Studies on Frozen Doughs. II. Flour Quality Requirements for Bread Production from Frozen Dough[1]

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ABSTRACT

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Extensigraph properties and bread loaf volumes were determined for frozen doughs that had been stored for up to 10 weeks or thawed and refrozen after an initial frozen storage period of one week. Four flours were used: three differed in protein quality (strength) but contained approximately the same amount of protein, and two had the same protein quality but differed in protein content. A modified extensigraph procedure developed for fermented doughs was used in this study. Yeast activity was assessed with the gassing power test. Extensigraph results (maximum resistance and extension) showed that dough strength decreased markedly on freezing and thawing and gradually during frozen storage. Similarly, loaf volume decreased markedly with freezing and thawing and gradually during frozen storage. Results of experiments in which yeast activity was maintained at the same level as that in nonfrozen doughs showed that the loss of dough strength on freezing, on thawing, and during frozen storage was the main reason for the decline in bread loaf volume. Accordingly, for best bread quality from frozen doughs, very strong flours should be used. Protein content, in the range covered in the present study, appears to be less important than protein quality.

The quality of bread produced from frozen dough depends strongly on the characteristics of the yeast and the flour. In this context, the nature of the yeast has been extensively studied, whereas the nature of the flour has received less attention. Lorenz and Bechtel (1965) obtained bread of equal quality from frozen doughs from spring and winter wheat flours. Marston (1978) reported that for best results, medium to strong baker's flour with a protein content of 11 to 13% should be used. Wolt and D'Appolonia (1984b) were the first to suggest that protein quality (strength) was important for bread production from frozen dough. Neyreneuf and Van der Plaat (1991) reported that the quality of French bread from frozen dough was directly related to the protein content of the French type of bread flour.

Our previous study (Inoue and Bushuk 1991) showed that the quality of bread from frozen dough depended on the strength of the dough. It suggested that very strong flours would give better results than weaker flours. To test this possibility, we performed experiments using flours milled from commercial samples of wheat of approximately the same protein content but of different quality. The results are presented in this article.

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MATERIALS AND METHODS

Flours

Four different flours were used in this study: A, straight-grade flour milled from commercial wheat of grade No. 1 Canada Western Red Spring (CWRS), 14.5% guaranteed protein; B, straight-grade flour milled from a blend of commercial No. 1 CWRS, 14.5% guaranteed protein, and No. 1 CWRS, 13.5% guaranteed protein; C, straight-grade flour milled from a commercial sample of Canada Prairie Spring wheat; D, straight-grade flour milled from a commercial sample of Canada Utility wheat. This sample comprised grain of a pure variety, Glenlea.

Protein content, ash content, and falling number value of the flour samples were measured according to AACC (1983) methods 46-10, 08-01, and 56-81B, respectively. The starch damage was estimated by the enzymatic procedure of Farrand (1964). The farinograms were obtained by the 50-g bowl and constant flour weight procedure (Method 54-21, AACC 1983) and the extensigrams using the procedure described by Holas and Tipples (1978).

Yeast

Compressed baker's yeast (Fleischmann's Yeast Limited, Toronto, Canada) was used within one week of its receipt.

Dough Formulation

The leaner frozen dough formula developed in the previous study (Inoue and Bushuk 1991) was used. Dough formulation was as follows: flour, 100%; yeast, 5%; sugar, 2.5%; salt, 1.0%; shortening, 1.5%; ascorbic acid, 100 ppm (flour basis); water, optimum amount.

Dough Mixing

The short-time dough mixing procedure described previously (Inoue and Bushuk 1991) was used. For each batch, doughs containing 200 g of flour were mixed in a GRL-200 mixer (Grain Research Laboratory, Winnipeg, Manitoba) equipped with a GRL energy input meter (Kilborn 1979). Doughs were mixed just beyond the peak development, indicated by the mixing curve, as follows: flour A, 7 min at 110 rpm; B, 7 min at 110 rpm; C, 8 min at 110 rpm; and D, 12 min at 140 rpm. We assumed that the variation in mixing time was not significant in terms of yeast activity. For flours A–C, loaf volume of bread from doughs mixed at 110 and 140 rpm did not significantly differ (results not shown). Dough temperature during mixing was maintained at 23.5 ± 0.5°C.

