Sponge-and-Dough Bread. I. Reduction of Fermentation Time and Bromate Requirement by the Incorporation of Salt in the Sponge[1]

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ABSTRACT

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The effects of adding 0–1% salt to the sponge at varying bromate levels and sponge fermentation times upon the baking quality of sponge-and-dough bread produced from Canadian wheat flours were studied. With a 4.5-hr sponge fermentation, addition of sponge salt at levels of 0.5 or 1% based upon total flour produced superior bread compared to that produced with sponge salt levels of 0 and 0.15%. In addition, optimum bromate requirements were 5–15 ppm lower with the higher sponge-salt levels. With a 2.5-hr sponge fermentation, bread of inferior quality was produced when 0.15% salt was added to the sponge. However, with 1% sponge salt, bread quality was excellent with the short fermentation time, whereas optimum bromate requirements were similar to those of the standard procedure (0.15% sponge salt and a 4.5-hr fermentation). The results suggest that the addition of 1% sponge salt in commercial sponge-and-dough procedures may provide a method of reducing sponge time and/or oxidation requirements without any basic changes in processing conditions.

Although no-bulk fermentation methods have increased in popularity in many parts of the world, the conventional sponge-and-dough process continues to be used extensively in North America and almost exclusively in Japan for the production of white pan bread. The continuing extensive use of this method generally has been attributed to the high quality of the product, which has superior flavor and aroma, silky texture, fine grain, good crumb color, and excellent keeping quality. In addition, the sponge-and-dough method is tolerant to variations in processing conditions and ingredients (Ford 1968, Garnatz 1957, Merritt 1950, Pyler 1978) and has minimal requirements for chemical additives such as bromate. This last factor is of particular importance in countries such as Japan where consumer resistance to the use of chemical additives is strong. However, the sponge-and-dough method also has some major economic disadvantages because of the long (approximately 4.5-hr) sponge fermentation required to obtain optimum bread quality. This results in long processing time, reduced dough absorption caused by fermentation losses, and increased floor space requirements.

Attempts to significantly reduce sponge time, which could result in considerable economic saving and increased throughput, generally have resulted in bread of commercially unacceptable quality. Investigations by Merritt (1950) on ingredient level effects and by the Grain Research Laboratory[3] (GRL) on the effects of mixing, oxidation, temperature, and sponge water level did not reveal a formulation that would reliably produce optimum bread over a range of flour quality when sponge times of approximately 2.5 hr were used.

These failures probably can be attributed to the considerable time required for the gluten in the sponge to undergo structural modifications resulting in an optimum state before dough-up. Furthermore, these structural changes appear to be closely related to the sponge "drop" or "collapse" time. In commercial practice, optimum sponge times are obtained by allowing fermentation to proceed approximately 60–75% past sponge drop time (Pyler 1978).

In our laboratory, we have used the GRL dough height tracker (Kilborn and Preston 1981) to study the effects of various ingredients and additives upon sponge fermentation heights. We noted that addition of salt had a profound effect upon sponge fermentation curves. As salt concentration was increased from 0 to 1.4%, a large reduction was found in the sponge drop at approximately 130 min, although differences in final sponge heights after 270 min were less evident.[3] On the hypothesis that sponge drop might retard desirable gluten modification by the disruption of the gluten structure, studies were initiated to determine the effect upon bread quality of increasing levels of salt in the sponge in connection with various fermentation times.

The study presented here is that portion of our work dealing with the successful reduction of sponge time from 4.5 to 2.5 hr by the addition of salt to the sponge with a laboratory sponge-and-dough procedure. In addition, results are presented that show the potential use of sponge salt for the reduction of bromate requirement with conventional sponge times.

