The Effect of Oxidation and Intermediate Proof on Work Requirements for Optimum Short-Process Bread[1,2]

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ABSTRACT

Cereal Chem. 56(5):407-412

The relative effects on bread quality of work input level, chemical oxidation, and intermediate proof were examined in a short baking process. Optimum bread was produced when doughs containing appropriate levels of chemical oxidants, were mixed to maximum consistency at a sufficiently high intensity and were then given an intermediate proof between rounding and final molding. When oxidants were not used, loaf volume was reduced and much higher work levels were required to produce satisfactory bread—two to six times the work required to achieve peak consistency, as judged by a mixing curve. The amount of work required depended on the extent to which the mixing action incorporated atmospheric oxygen and on the ratio of intermediate proof to final proof (in situations where there was a fixed time between mixing and baking). The minimum period of intermediate proof required to produce acceptable bread was markedly greater in the absence of added oxidants, and it decreased as work input was increased. Lack of a sufficient period of intermediate proof in a short baking system cannot be adequately compensated for by extending final proof.

Previous articles from our laboratory (Kilborn and Tipples, 1972a, 1972b, 1973, 1975, 1977) examined some of the variables affecting mechanical dough development and clearly indicated that, for baking methods with a mixing stage close to make-up, optimum bread is produced when doughs are mixed to slightly beyond peak consistency as judged by a mixing curve. By contrast, Heaps, Frazier, and co-workers (Daniels and Frazier 1978, Frazier et al 1975, Heaps et al 1965, 1967) demonstrated that very high levels of energy must be expended at the mixer—about six times that recommended for the Chorleywood Bread Process—to produce both maximum development of dough structure, as determined by rheological measurements, and optimum bread. This article is an attempt to resolve the apparent contradiction between these two observations.

The general conditions for our testing have usually included addition of both fast and slow acting chemical oxidants, use of an intermediate proof period of 20–25 min between rounding and final molding, and a total time between mixing and baking of about 80 min. Under these conditions, optimum bread is always produced when doughs are mixed to near peak consistency as judged by the mixing curve. In the baking method used by Frazier et al (1975) and Daniels and Frazier (1978), no oxidants were used and doughs were molded and panned directly after mixing. There was no intermediate proof; the 45-min processing time included rest time only for the rheological test procedure. Under these conditions, best bread was obtained when dough mixing (in their case, at a constant rate of energy input) was continued to about 300 kJ/kg, considerably in excess of the 11 Whr/kg (40 kJ/kg) normally recommended for the Chorleywood Bread Process (Chamberlain et al 1965). To explain the differences, we examined work input level, chemical oxidation, and intermediate proof to determine their relative effects on bread quality in a short process.

MATERIALS AND METHODS

The baking formula used in this study was the same as that used for previous published studies (Kilborn and Tipples 1973). The formula consisted of 100% flour, 3.0% yeast, 1.0% salt, 2.5% sucrose, 0.3% barley malt syrup (250° Lintner), 0.1% ammonium phosphate (monobasic), 1.5% shortening, oxidants as indicated, and water adjusted for each flour.

[1]Paper 419 of the Canadian Grain Commission, Grain Research Laboratory, Winnipeg, Manitoba, Canada, R3C 3G9.

[2]Presented at the Sixth International Cereal and Bread Congress, Winnipeg, Canada, September 1978.

0009-0352/79/000064$3.00/0

We used an 80-min constant fermentation period between the end of mixing and the beginning of oven baking. Mixing time varied depending on the mixer, the flour, and the work levels. To study the effect of different intermediate proof times, final proofing times were adjusted so that the sum of intermediate proof time and final proof time equaled 80 min. Some comparative work used a constant final proof time of 55 min. The two mixers used were the GRL experimental mixer (Kilborn and Tipples 1969) with a single Z blade and a closed bowl, and the GRL-1000 (Kilborn and Tipples 1974), with open bowl and pin-type mixing action.

Doughs containing 220 g of flour were mixed in the experimental mixer; with one exception, all doughs were mixed in a closed system with the perspex block in place. Dough temperature from the mixer was 35°C. The dough was immediately scaled to give two 100-g flour doughs. When the GRL-1000 mixer was used, sufficient dough (800-g flour equivalent) was mixed at one time to permit the scaling of seven 100-g flour doughs.

Work at the mixer was measured with a modified version of the GRL energy input meter (Kilborn and Dempster 1965) programmed to allow for mechanical efficiency and dough weight. It provided a signal representing net power in watts per kilogram of dough and accumulated energy values which was recorded on a counter in watt hours per kilogram of dough.