Mixed doughs were divided into 160-g pieces and fermented for 20 min in a fermentation cabinet controlled at 28°C and 90–95% relative humidity. Three fermented dough pieces of each flour were molded on a GRL sheeter-molder (Kilborn and Irvine 1963), panned, and then final-proofed in the fermentation cabinet for 45 min. The height of the proofed dough pieces was measured. The average height of three doughs was used as the standard proofing height for the analogous frozen doughs.

Loaves were baked at 218°C for 25 min. After 30 min of cooling, loaf volume was determined by rapeseed displacement.

Preparation of Frozen Doughs

The dough pieces were frozen in an upright freezer at −20°C immediately after molding, placed in polyethylene bags, vacuum sealed, and stored in a chest freezer at −20°C as described previously (Inoue and Bushuk 1991). After one day, three dough pieces of each flour were thawed at −2°C for approximately 15 hr, panned, and final-proofed until the dough height reached the predetermined standard proofing height. This procedure was repeated every two weeks over a 10-week period. The average of proof times for the three replicate dough pieces was recorded as the final proof time for that treatment. After final proofing, the doughs were baked, and loaf volumes were measured.

In addition to the frozen storage test, selected frozen dough pieces were subjected to an additional thawing and refreezing during the first week of frozen storage. These doughs were processed into bread as indicated above.

Extensigraph Procedure for Frozen Dough

The extensigraph procedure described previously (Inoue and Bushuk 1991) was used with some minor modifications. Dough pieces of the same weight as those used in baking (160 g) were molded into 16.0-cm-long cylinders and clamped into the modified dough holder (Kilborn and Preston 1982). The test pieces were proofed in the fermentation cabinet (45 min for nonfrozen doughs and 75 min for thawed doughs) and stretched using the straight stretching bar (12 mm in diameter). After these proofing times, the nonfrozen and thawed doughs were of the same temperature (28°C). Three dough pieces were tested for each treatment.

Gassing Power

Gassing power of nonfrozen and frozen doughs was measured as follows. Molded doughs were remixed in the GRL-200 mixer for 5 min at 90 rpm and 30 ± 0.5°C. Thirty grams of the remixed dough was placed in a gassing power pressure meter and allowed to ferment for 90 min at 30°C (Method 22-11, AACC 1983). After the fermentation, pressure (mm Hg) was recorded. Duplicate samples were tested for each treatment and average results reported.

RESULTS AND DISCUSSION

Baking and Rheological Results for Nonfrozen Doughs

Characteristics of the four flours are given in Table I and Figure 1. Flours A and B are of the same quality (strength) but differ in protein content. In terms of dough strength determined by farinograph and extensigraph, such flours are generally designated as strong. Flours B–D contain approximately the same amount of protein but differ in strength. D is the strongest (very strong), followed by B and C, both of which would be classified as strong but weaker than D. The strength designations, based on Canadian experience, are generally consistent with our farinograph and extensigraph results. Flours A and B gave lower loaf volumes than did flours C and D (see Table I). Flour C had the highest gassing power, probably because of its higher α-amylase activity as indicated by the lower falling number value. The higher α-amylase activity had no detrimental effect on loaf volume (results not shown). The final-proofed dough of flour C (Table I) had a high extensibility similar to the result obtained for the non-yeasted dough (Fig. 1).

Extensigraph results for the nonfrozen doughs of flours C and D were consistent with the very strong dough characteristics

TABLE I
Characteristics of Flour Samples[a]