MATERIALS AND METHODS

Flours

Seven straight-grade flours were examined. Analytical and farinograph properties of these flours are shown in Table I. Flour A was milled on the GRL Pilot Mill from a commercial sample of No. 1 CWRS-13.5, a Canada Western red spring (CWRS) wheat, and was used for the larger factorial portion of this study. The other samples were milled on a laboratory Allis-Chalmers mill from four samples of grade 1 CWRS of varying protein contents and one sample each of grade 3 CWRS and grade 1 Canada Western red winter (CWRW) wheats obtained from western Canada carlot composites for the crop year 1979–1980.

Baking

The GRL sponge-and-dough procedure, using 200 g of flour as previously described (Kilborn and Preston 1981), was used in the present study with three exceptions: 1) Salt level in the sponge was varied from 0–2 g (0–1% based upon total flour, 0–1.43% based upon sponge flour). The final salt level in the dough was maintained at 2.4% by adjusting the amount of salt added at dough-up. 2) Potassium bromate was varied from 0 to 20 ppm for flour A and from 10 to 20 ppm for the other flours. 3) Sponge water, which in this procedure is normally added at 2% below final absorption, was also added at 4% final absorption. Optimum baking absorptions for all flours were within 1% of farinograph absorptions (Table I).

All loaves were baked in duplicate. Loaf volumes were measured by rapeseed displacement 30 min after removal from the oven; loaves were then stored for 20 ± 4 hr in a bread-storage cabinet. The standard derivation for replicates was 40 cc. After visual appraisal of loaf appearance, the stored loaves were cut cross-wise and visually evaluated for crumb structure and crumb color as described by Kilborn and Tipples (1981). Total bread score was determined by multiplying the values for loaf volume, loaf appearance, crumb structure, and crumb color and dividing by 10,000, after correcting individual numerical values for such factors as greyness, age, openness, etc. For individual bread characteristics and total bread scores, higher numbers indicated higher quality. The standard derivation for replicate bread scores was four units.

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[3]Unpublished data.

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RESULTS AND DISCUSSION

Effect of Sponge Salt and Bromate Level

With 4.5-hr Sponge Fermentation. The effects of sponge-salt level and bromate level upon individual bread properties of CWRS wheat flour (flour A), using a 4.5-hr sponge with the GRL sponge-and-dough procedure are shown in Table II. Figure 1 shows the relationship between salt level, bromate level, and total bread score. All doughs had good machinability and handling properties as judged by an experienced operator.

With 0% sponge salt, total bread scores increased with increasing bromate levels. The largest increases occurred from 0 to 15 ppm as evidenced by improvements in loaf volume, crumb color, and loaf appearance. However, even with 20 ppm bromate, the bread had a slightly green appearance.

With 0.15% sponge salt, which is normally used in the GRL sponge-and-dough procedure, bread of good quality was produced with either 15 or 20 ppm bromate. However, as bromate was reduced, total bread score decreased greatly, loaf volume and crumb structure decreased, and greenness increased. In general, the bread scores for the 0.15% salt level were higher than but parallel to those of the 0% salt level with increasing bromate.

Addition of 0.5% sponge salt gave bread scores higher than those obtained with 0 or 0.15% salt at corresponding bromate levels. With the exception of 0 ppm, all levels of bromate resulted in high bread scores, loaf volumes, and external and internal loaf characteristics. However, on the basis of age, 15 ppm bromate was judged to be the optimum level; lower levels resulted in slightly green (young) characteristics, and at 20 ppm bromate the bread appeared slightly old. Of all salt levels studied, the 0.5% sponge-salt level appeared to give the best results when bromate tolerance was considered.

The highest bread scores were obtained with 1% sponge salt at bromate levels of 5 and 10 ppm. However, even with no bromate, good bread was produced, as evidenced by the high bread score of 85 and the large loaf volume (2,120 cc). With bromate levels above 10 ppm, bread scores were significantly reduced, which was mainly attributable to keyholing (the tendency of side walls to cave in). This latter effect is normally associated with over-oxidation during long fermentation processes.