The scaled dough pieces were rounded by hand and placed in earthenware crocks at 35°C for the intermediate proof. Doughs were then removed from the fermentation cabinet, sheeted three times at gaps of 8.7 mm, 4.8 mm, and 3.2 mm, rolled into cylinders using the GRL sheeter-molder (Kilborn and Irvine 1963), placed in baking pans, and returned to the fermentation cabinet for final proofing at 35°C. Loaves were baked for 25 min at 220°C.

Two straight-grade flours were used. Flour A, milled from a sample of Canada Western red spring wheat, had a protein content of 12.8%, an ash content of 0.41%, and a damaged starch level of 27 Farrand units. Farinograph absorption was 62%, and dough development time was 4.75 min. Baking absorption was 65%.

Flour B, milled from soft wheat, had a protein content of 11.1% and an ash content of 0.50%. Starch damage was 4 Farrand units, farinograph absorption 56%, dough development time 2.5 min, and baking absorption 59%.

EXPERIMENTAL PROCEDURES AND RESULTS

Flour A.

Experimental Mixer. Figure 1 shows the bread made from flour A, with no added oxidants. Doughs were mixed at 260 rpm in the experimental mixer, where contact of the dough with air is restricted by the closed-bowl system. The top row shows two mixing levels with no intermediate proof; the bottom row shows the same mixing levels and an intermediate proof of 25 min. With no intermediate proof, the bread from dough mixed to peak

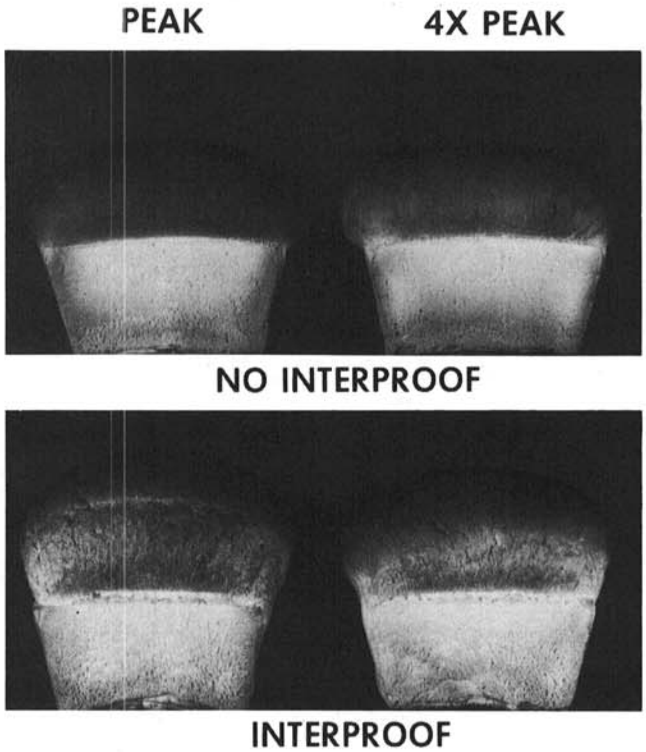

Fig. 1. External appearance of loaves baked from flour A, with no added oxidants. **Left**, doughs mixed to 1.1 times peak consistency. **Right**, doughs mixed to four times peak consistency. **Top**, no intermediate proof. **Bottom**, 25-min intermediate proof. All doughs were mixed at 260 rpm in GRL experimental mixer.

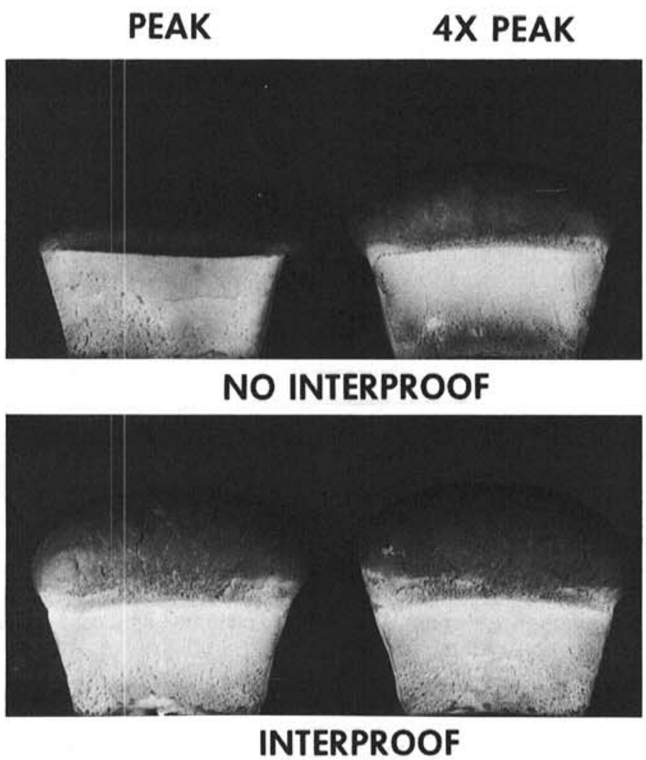

Fig. 2. External appearance of loaves baked from flour A, with 10 ppm of potassium iodate added to the doughs. **Left**, doughs mixed to 1.1 times peak consistency. **Right**, doughs mixed to four times peak consistency. **Top**, no intermediate proof. **Bottom**, 25-min intermediate proof. All doughs were mixed at 260 rpm in GRL experimental mixer.