	Flours			
Quality Tests	**A**	**B**	**C**	**D**
Protein content, %	14.4	13.9	13.7	13.7
Ash content, %	0.52	0.54	0.58	0.60
Starch damage (Farrand unit)	21	23	11	25
Falling number value	538	566	337	500
Farinograph				
Absorption, %	65.1	63.5	58.6	58.9
Dough development time, min	7.0	6.0	5.5	30.5
Gassing power,[b,c] mm Hg	459 ± 5	461 ± 8	519 ± 11	477 ± 5
Standard proofing height,[b,d] cm	10.0 ± 0	10.0 ± 15	10.1 ± 0	9.8 ± 0.1
Extensigraph				
Maximum resistance,[b,d] BU	627 ± 6	623 ± 15	680 ± 10	1,273 ± 21
Extensibility,[b,d] mm	121 ± 3	120 ± 2	137 ± 2	102 ± 3
Loaf volume,[b,d] cm^3	792 ± 8	780 ± 5	838 ± 5	863 ± 8

[a] Reported on 14.0% moisture basis.
[b] For nonfrozen dough by frozen dough procedure.
[c] Mean and standard deviation of duplicates.
[d] Mean and standard deviation of three replicates.

obtained by the standard extensigraph procedure (compare results of Fig. 1 with those of Table I). Flour D, the strongest of the four flours, had the lowest standard proofing height. However, it gave the highest loaf volume, i.e., its dough had the highest oven spring during baking.

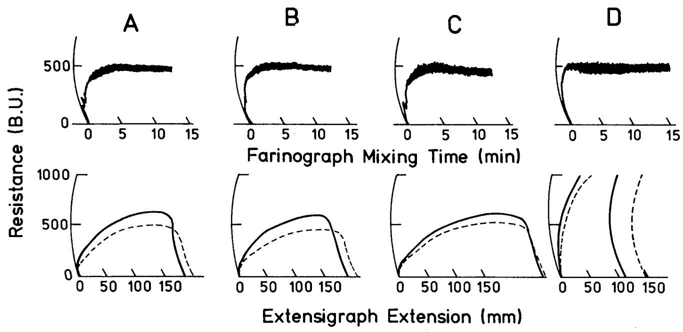

Fig. 1. Farinograms and extensigrams of flour samples A–D. In extensigrams, broken and solid lines represent 45- and 135-min curves, respectively.

