 15 min, and then cooled to 50°C. Pasting temperature, peak viscosity, 15-min viscosity, and viscosity at 50°C were measured.

RESULTS AND DISCUSSION

Influence of Yeast Type

Table III gives pertinent information on the three yeast samples used in this study. The protein content of the CY and IDY samples were very similar, whereas the ADY had a much lower protein content. Lower protein yeast is used for ADY production because high-protein yeast does not survive the conventional drying

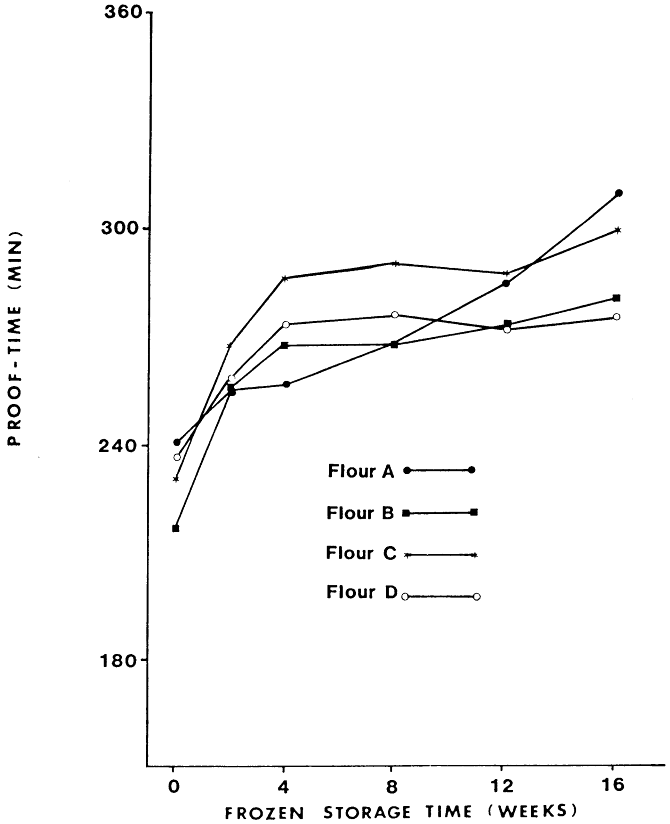

Fig. 5. Proof-time stability of frozen doughs made from flours A, B, C, and D. Study II.

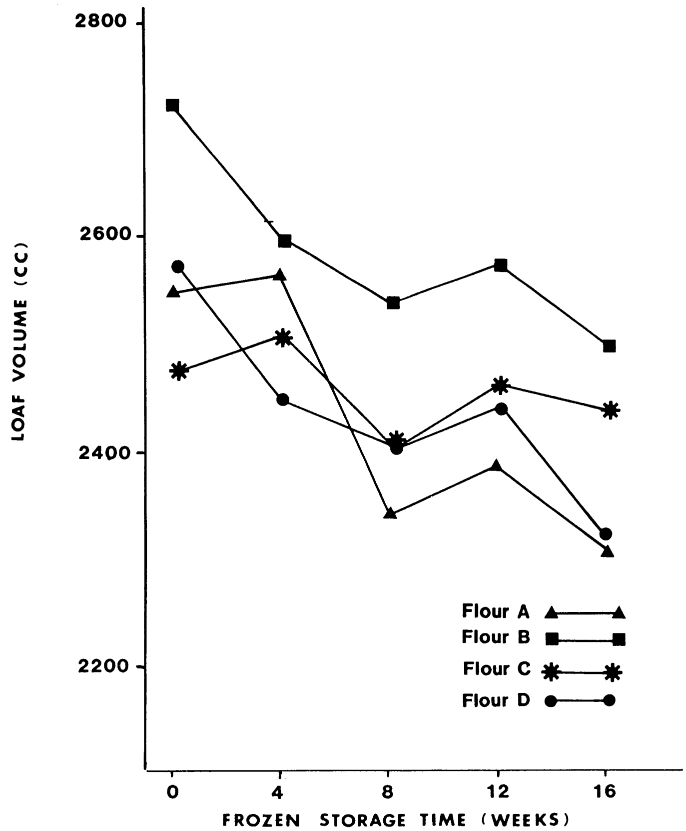

Fig. 6. Loaf volume stability of frozen doughs made from flours A, B, C, and D. Study II.