consistency was extremely poor. The dough mixed to an energy level corresponding to four times that required for peak dough consistency produced some improvement in bread volume and appearance, but the product was still inferior. Introduction of a period of intermediate proof between rounding and molding produced a marked improvement for both mixing conditions. Loaf volume increased by about the same extent in both cases. However, mixing to four times peak produced a marked improvement in loaf appearance, particularly in the age characteristics.

For loaves shown in Fig. 2, the format and conditions were the same as in Fig. 1 except that 10 ppm of potassium iodate was added to the doughs. In this case the best bread was produced from doughs mixed to peak consistency. Intermediate proof was required for optimum bread. With intermediate proof and mixing to four times peak consistency, loaf volume decreased and the bread had "old" characteristics. Very high work levels reduced bread quality.

Figure 3 shows a comparison of the bread obtained with no added oxidant from open bowl mixing and from closed bowl mixing using the experimental mixer. All doughs were given an intermediate proof of 25 min. The two top loaves were obtained from dough mixed to 1.5 times the energy required for peak consistency, but doughs used to produce the two bottom loaves received five times the energy required for peak consistency. The effect of work was more apparent for the loaves from open bowl mixing, which exposed the dough to air during mixing. For this reason and the fact that we could obtain several 100-g flour doughs from a single mix, the GRL-1000 mixer, which has an open bowl, was used for most of this study.

GRL-1000 Mixer with No Added Oxidation. Doughs were mixed on the GRL-1000 at 165 rpm and no improvers were added. Three mixing levels were examined: The work level needed to reach peak consistency and work levels corresponding to two and four times the energy required for peak consistency. Work levels used were 5.5, 11, and 22 Whr/kg of dough, respectively. Intermediate proof times were varied from 0 to 30 min in 5-min increments. Figure 4 shows loaf volume plotted against intermediate proof time for this series of loaves. The thick, unbroken portions of the curves indicate loaves with satisfactory external appearance and age characteristics and a fine-celled crumb structure. The dough mixed to peak consistency and given no intermediate proof produced bread of very poor volume and unsatisfactory loaf charactertistics. As intermediate proof time was increased, both external appearance and crumb structure improved, although none of the loaves fully met the criteria for satisfactory bread. Bread from dough mixed to two times peak consistency with no intermediate proof was higher in volume than that produced from dough mixed to peak. Loaf volume and bread characteristics improved with increasing intermediate proof time, and satisfactory bread was obtained at 20, 25, and 30 min. The dough mixed to four times peak gave good loaf volume for all intermediate proofing times examined. Other bread properties were satisfactory, however, only when intermediate proof time was 15 min or longer.

The same data were used to plot loaf volume against energy used in mixing (Fig. 5). The numbers on the graph represent the intermediate proof times in minutes. It may be concluded that high work levels are required in the absence of oxidation to obtain bread of high volume. The profound effect of intermediate proof time on overall bread quality is more apparent (Fig. 6) when a number representing the product of all the loaf parameters (loaf volume, loaf appearance, crumb structure, and crumb color) is plotted against energy input. This illustration also shows the distinct differences for the three levels of energy input. In the absence of added chemical oxidation, therefore, the best bread was unquestionably obtained at the highest work input level with an extended period of intermediate proof.

GRL-1000 Mixer with Added Oxidants. For this part of the study, doughs contained a combination of 37.5 ppm of ascorbic acid and 30 ppm of potassium bromate and were mixed using the same three levels of energy input, ie, 5.5, 11, and 22 Whr/kg of dough. Under these conditions, bread of high volume and other satisfactory characteristics was obtained for doughs mixed to peak consistency, provided a minimum of 10 min of intermediate proof was used (Fig. 7). Doughs mixed to two times peak work produced bread of similar volume, but loaf characteristics were satisfactory over a much narrower range of intermediate proof. Doughs mixed to four times peak produced bread having "old" characteristics and a wild break and shred. In most cases, crumb structure was very open. Loaf volume was lower by about 100 cc at all intermediate proof times than it was in the other two mixing situations.