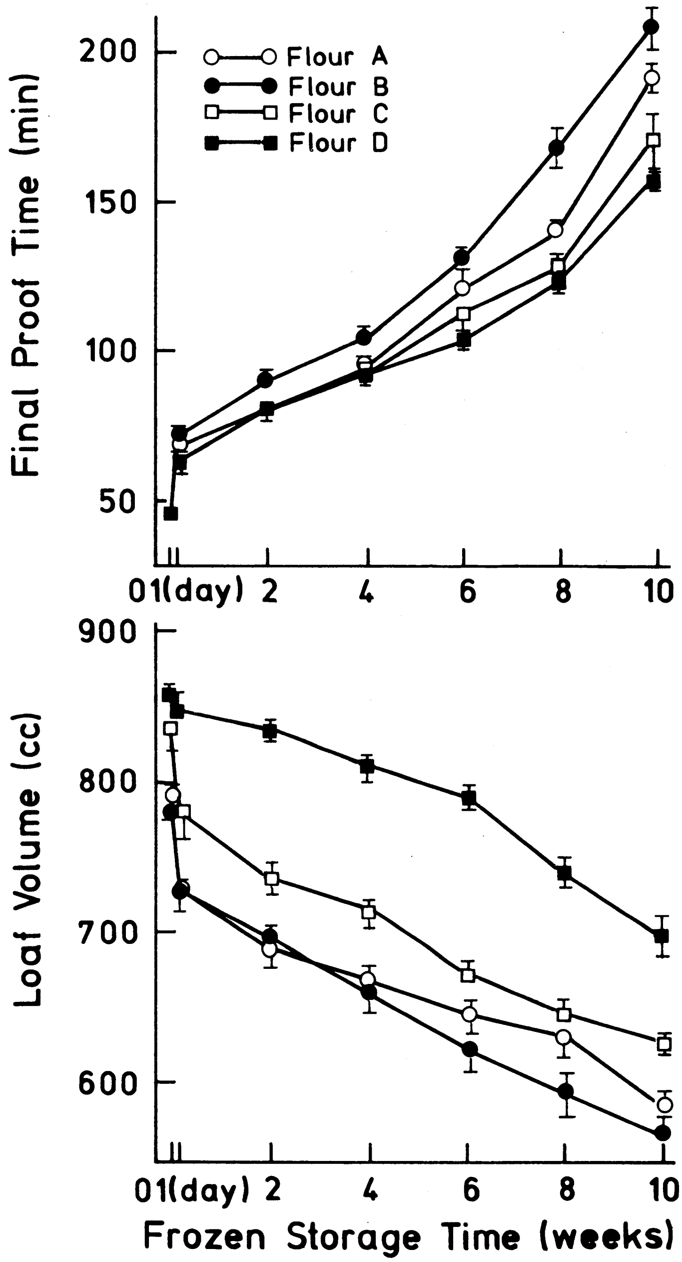

Fig. 2. Effect of frozen storage time on final proof time and loaf volume of doughs.

Baking Results for Frozen Doughs

Final-proof time increased and loaf volume decreased (Fig. 2) with increasing storage time. The magnitude of the change of each parameter appears to be related to flour strength. After one day of frozen storage, breads from flours A–C showed a significant decrease of loaf volume (7.8, 6.7, and 6.7% for flours A–C, respectively). Bread from flour D, the strongest of the four flours, showed a smaller decrease of loaf volume (2.3%). The loss of loaf volume appears to be due to changes that occurred at freezing. Doughs from flour D required the shortest final-proof time and gave the highest loaf volumes (Fig. 2) throughout the entire frozen storage period investigated. On the other hand, doughs from flour B required the longest final-proof time and gave the lowest loaf volume. Flour A, which had the same quality (strength) as flour B but a slightly higher protein content, produced doughs requiring a slightly shorter final-proof time and yielding a higher loaf volume than the doughs of flour B. The final-proof time of flour C doughs was shorter than that of doughs from flours A and B. However, the decrease in loaf volume of flour C doughs (during frozen storage) was similar to that of doughs from flours A and B, despite the higher initial (nonfrozen dough) loaf volume.

The decrease in loaf volume because of an additional thaw-freeze cycle (Table II) was lowest for flour D doughs, the strongest of the four flours.

The baking results indicate that the effects of flour strength on changes during frozen storage were significant. The effect of flour protein content, in the range covered in the present study, was relatively small. Our results are consistent with those of Wolt and D'Appolonia (1984b), who reported that flour protein quality was important for optimal bread quality from frozen dough. Additionally, our results showed that the gradual decline of baking potential during frozen storage can be offset by using flour that is too strong for conventional bread production.

Extensigraph Results for Frozen Doughs

Maximum extensigraph resistance (Fig. 3) showed a marked drop after one day of frozen storage for all four flours. This drastic loss of dough strength appears to be due to changes caused by the initial freezing. There is no clear relationship between the magnitude of the initial drop in maximum resistance and flour strength. During prolonged frozen storage, maximum resistance decreased gradually at approximately constant rate. The rate appears to be dependent on flour strength; it is slowest for the strongest flour (D) and fastest for the two weakest flours (A and B).

The results for dough extensibility during frozen storage (Fig.

TABLE II
Effect of Thawing and Refreezing on Baking Characteristics[a]

Sample	Proof Time (min)	Loaf Volume (cm^3)
Flour A		
Nonfrozen	45 ± 0	792 ± 8
Frozen[b]	72 ± 1	732 ± 10
Refrozen[c]	74 ± 4	700 ± 15
Flour B		
Nonfrozen	45 ± 0	780 ± 5
Frozen	71 ± 1	725 ± 9
Refrozen	76 ± 5	698 ± 6
Flour C		
Nonfrozen	45 ± 0	838 ± 13
Frozen	69 ± 1	793 ± 15
Refrozen	71 ± 2	747 ± 21
Flour D		
Nonfrozen	45 ± 0	863 ± 8
Frozen	69 ± 3	855 ± 15
Refrozen	70 ± 2	835 ± 18

[a] Mean and standard deviation of three replicates.
[b] Frozen and stored at −20°C for one week.
[c] Subjected to an additional thawing and refreezing during one week of frozen storage.

3) are not clear-cut. Although all four doughs showed a gradual increase in extensibility (consistent with dough weakening) with storage time, the increasing trend did not show any relationship with dough strength.