With 2.5-hr Sponge Fermentation. For studying the effects of salt and bromate levels with a 2.5-hr sponge fermentation, the same

TABLE I
Analytical and Peak Farinograph Properties of Flours[a]

Flour		Flour Protein (%)	Flour Ash (%)	Starch Damage[c]	Gassing Power[d] (mm)	Amylograph Peak Viscosity (BU)	Farinograph	
Name	Official Designation[b]						Absorption (%)	DDT[e] (min)
A	1 CWRS-13.5	12.7	0.39	31	425	505	65.6	5.25
B	1 CWRS-15.0	14.4	0.44	23	390	510	66.1	5.25
C	1 CWRS-13.5	13.0	0.44	29	410	495	65.5	4.75
D	1 CWRS-12.5	12.0	0.44	30	435	445	65.0	4.25
E	1 CWRS-11.5	11.6	0.47	31	440	430	64.7	3.75
F	3 CWRS	11.7	0.47	29	570	100	64.3	3.50
G	1 CWRW	10.4	0.46	26	465	230	59.1	4.50

[a] Results based on 14.0% moisture basis.
[b] CWRS = Canada Western red spring, CWRW = Canada Western red winter; official designation includes grade and guaranteed protein level.
[c] In Farrand units.
[d] After 6 hr.
[e] Dough development time.

TABLE II
Effect of Sponge-Salt Level and Bromate Level with a 4.5-hr Sponge Fermentation Time on Individual Bread Characteristics of a No. 1 CWRS-13.5[a] Wheat Flour[b]

Sponge Salt (%)	Bromate Level (ppm) 0	5	10	15	20
0.0					
Loaf volume, cc	1,780	1,870	1,920	2,000	2,000
Appearance[c]	5.2-vg	6.0-g	6.2-g	6.8-slg	6.8-slg
Crumb structure[c]	6.0-o+	6.0-o+	6.5-o+	6.2-o+	6.5-o+
Crumb color[c]	7.8	8.2	9.0	9.0	8.8
0.15					
Loaf volume, cc	1,890	1,960	2,020	2,040	2,025
Appearance	6.5-g	6.8-slg	7.5-slg	7.5	7.5
Crumb structure	6.0-o+	6.5-o	6.8-o++	6.8-o++	6.8-o++
Crumb color	8.0	8.5	8.8	9.0	9.0
0.50					
Loaf volume, cc	2,040	2,100	2,110	2,130	2,150
Appearance	7.5-slg	7.5-slg	7.5-slg	7.5	7.8-slo
Crumb structure	6.2-o+	6.8-o	6.8-o	6.8-o+	6.8-o+
Crumb color	8.5	9.0	9.2	9.2	9.0
1.0					
Loaf volume, cc	2,120	2,180	2,180	2,240	2,130
Appearance	7.8-slg	7.8	7.5-slo	7.8-sloKH	7.0-sloKH
Crumb structure	6.8-o++	6.8-o++	7.0-o+	6.8-o++	6.8-o+
Crumb color	9.0	9.0	9.0	9.0	8.8

[a] Grade 1 Canada Western red spring, 13.5% protein guaranteed.
[b] Letters on scores: g = green (young), v = very, sl = slightly, o = open (crumb structure) or old (appearance), KH = keyhole, + = more of specified characteristic.
[c] Higher scores indicate higher quality. Maximum score = 10.

sponge-salt levels but only 10, 15, and 20 ppm bromate were used. Lower levels of bromate did not meet oxidation levels at the two lower salt levels did not lead to much improvement in total bread score. Data for individual bread characteristics with the 2.5-hr sponge fermentation are given in Table III, and total bread scores are plotted in Fig. 2. As in the case of the 4.5-hr fermentation, no problems in dough handling properties were encountered.

When sponge-salt levels were increased in the presence of 10, 15, and 20 ppm bromate, large increases were found in total bread scores and loaf volumes (Fig. 2, Table III). The highest sponge salt level (1%) produced the best bread. With no salt in the sponge, bread scores were poor because of low loaf volumes and green loaf characteristics. At higher bromate levels (above 20 ppm), greenness disappeared but loaf volumes did not show any improvement (data not shown).