Discussion. Figure 8 brings together important aspects of the results shown in Figs. 4 and 7. Only the results from loaves having satisfactory appearance and crumb structure are shown. If oxidation (whether added by using chemicals or by extended mixing in air) plays a dominant role in dough development, then the order of these curves may be related to the degree of oxidation. Mixing to two times peak work with added oxidants (the greatest degree of oxidation) gave bread of high volume using a relatively short intermediate proof time, but tolerance to variation in intermediate proof time was limited. At 20 min intermediate proof, the bread had "old" characteristics. The dough containing oxidants and mixed to peak consistency produced bread of high volume with the greatest tolerance to variation, although loaf volume was reduced significantly at 30 min.

Without added oxidation, the doughs mixed to four times peak work produced bread of moderate volume that was satisfactory over the range of 15–30 min intermediate proof. At two times peak work the loaf volume was slightly lower than at four times peak work in the intermediate proof time range of 20–30 min. Doughs mixed to peak consistency with no added oxidants (the lowest degree of oxidation) produced satisfactory crumb structure only at 30-min intermediate proof, but the bread had slightly "green" characteristics and loaf volume was considerably lower than that obtained by mixing to two and four times peak consistency.

Bringing together all factors examined, intermediate proof requirements for the different mixing conditions are summarized in Table I. With added oxidants and mixing to four times peak work, loaf volume was highly variable, and unsatisfactory internal and external characteristics were obtained at all intermediate proof times. Mixing to two times peak work produced satisfactory bread in the range of 8–16 min intermediate proof. Within this range, loaf volume was 985 ± 15 cc. Mixing to peak produced bread of equally high volume and the widest tolerance to variation of intermediate proof time.

Without added oxidants, longer intermediate proof times are

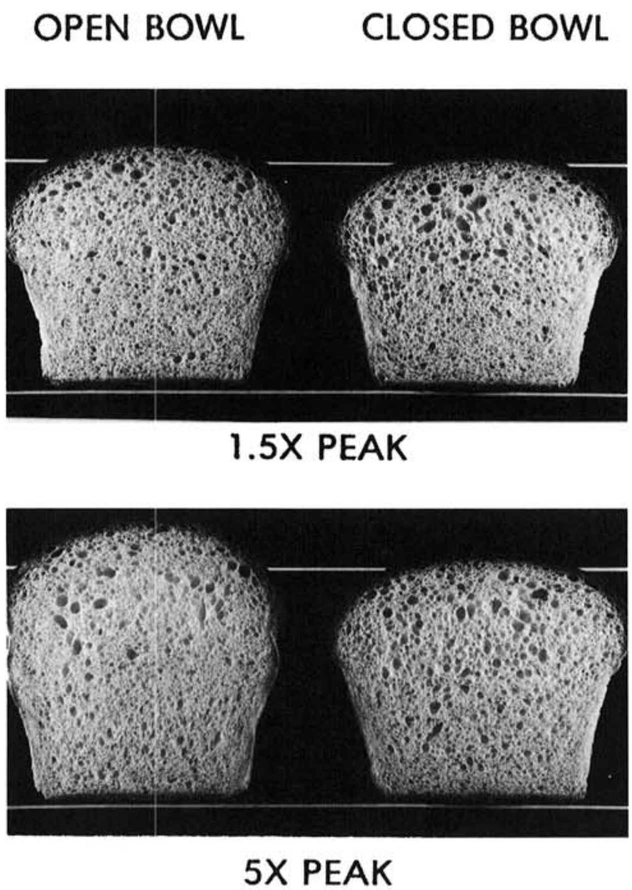

Fig. 3. Longitudinal sections of "pup" loaves baked from flour A with no added oxidants. Doughs were mixed in the GRL experimental mixer. **Left,** open bowl. **Right,** closed bowl. **Top,** doughs mixed to 1.5 times peak. **Bottom,** doughs mixed to five times peak. All doughs received 25-min intermediate proof.

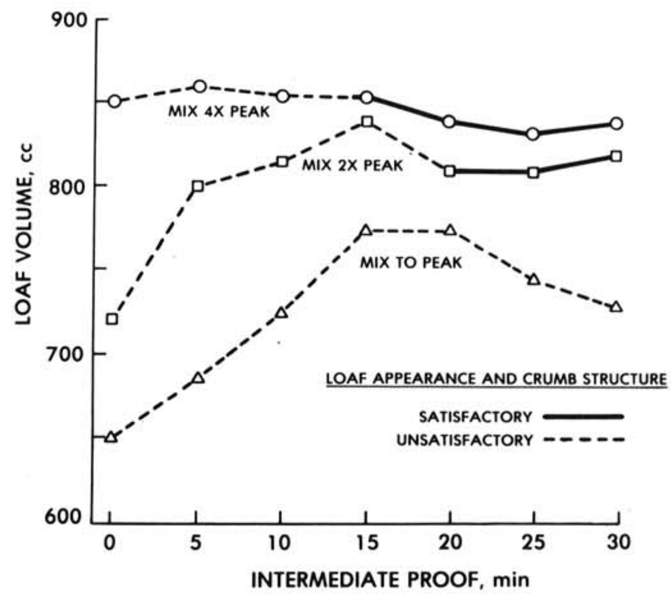

Fig. 4. Flour A, with no added oxidants. Effect of intermediate proof time on loaf volume for three mixing work levels using the GRL-1000 mixer at 165 rpm and no added oxidants.