TABLE V
Effect of Flour Type on Internal and External Characteristics of Bread from Frozen Dough[a]

	Storage Time					
Flour Type	**1 Day**	**2 Weeks**	**4 Weeks**	**8 Weeks**	**12 Weeks**	**16 Weeks**
A						
External appearance	9.0	9.0	8.5	8.5	8.5	7.5
Grain and texture	8.0	8.5	8.0	8.0	8.0	7.5
Crumb color	8.0	8.0	8.0	8.0	8.0	8.0
Crust color	10.0	10.0	10.0	10.0	10.0	10.0
B						
External appearance	9.0	8.5	8.5	9.0	8.0	8.0
Grain and texture	8.0	8.0	8.0	8.0	7.5	7.5
Crumb color	7.0	7.0	7.0	7.5	7.5	7.5
Crust color	10.0	10.0	10.0	10.0	10.0	10.0
C						
External appearance	8.0	8.0	8.0	8.0	7.0	7.0
Grain and texture	9.0	9.5	9.0	9.0	8.0	7.5
Crumb color	9.0	9.0	9.0	9.0	9.0	9.0
Crust color	10.0	10.0	10.0	10.0	10.0	10.0
D						
External appearance	8.0	8.0	8.0	8.0	8.0	7.0
Grain and texture	7.0	7.5	7.0	7.5	7.0	6.5
Crumb color	8.5	8.5	8.5	8.5	8.0	8.0
Crust color	10.0	10.0	10.0	10.0	10.0	10.0

[a]Evaluated on a scale of 1–10, with 10 being the best. Data from Stability Study II.

process. The type of drying process used for the manufacture of IDY allows for the drying of high-protein yeast. The gassing power for the IDY on a dry basis is only slightly lower than that of the compressed yeast (Table III), whereas the ADY displayed a slightly lower gassing power than the two other yeast types.

Fresh compressed yeast had a lower percentage of dead yeast cells than either ADY and IDY. Dead yeast cells are believed to release glutathione (GSH), but fresh compressed yeast contained a considerable amount of dead cells (4.9%) and leached no detectable amount of GSH.

Therefore, the dry process itself, not the dead cells per se, results in the release of GSH from both ADY and IDY.

In frozen-dough stability studies, proof times were initially lower for ADY and IDY doughs than for CY dough (Fig. 1). However, after extended storage the proof time of the ADY and IDY doughs surpassed those of the CY doughs. In general, the CY dough had lower proof time during frozen storage than did the IDY and ADY frozen doughs. Kline and Sugihara (1968) also reported that CY performed better than ADY in frozen dough. They suggest that GSH released from ADY weakens the gluten network, which results in poor gas retention and longer proof times. Wolt and

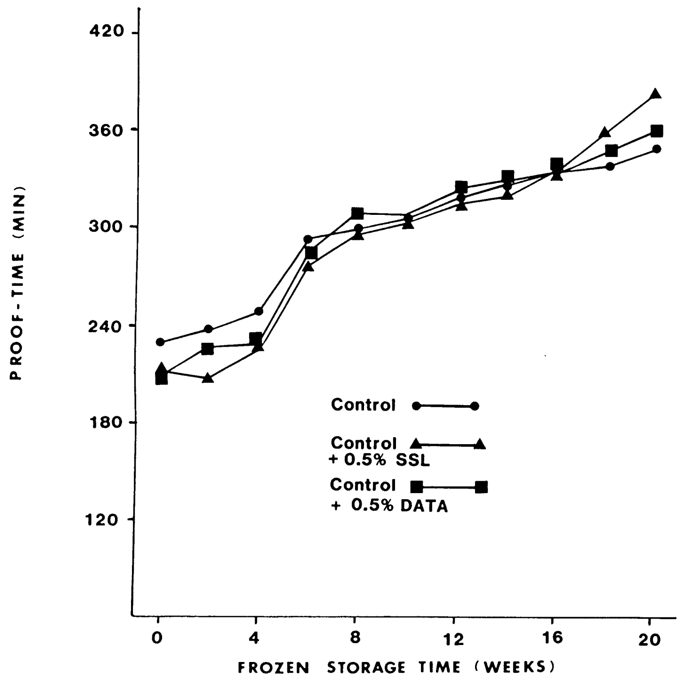

Fig. 7. Effect of sodium stearoyl lactylate (SSL) and diacetyl tartaric acid (DATA) on proof-time stability of frozen dough. Study I, flour B.