With 0.15% sponge salt, bread scores were somewhat better than with 0% sponge salt at corresponding bromate levels. This was mainly from increases in loaf volume. However, bread scores were still much lower than corresponding values obtained after the 4.5-hr fermentation.

The bread scores of the two higher sponge-salt levels (0.5 and 1%) were much higher than those of the two lower salt levels, with 1% sponge salt giving the highest values. Although bread scores with 0.5% sponge salt were lower with the 2.5-hr fermentation than with

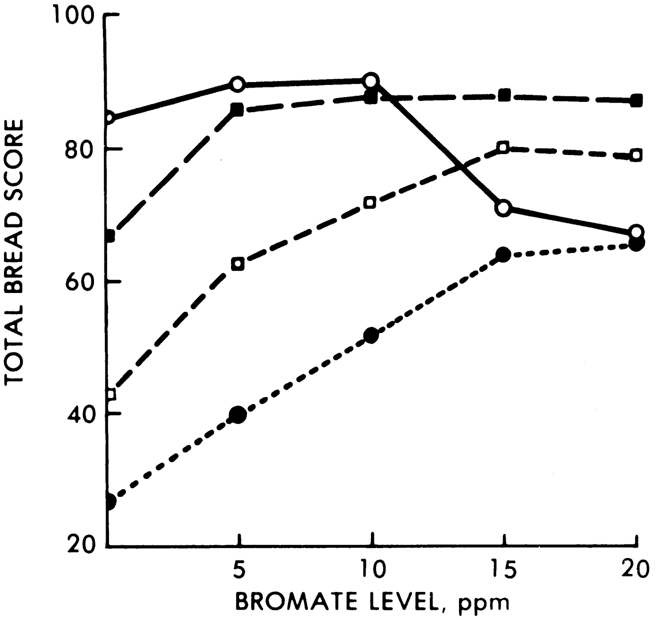

Fig. 1. Relationships between total bread score and bromate level with four levels of sponge salt, using a 4.5-hr fermentation. Salt levels: ● = 0%, □ = 0.15%, ■ = 0.5%, o = 1%.

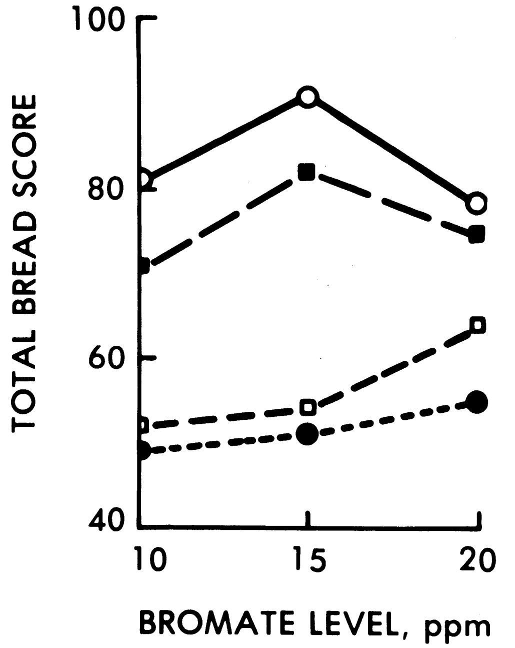

Fig. 2. Relationships between total bread score and bromate level with four levels of sponge salt, using a 2.5-hr fermentation. Salt levels: ● = 0%, □ = 0.15%, ■ = 0.5%, o = 1%.