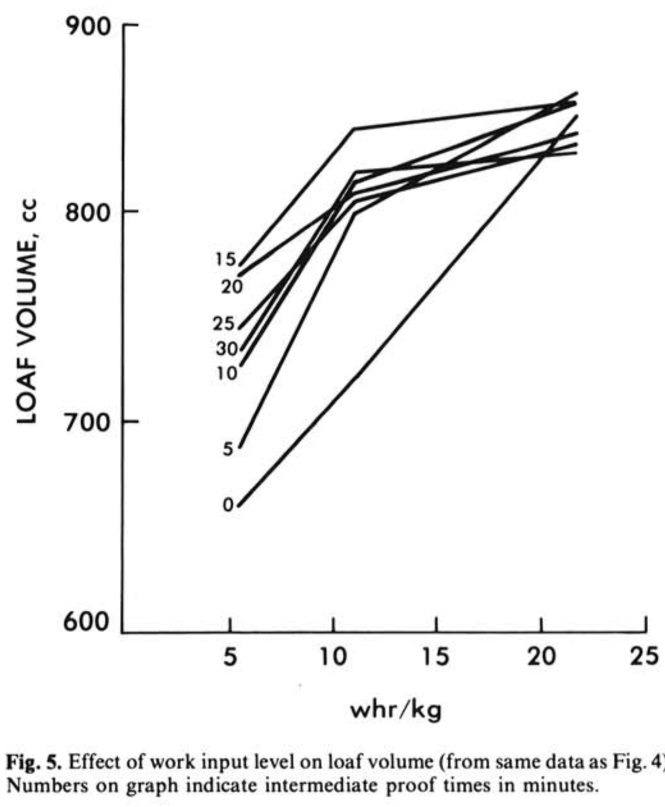

Fig. 5. Effect of work input level on loaf volume (from same data as Fig. 4). Numbers on graph indicate intermediate proof times in minutes.

required to produce bread of satisfactory external and internal characteristics. Mixing to four times peak work produced loaf volumes that, while markedly lower than when oxidants were used, were still at a respectable level for many types of bread. With doughs mixed to two times peak work, loaf volume was further reduced and the intermediate proof time requirements were increased.

Mixing to peak consistency produced only one instance of satisfactory crumb structure. This occurred using an intermediate proof time of 30 min. However, the bread had "green" external characteristics.

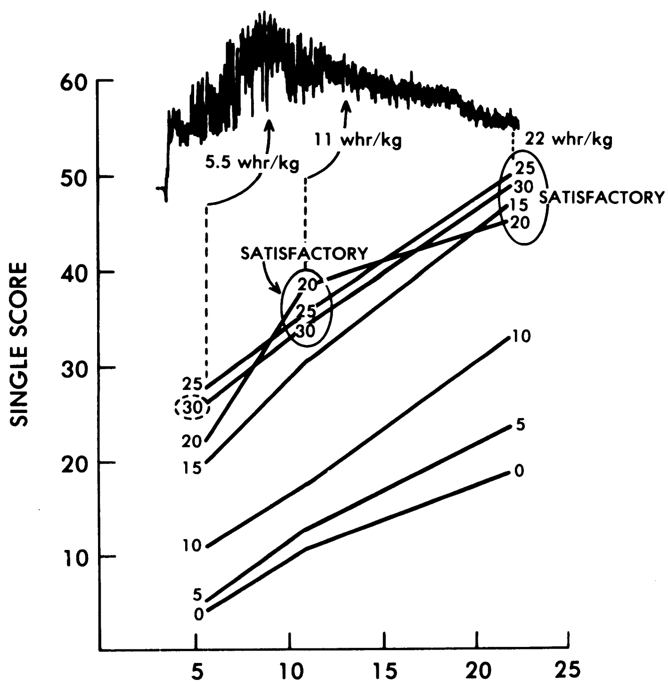

Fig. 6. Effect of work input level on overall bread quality (single score representing the product of loaf volume, loaf external appearance, crumb structure, and crumb color). Numbers on graph indicate intermediate proof times in minutes. GRL-1000 mixing curve is shown at top.

Flour B

Although flour B was a much weaker type of flour, the observations of loaf quality in relation to work and oxidation paralleled the observations made with the first flour (Fig. 9). The largest loaf was obtained by using added oxidants and mixing to peak consistency. Intermediate proof requirements for satisfactory age and crumb structure were from 8 to 13 min. Achievement of satisfactory age and crumb characteristics in the absence of added oxidants required mixing to three times the work needed to achieve peak consistency and using a longer period of intermediate proof. Under these conditions, loaf volume was 88% of that obtained using oxidants. Mixing to peak consistency in the absence of added oxidants did not produce satisfactory bread.