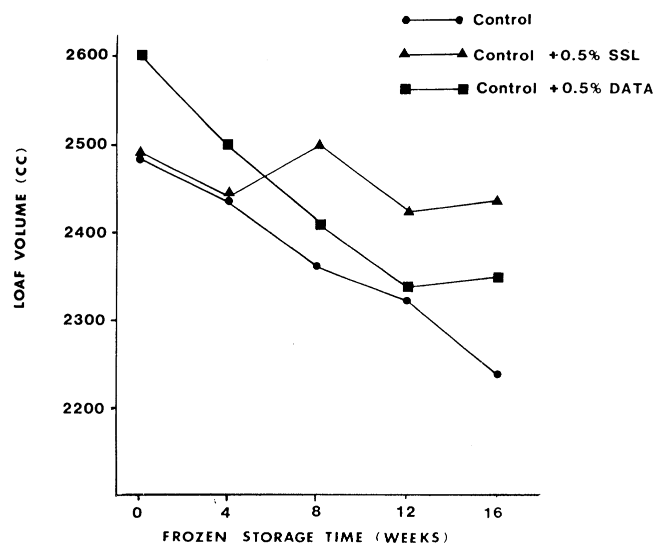

Fig. 9. Effect of sodium stearoyl lactylate (SSL) and diacetyl tartaric acid (DATA) on loaf-volume stability of frozen dough. Study II, flour A.

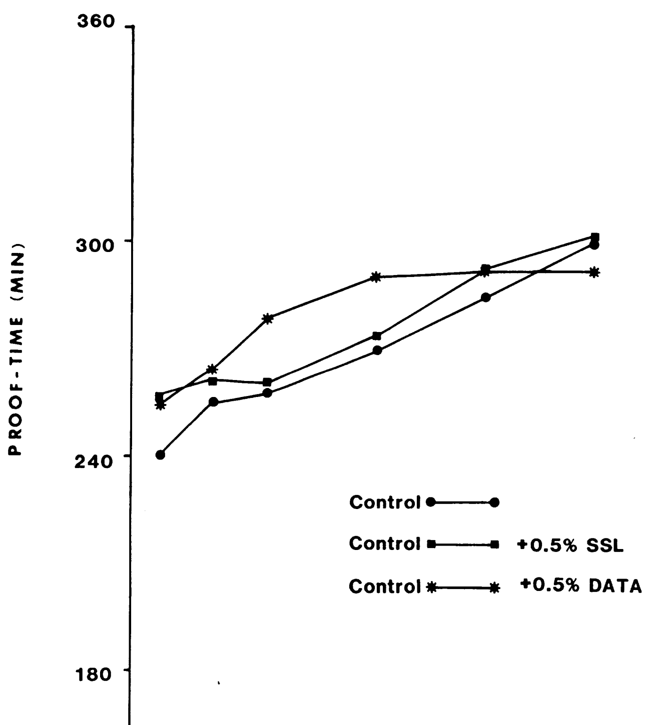

Fig. 8. Effect of sodium stearoyl lactylate (SSL) and diacetyl tartaric acid (DATA) on proof-time stability of frozen dough. Study II, flour A.