For flours A–C, the decrease in maximum resistance during frozen storage was significantly correlated with the increase in final-proof time and decrease in loaf volume (Table III). These correlations were not significant for flour D. These results indicate that the loss of dough strength during frozen storage was sufficient to significantly lower the breadmaking potential of flours A–C but not that of flour D, the strongest of the four flours.

Maximum extensigraph resistance of the doughs of all four flours decreased markedly because of an additional thaw-freeze cycle (Table IV). The change in dough properties of flour D was not reflected by a drop in loaf volume (Table II) to the same extent as for the other three flours.

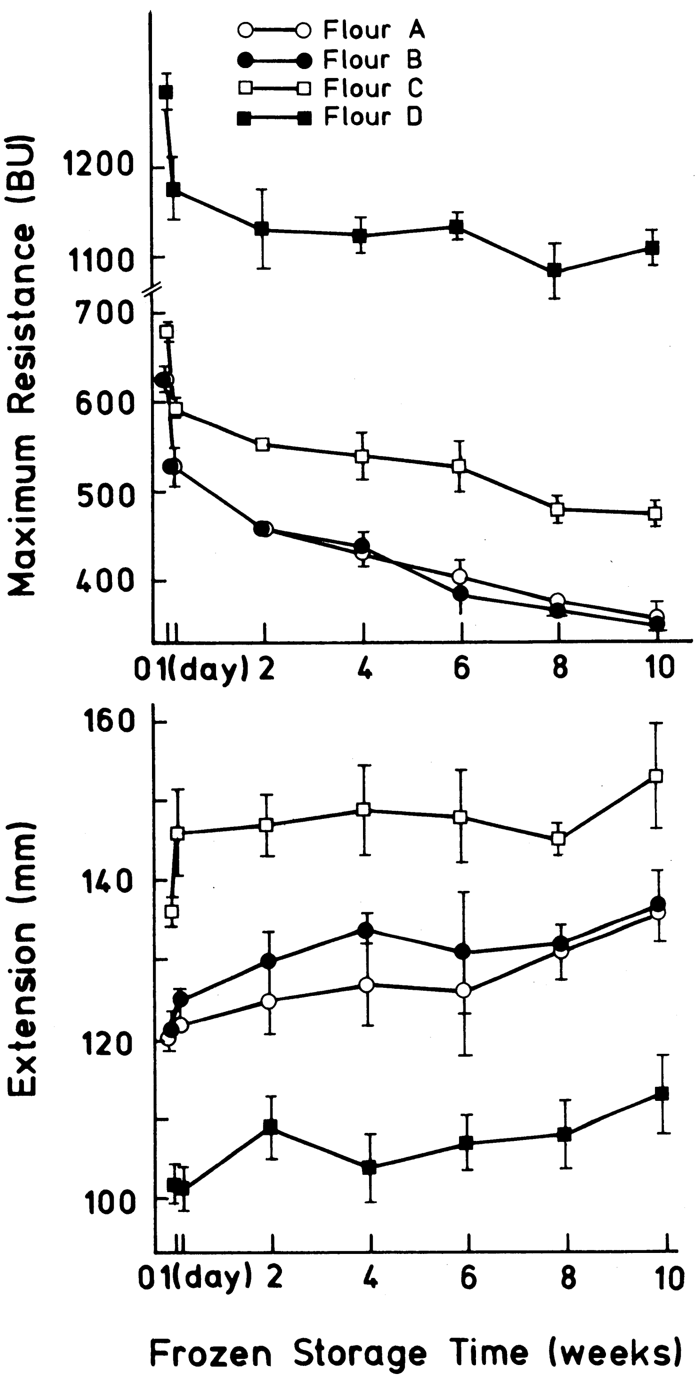

Fig. 3. Effect of frozen storage time on maximum extensigraph resistance and extension of doughs.