Constant Fermentation vs. Constant Proofing Time

In designing this experiment involving constant fermentation, we encountered a dilemma. There appeared to be three basic choices, none of which was completely satisfactory:

Constant fermentation time between the end of mixing and the start of baking. The disadvantage is that total fermentation time

TABLE I
Summary of Intermediate Proof Requirements and Tolerance for Flour A

Added Oxidants	Mixing	Intermediate Proof (min)	Loaf Volume (cc/100 g of Flour)
Ascorbic acid plus bromate[a]	4 times peak	...	Highly variable
	2 times peak	12 ± 4	985 ± 15
	Peak	18 ± 9	980 ± 25
None	4 times peak	22 ± 8	845 ± 10
	2 times peak	25 ± 5	815 ± 5
	Peak	(30)	(730)

[a] 37.5 ppm ascorbic acid plus 30 ppm bromate.

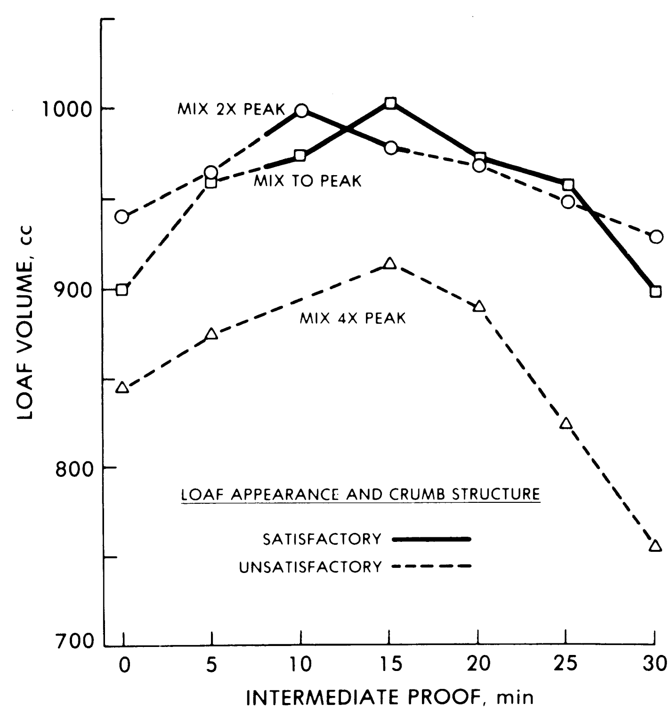

Fig. 7. Effect of intermediate proof time on loaf volume for three mixing work levels using the GRL-1000 mixer at 165 rpm with flour A and addition of 37.5 ppm of ascorbic acid and 30 ppm of potassium bromate.

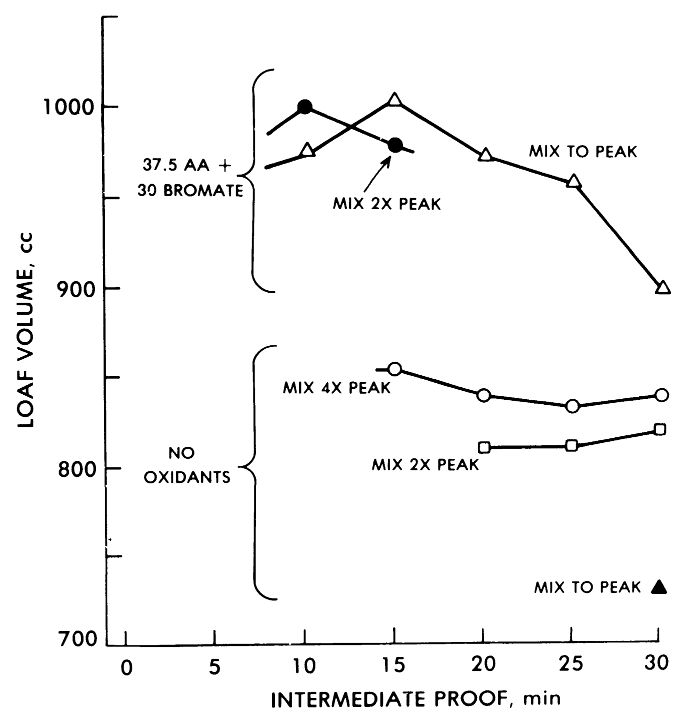

Fig. 8. Summary of results (flour A) shown in Figs. 4 and 7, showing only points where satisfactory bread was obtained.

varies with mixing time. For example, mixing doughs from flour A to peak consistency required about 4 min on the GRL-1000 mixer. With 80 min from the end of mixing, the total fermentation period was 84 min. By constrast, mixing to four times peak required 13 min, for a total fermentation time of 93 min.