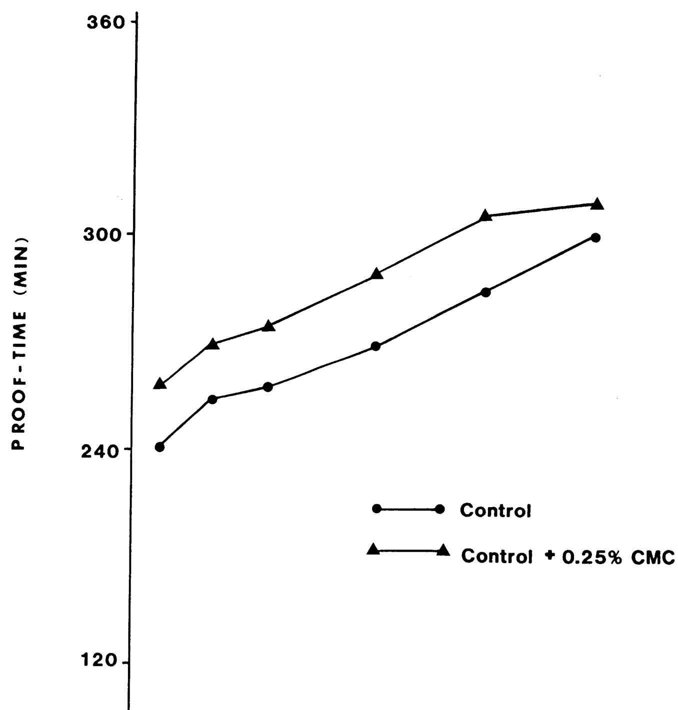

Fig. 10. Effect of carboxymethyl cellulose (CMC) on proof-time stability of frozen dough. Study II, flour A.

D'Appolonia (1984) concluded that GSH leached from yeast is not important in the proof-time stability of frozen doughs.

The difference in GSH levels leached from yeast cannot therefore be used to explain performance differences between dry yeasts and CY. The differences in proof-time stability of frozen doughs containing different yeast types must then be directly related to the performance of the yeast itself. The drying process is known to damage the cell wall of the yeast. This damage may cause dry yeast to become more vulnerable to damage during freezing. Kline and Sugihara (1968) reported that bromate has a definite deleterious effect on yeast activity. Dry yeasts might be more susceptible to the inhibitory effect of bromate.

Effect of Flour Type on Frozen Dough Stability

Table IV gives the analytical data on the four flour samples, while Figs. 2 and 3 show the respective farinograms and extensigrams.

In Study I, flours A and B produced doughs with stability similar to those in frozen storage (Fig. 4). In Stability Study II, both flours were evaluated again; this time, however, doughs were proofed to 4.0 cm above the pan height. Flour B outperformed flour A (Fig. 5) in Study II. Flours C and D were also tested for stability in Study II. Flours C and D gave fairly consistent proof times over the 16 weeks of frozen storage. For flour C, however, these proof times were substantially higher than the other flours tested (Fig. 5). Figure 6 shows the loaf-volume stability of doughs made from flours A, B, C, and D in Study II. Flour B gave bread with consistently larger volumes than the other three flours.

When the overall stability of the flours evaluated in Study II are compared, flour type appears to influence proof-time levels as well as the rate of change in proof time with frozen storage. Additionally, flour type will influence oven spring characteristics of a dough. Flour B, which was milled from 100% hard red spring wheat, produced a dough structure with good oven spring, which is desirable for a frozen bread dough. Neither flour protein content nor rheological properties were related to the performance of a particular flour in a frozen-dough formulation.

Table V shows the effect of flour type on the internal and external characteristics of bread obtained in Study II. The overall external characteristics of the bread remained fairly stable throughout the storage period. Loaves were inferior in quality at the latter stages of storage because loaf volume was reduced and internal characteristics were poor. Loaves produced from flours C and D had lower scores for external appearance because very little break and shred was present.

Grain and texture scores decreased with prolonged frozen storage, because the grain was open and the crumb felt gummy. Flour C consistently produced bread with a finer grain and a silkier texture than did other flours. Additionally, the gummy characteristics of the crumb noted with prolonged frozen storage were not as evident for loaves produced with flour C.

Effect of Dough Additives on Frozen-Dough Stability

Several workers have reported that surfactants increase the stability of frozen doughs (Davis 1981, Marston 1978).

Figure 7 shows the proof-time stability curves for frozen doughs produced, in Study I, from flour B, alone and with 0.5% SSL and 0.5% DATA, respectively. The data indicate that the surfactant decreased proof time in the first four to six weeks of frozen storage. After this initial period, proof times of the doughs with SSL were comparable to those of the control. In Stability Study II, in which flour A was used, doughs with SSL gave proof times very comparable to those of the control (Fig. 8). The use of DATA appeared deleterious to the proof-time stability of flour A (Fig. 8). There is no apparent explanation for the difference in the effect of