Gassing Power Results

The gassing power of all thawed doughs remained at a level close to that of the nonfrozen control dough during the first two weeks of storage but decreased significantly after six and 10 weeks (Table V). The lower yeast activity appears to be the cause of a concomitant increase in final-proof time and perhaps of some of the decrease in loaf volume (Fig. 2). Kline and Sugihara (1968) reported that the thawed dough will not give the same loaf volume as the nonfrozen control if yeast activity was not maintained. In addition, the decreased gassing power in doughs stored for more than six weeks may have affected the rheological properties of final-proofed doughs, as suggested by Kilborn and Preston (1982).

TABLE III
Correlation Coefficients between Maximum Resistance and Baking Quality Parameters of Doughs Subjected to Frozen Storage Test

Flour Sample	Maximum Resistance vs. Final Proofing Time[a]	Maximum Resistance vs. Loaf Volume[b]
A	−0.90*[c]	0.98**
B	−0.92*	0.97**
C	−0.94*	0.98**
D	−0.70	0.72

[a] Nonfrozen dough was included; $n = 7$.
[b] Nonfrozen dough was not included; $n = 6$.
[c] Significant at $P < 0.05$ and 0.01 for * and **, respectively.

TABLE IV
Effect of Thawing and Refreezing on Extensigraph Properties[a]

Sample	Maximum Resistance (BU)	Extensibility (mm)
Flour A		
Nonfrozen	627 ± 6	121 ± 3
Frozen[b]	523 ± 12	123 ± 9
Refrozen[c]	483 ± 12	117 ± 3
Flour B		
Nonfrozen	623 ± 15	120 ± 2
Frozen	517 ± 6	124 ± 2
Refrozen	477 ± 12	119 ± 7
Flour C		
Nonfrozen	680 ± 10	137 ± 2
Frozen	580 ± 10	143 ± 5
Refrozen	540 ± 10	132 ± 2
Flour D		
Nonfrozen	1,273 ± 21	102 ± 3
Frozen	1,183 ± 6	105 ± 5
Refrozen	1,127 ± 20	104 ± 4

[a] Mean and standard deviation of three replicates.
[b] Frozen and stored at −20°C for one week.
[c] Subjected to an additional thawing and refreezing during one week of frozen storage.

TABLE V
Effect of Frozen Storage Time and of Thawing and Refreezing on Gassing Power[a]

Storage Time	Flour Sample A	B	C	D
Nonfrozen control	459 ± 5	461 ± 8	519 ± 11	477 ± 5
Frozen				
1 day	447 ± 7	437 ± 10	487 ± 9	450 ± 7
1 week	461 ± 4	455 ± 7	487 ± 9	453 ± 4
1 week (refrozen)[b]	447 ± 11	447 ± 7	472 ± 23	442 ± 14
2 weeks	445 ± 6	441 ± 5	487 ± 8	454 ± 8
6 weeks	363 ± 6	351 ± 11	379 ± 8	380 ± 5
10 weeks	254 ± 10	245 ± 9	251 ± 12	244 ± 6

[a] Mean and standard deviation of duplicates (mm Hg).
[b] Subjected to an additional thawing and refreezing during the storage time.

The doughs that were subjected to an additional thawing and refreezing during the first week of frozen storage had a gassing power close to that of the nonfrozen control dough (Table V). A similar finding was reported by Bruinsma and Giesenschlag (1984).

Kline and Sugihara (1968) postulated that some weakening of dough during frozen storage may be caused by a release of reducing substances from yeast cells that had died during storage. This hypothesis has been refuted by Wolt and D'Appolonia (1984a). On the other hand, Varriano-Marston et al (1980) postulated that ice crystallization during freezing of dough could contribute to the weakening of the three-dimensional gluten network responsible for gas retention. They also acknowledged the possible contribution to dough weakening of reducing substances from disrupted yeast cells. By means of light microscopy, they observed an increase in the number of disrupted yeast cells. On the other hand, scanning electron microscopy results showed an alteration of the gluten network in doughs that had been subjected to freezing and thawing. Berglund et al (1990, 1991) also observed a significant alteration in dough ultrastructure after freezing.