Constant fermentation time between the beginning of mixing and the start of baking. Here, the time during which dough can collect gas and expand decreases as mixing time increases.

Constant fermentation time between the beginning of mixing and the start of baking and use of an extremely high-speed mixer. Here, total fermentation does not vary significantly, but the experiment is restricted to the GRL experimental mixer. In order to control temperature over a wide range of conditions, this mixer uses a closed system, which, in turn, restricts the air.

The first option was chosen as being more closely related to the practical procedure of baking. Table II lists results of a comparison of constant fermentation as measured from the beginning of mixing and constant fermentation as measured from the end of mixing. The effect of fermentation time is evident (particularly for the samples mixed 13 min), and the results are modified to some degree. However, the trend remains valid: Volume and bread quality increase with increasing work in the absence of added oxidation. The fact that intermediate proof has been shortened may also account for some reduction in the volume because the dough has less opportunity to collect gas and to stretch.

The effect of keeping the proofing time constant and allowing the fermentation time to vary with changes in intermediate proof also was examined. This was given some consideration in view of the long proofing times required when using short intermediate times and a fixed fermentation period. A comparison of results at different periods of intermediate proof in conjunction with constant proof and with constant fermentation is shown in Figs. 10 and 11. The solid lines again represent bread having satisfactory external appearance and crumb structure scores. There were no overall advantages to be gained by keeping final proof time constant, and results did not conflict with the general treands for a constant fermentation time. The importance of intermediate proof in a short baking system is apparent, and extending the final proof time does not compensate for short intermediate proof times.

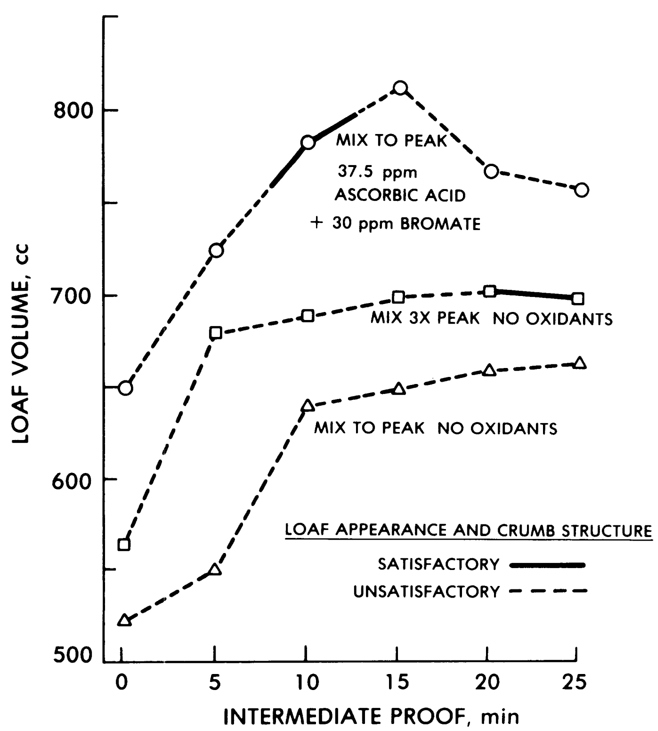

Fig. 9. Effect of intermediate proof time on loaf volume for three mixing conditions using flour B with the GRL-1000 mixer at 165 rpm.

CONCLUSIONS

We have demonstrated that the optimum amount of mixing for short-process breadmaking depends to a large extent on the amount of chemical oxidation added. To produce satisfactory bread in the absence of added oxidation, doughs must be mixed considerably past peak consistency to a stage normally considered well into the dough breakdown region. Under these conditions, a period of intermediate proof is essential for minimizing or eliminating "green" external loaf characteristics and for producing a thin-walled cell structure with a conventional pore pattern. Loaf volume is not as great as when oxidants are used.

When levels of chemical oxidants are appropriate, optimum bread and the greatest tolerance to intermediate proof time are obtained when doughs are mixed to peak consistency.

Mixing work requirements appear to be inversely proportional to the amount of added oxidation, and when doughs contain less than optimum levels of added oxidant, mixing must be continued beyond peak consistency for best results.