TABLE VI
Effect of Dough Additives on Extensigraph Properties of Frozen Dough

Additive Used and Dough Storage Time	Extensibility (E) (cm)	Resistance (R) (cm)	Proportional Number R/E
Control			
1 day	26.3	4.7	0.178
10 weeks	17.8	6.6	0.370
Sodium stearoyl lactylate			
1 day	27.6	4.5	0.163
10 weeks	20.6	5.5	0.267
Diacetyl tartaric acid			
1 day	26.5	4.1	0.158
10 weeks	21.8	6.1	0.280
CMC			
1 day	22.6	4.0	0.177
10 weeks	18.7	6.1	0.326

TABLE VII
Effect of Dough Additives on Internal and External Characteristics of Bread from Frozen Dough[a]

Dough Additive	Storage Time					
	1 Day	2 Weeks	4 Weeks	8 Weeks	12 Weeks	16 Weeks
Control						
External appearance	9.0	9.0	8.5	8.0	8.0	8.0
Grain and texture	8.5	8.5	8.0	8.0	8.0	8.0
Crumb color	8.5	8.5	8.5	8.0	8.0	8.0
Crust color	10.0	10.0	10.0	10.0	10.0	10.0
SSL[b]						
External appearance	9.0	9.0	8.5	8.0	8.0	7.5
Grain and texture	9.5	9.0	8.5	8.5	8.0	8.5
Crumb color	9.5	9.5	8.5	9.0	8.0	8.5
Crust color	9.0	9.5	9.5	9.5	10.0	10.0
DATA[c]						
External appearance	8.5	8.0	8.5	8.0	8.0	8.0
Grain and texture	8.5	8.5	8.0	7.5	7.5	7.5
Crumb color	9.0	9.5	8.5	8.5	8.0	8.0
Crust color	10.0	10.0	10.0	10.0	10.0	10.0
CMC[d]						
External appearance	7.5	7.5	8.0	7.5	7.0	7.0
Grain and texture	7.5	7.5	8.0	7.5	7.0	7.5
Crumb color	8.0	8.0	7.5	7.5	7.5	7.5
Crust color	10.0	10.0	10.0	10.0	10.0	10.0

[a] Evaluated on a scale of 1–10, with 10 being the best. Data are from Stability Study II in which flour A was used.
[b] Sodium stearoyl lactylate.
[c] Diacetyl tartaric acid.
[d] Carboxymethyl cellulose.

DATA on proof times of doughs made with flours A and B. Figure 9 shows the effect of SSL and DATA on loaf volume of frozen doughs during storage. SSL was found to be more effective than DATA in maintaining volume of loaves baked from frozen dough.

Figure 10 shows the proof-time stability curves of doughs with and without CMC. CMC is used as a stabilizer in ice cream and other frozen foods to inhibit the growth of ice crystals. Preliminary studies showed that CMC depresses loaf volume. Figure 10 clearly shows that CMC did not change the shape of the stability curve, but only displaced it upward.

Table VI shows the effects of dough additives on the extensigraph properties of frozen dough. Rheological changes due to extended frozen storage appeared to be less pronounced with the use of SSL and DATA. CMC did not have much effect on the rheological changes associated with frozen dough.

Table VII gives the scores for the internal and external characteristics of bread made from frozen doughs containing different dough additives. As frozen storage increased, loaf volume decreased, resulting in lower break and shred. The reduction in break and shred was not as evident with bread containing SSL and DATA.

As frozen storage and proof times increased, the grain of the bread developed a more open cell structure. Breads with SSL gave an initially finer grain and texture than did the control. SSL, however, inhibits the deleterious effects of frozen storage on crumb cell structure.

Changes in Starch Characteristics of Bread Crumb from Frozen Dough

In Stability Study II, bread produced from dough frozen for approximately eight weeks began to take on a gummy crumb character. Table VIII shows the effects of dough additives on the

TABLE VIII
Effect of Dough Additives on the Pasting Properties of Bread Crumb from Frozen Dough