The results of the present study suggest that the changes in gassing power of doughs during frozen storage and during an additional thawing and refreezing cycle (Table V) are not consistent with the observed changes in extensigraph maximum resistance (Fig. 3 and Table IV). The decrease in gassing power due to freezing and thawing and refreezing was not significant, but the decrease due to extended frozen storage was significant. On the other hand, the decrease in maximum resistance due to two freeze-thaw cycles was greater than that due to prolonged frozen storage. These results suggest that changes in the ultrastructure of dough are probably because of ice crystallization (Varriano-Marston et al 1980, Berglund et al 1991), which weakened dough rheological properties. Whether reducing compounds released from dead yeast cells were involved in the dough weakening (Kline and Sugihara 1968) or not was not resolved in the present study. The details of the mechanism of dough weakening during frozen storage remain to be elucidated.

Figure 4 shows the relationships between loaf volume and maximum extensigraph resistance of doughs subjected to frozen storage and to thawing and refreezing under conditions of decreasing and constant gassing power. For doughs in which the gassing power was maintained at a level equal to that of nonfrozen dough, loaf volume and extensigraph maximum resistance were essentially linearly related. The slopes of the lines for flours A–C were similar (0.62, 0.53, and 0.69 for flours A–C, respectively), but the slope for flour D was considerably lower (0.19). These results indicate clearly that the doughs from flours A–C lost some of their baking potential (because of the decrease in dough strength) despite adequate yeast activity. On the other hand, the dough from flour D (the overly strong flour) maintained a high baking potential, despite the weakened dough rheological properties, as long as the yeast activity was adequate. Even after prolonged frozen storage, the dough of flour D retained sufficient strength to give a higher oven spring necessary as reflected by the higher loaf volume.

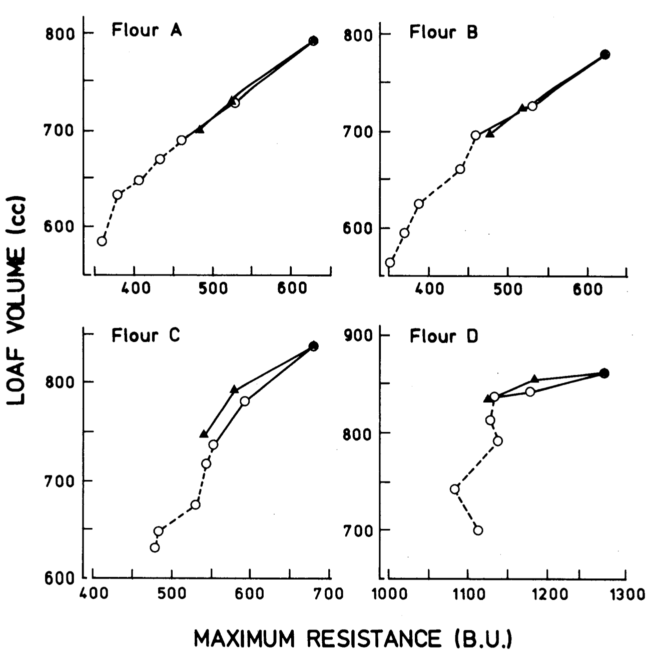

Fig. 4. Relationships between maximum extensigraph resistance and loaf volume of doughs for the frozen storage test (○) and refreezing test (▲). Solid line, gassing power maintained at a constant level; broken line, gassing power decreased with storage.

CONCLUSIONS

This study showed that the loss of breadmaking potential of frozen doughs from flours that have optimal strength for conventional bread baking results primarily from the decrease of dough strength and, to a lesser extent, from the gradual loss of yeast activity during frozen storage. Dough strength decreased sharply after initial freezing and thawing (similarly during any additional thawing and refreezing) and gradually during frozen storage. Similar dough weakening results were obtained for doughs in which the yeast activity was allowed to decline with storage and for doughs in which the yeast activity was maintained at a level equal to that of nonfrozen doughs. The flour from an overly strong wheat variety, which in Canada is considered unsuitable for conventional bread production, performed better in the frozen-dough procedure than flours with dough strength that is considered optimal for conventional baking. The superior performance of the overly strong flours appears to be due to their ability to maintain higher oven spring during baking even after losing some of their intrinsic strength on freezing and frozen storage.

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