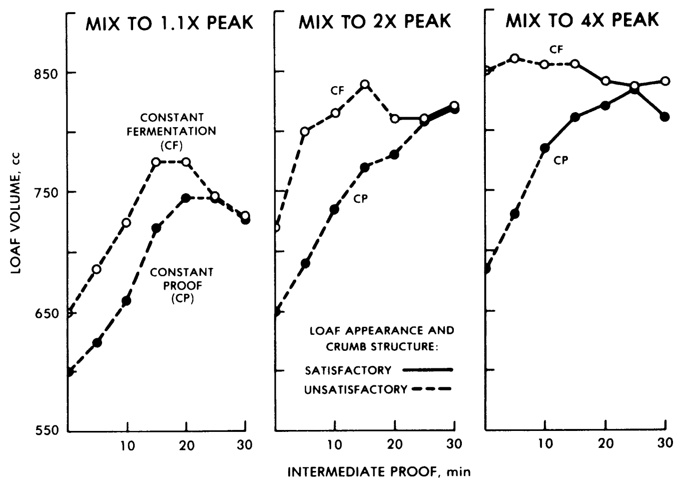

Fig. 10. Effect of intermediate proof time on loaf volume for flour A using no chemical oxidants. Constant fermentation (80 min between end of mixing and baking) and constant final proof (55 min) are compared for three mixing work levels.

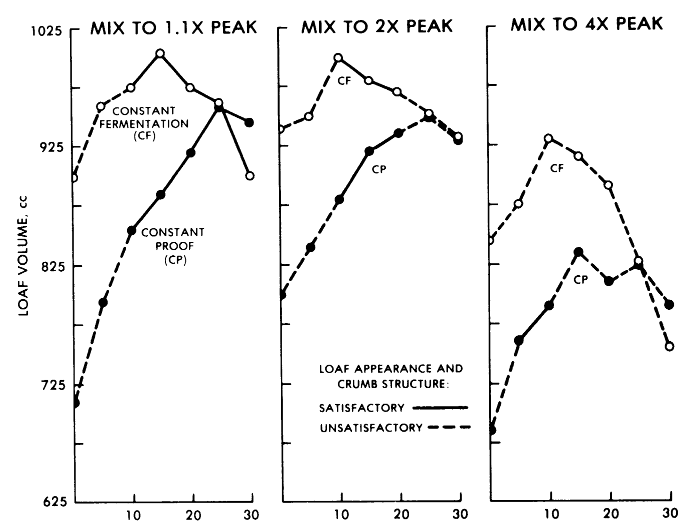

Fig. 11. Effect of intermediate proof time on loaf volume for flour A, with 37.5 ppm of ascorbic acid and 30 ppm of potassium bromate added to the doughs. Constant fermentation (80 min between end of mixing and baking) and constant final proof (55 min) are compared for three mixing work levels.

TABLE II
Comparison of Constant Fermentation Time Calculated from End of Mixing and from Start of Mixing

	Constant Fermentation From End of Mixing (80 min)		Constant Fermentation From Start of Mixing (84 min)	
	No Added Oxidants	37.5 ppm Ascorbic Acid + 30 ppm Potassium Bromate	No Added Oxidants	37.5 ppm Ascorbic Acid + 30 ppm Potassium Bromate
Mixing to 1.1 times peak energy				
Mixing time, min	3.9	3.9	3.9	3.9
Intermediate proof, min	25	25	25	25
Final proof, min	55	55	55	55
Total fermentation, min	83.9	83.9	83.9	83.9
Loaf volume, cc	745	960	745	960
Loaf appearance[a]	7.2-g	8.8	7.2-g	8.8
Crumb structure[b]	6.2-o	6.0-o	6.2-o	6.0-o
Crumb color[c]	5.8-dy	8.0	5.8-dy	8.0
Mixing to two times peak energy				
Mixing time, min	6.8	6.8	6.8	6.8
Intermediate proof, min	25	25	20	20
Final proof, min	55	55	57	57
Total fermentation, min	86.8	86.8	83.8	83.8
Loaf volume, cc	810	950	790	945
Loaf appearance[a]	7.5-vslg	8.0-old	7.2-vslg	8.0-slold
Crumb structure[b]	6.2-o	6.0-o	6.0-o	6.0-o
Crumb color[c]	6.2-dy	8.0	6.5-dy	8.0
Mixing to four times peak energy				
Mixing time, min	13	13	13	13
Intermediate proof, min	25	25	15	15
Final proof, min	55	55	55	55
Total fermentation, min	93	93	83	83
Loaf volume, cc	835	825	810	835
Loaf appearance[a]	8.2	7.5-old-w	7.8	8.0-slold
Crumb structure[b]	6.5-o	5.5-o	6.5-o	5.8-o
Crumb color[c]	7.5	8.5	8.0	7.5

[a] g = green, v = very, sl = slightly, w = wild break and shred.
[b] o = open.
[c] dy = dull yellow.

Intermediate proof time requirements are greater in the absence of added oxidation.

In a short baking system, the intermediate proof stage is very important. Lack of a sufficient period of intermediate proof cannot be adequately compensated for by extending final proof.

ACKNOWLEDGMENTS

We are grateful to E. J. Gander and G. Paulley for technical assistance.

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[Received February 21, 1979. Accepted March 23, 1979]