Dough Additive	Storage Time				
	1 Day	4 Weeks	8 Weeks	12 Weeks	16 Weeks
Control					
Pasting temperature (°C)	88.5	84.0	85.5	85.5	87.0
Peak viscosity	260.0	185.0	215.0	215.0	250.0
15 Min viscosity	260.0	185.0	220.0	205.0	260.0
Viscosity at 50°C	545.0	415.0	440.0	450.0	465.0
SSL[a]					
Pasting temperature (°C)	93.0	88.5	92.5	90.0	91.5
Peak viscosity	420.0	380.0	340.0	315.0	325.0
15 Min viscosity	315.0	295.0	315.0	275.0	300.0
Viscosity at 50°C	645.0	600.0	605.0	585.0	620.0
DATA[b]					
Pasting temperature (°C)	88.5	90.0	90.0	90.0	93.0
Peak viscosity	270.0	255.0	315.0	245.0	140.0
15 Min viscosity	270.0	255.0	315.0	245.0	140.0
Viscosity at 50°C	560.0	515.0	525.0	605.0	520.0
CMC[c]					
Pasting temperature (°C)	78.0	85.5	85.5	85.5	85.5
Peak viscosity	210.0	180.0	175.0	180.0	210.0
15 Min viscosity	210.0	165.0	175.0	175.0	245.0
Viscosity at 50°C	450.0	370.0	375.0	390.0	420.0

[a]Sodium stearoyl lactylate.
[b]Diacetyl tartaric acid.
[c]Carboxymethyl cellulose.

TABLE IX
Effect of Dough Additives on Soluble Starch, Amylose, and Amylopectin Extracted from Crumb of Frozen Dough Bread

Dough Additive	Storage Time				
	1 Day	4 Weeks	8 Weeks	12 Weeks	16 Weeks
Control					
Soluble starch, %	2.73	2.18	2.10	2.24	2.26
Amylose, %	0.49	0.37	0.32	0.32	0.26
Amylopectin, %	2.24	1.81	1.78	1.92	2.00
Ratio amylose/amylopectin	0.21	0.20	0.18	0.16	0.13
SSL[a]					
Soluble starch, %	2.13	2.23	1.77	1.64	1.74
Amylose, %	0.31	0.38	0.18	0.15	0.13
Amylopectin, %	1.82	1.85	1.59	1.49	1.61
Ratio amylose/amylopectin	0.17	0.20	0.11	0.10	0.08
DATA[b]					
Soluble starch, %	2.00	2.17	1.96	1.95	1.76
Amylose, %	0.32	0.37	0.27	0.19	0.17
Amylopectin, %	1.68	1.80	1.69	1.76	1.59
Ratio amylose/amylopectin	0.19	0.20	0.16	0.11	0.11
CMC[c]					
Soluble starch, %	2.53	1.72	2.24	2.44	2.27
Amylose, %	0.43	0.37	0.43	0.46	0.30
Amylopectin, %	2.10	1.35	1.81	1.98	1.97
Ratio amylose/amylopectin	0.20	0.27	0.24	0.23	0.15

[a]Sodium stearoyl lactylate.
[b]Diacetyl tartaric acid.
[c]Carboxymethyl cellulose.

pasting properties of bread crumb obtained from frozen dough. For the control bread peak viscosity, 15 min of viscosity and viscosity at 50°C tended to decrease over the storage period; the data, however, are not conclusive. The effects of dough additives on the amount of soluble starch, amylose, and amylopectin extracted from the crumb of the frozen dough bread are given in Table IX. The various dough additives affected the amount of soluble starch extracted from the crumb. SSL and DATA decreased the amount of soluble starch extracted from the crumb. Bread crumbs containing CMC gave only slightly lower soluble starch values after one day of storage than did the control. As frozen storage increased, the amount of soluble starch extracted from the crumb decreased for the control bread and for the bread containing SSL, DATA, and CMC. The changes in pasting properties for the control and the SSL bread crumb reported in this study were similar to data reported by Morad and D'Appolonia (1980a) on bread stored at 30°C.

Both amylose and amylopectin content in the soluble starch of the crumb decreased as storage increased. The ratio of amylose to amylopectin in the soluble starch of the crumb also decreased as frozen storage decreased. Again, these trends are similar to those reported for bread stored at 30°C (Morad and D'Appolonia 1980b).

The observed changes in starch characteristics are probably related to the extended proofing time and are not directly related to frozen-dough stability. Flour protein quality is important in frozen-dough proof-time stability. The surfactant SSL is effective in maintaining loaf-volume stability of frozen doughs but is not effective in reducing the time to proof thawed doughs to a specific height. Yeast type is not important in frozen-dough stability.

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