TABLE III
Effect of Sponge-Salt Level and Bromate Level with a 2.5-hr Sponge Fermentation Time on Individual Bread Characteristics of a No. 1 CWRS-13.5[a] Wheat Flour[b]

Sponge Salt (%)	Bromate Level (ppm) 10	15	20
0.0			
Loaf volume, cc	1,860	1,890	1,870
Appearance[c]	6.2-g	6.5-g	6.5-slg
Crumb structure[c]	6.5-o+	6.5-o+	6.5-o+
Crumb color[c]	8.8	8.5	8.5
0.15			
Loaf volume, cc	1,900	2,000	2,010
Appearance	7.0-g	6.5-slg	7.2-slg
Crumb structure	6.8-o+	6.5-o+	6.5-o+
Crumb color	8.2	8.5	8.2
0.50			
Loaf volume, cc	1,975	2,035	2,095
Appearance	7.2-slg	7.5-slg	7.5-slKH
Crumb structure	6.8-o+	6.8-o+	6.8-o+
Crumb color	8.8	9.0	9.0
1.0			
Loaf volume, cc	2,140	2,140	2,135
Appearance	7.2-slg	7.5	8.0-slKH
Crumb structure	6.8-o	6.8-o	6.8-o+
Crumb color	9.0	9.0	9.0

[a]Grade 1 Canada Western red spring, 13.5% protein guaranteed.
[b]Letters on scores: g = green (young), sl = slightly, o = open (crumb structure) or old (appearance), KH = keyhole, + = more of specified characteristic.
[c]Higher scores indicate higher quality. Maximum score = 10.

TABLE IV
Effect of Grain Research Laboratory Mixer Speed on Bread Quality of a No. 1 CWRS-13.5[a] Wheat Flour[b]

Procedure	Mixer Speed (rpm) 135	105	85	70
0.15% Salt and 4.5-hr fermentation[c]				
Loaf volume, cc	2,060	2,020	2,120	2,000
Appearance	7.2-slo	7.2-slo	7.5-slo	7.2
Crumb structure	6.8-o+	6.8-o+	6.8-o+	6.8-o+
Crumb color	8.2	8.2	8.2	8.2
Total bread score	71	68	74	72
Mixing time[d]	5.2	7.7	10.1	13.5
1.0% Salt and 2.5-hr fermentation[c]				
Loaf volume, cc	2,180	2,160	2,140	2,020
Appearance	7.5	7.5	7.2	7.2
Crumb structure	6.8-o	6.8-o	6.8-o	6.8-o
Crumb color	8.8	8.8	9.0	8.8
Total bread score	91	90	87	81
Mixing time[d]	5.9	8.7	12.4	17.4

[a]Grade 1 Canada Western red spring, 13.5% protein guaranteed.
[b]Letters on scores: sl = slightly, o = open (crumb structure) or old (appearance), + = more of specified characteristic.
[c]15 ppm bromate.
[d]Mixing time required to impart 5.0 *W*hr/kg.

the 4.5-hr fermentation, 15 and 20 ppm bromate still produced acceptable bread. With 1% sponge salt, all levels of bromate produced highly acceptable bread. Bread scores were similar to those obtained after the 4.5-hr fermentation, although bromate requirements for optimum performance were higher by 5–10 ppm. Bread made from grade 1 CWRS with 1% sponge salt, 2.5 hr of fermentation, and 10 or 15 ppm bromate was superior to bread made with the same flour and the standard procedure (0.15% sponge salt, 4.5 hr of fermentation, and 15 or 20 ppm bromate).

Effect of Mixing Speed

Increasing sponge-salt levels resulted in increased dough-mixing requirements measured in both energy and time. This suggested the possibility that slower-speed commercial mixers might encounter problems with critical speed requirements (Tipples and Kilborn 1975). Therefore, the effects of mixing speed at constant energy input (5.0 Whr/kg) on the quality of bread produced by the standard GRL sponge-and-dough procedure was compared to the quality of bread produced by the 1% sponge salt and 2.5-hr fermentation procedure, which appeared to have the greatest mixing requirements. The effect of mixing speed on the standard procedure was insignificant (Table IV), and only a small reduction in baking quality occurred as mixing speed was reduced with the 1%-salt procedure. These results suggest that lower-speed commercial mixers would be capable of properly developing doughs at all levels of sponge salt utilized in this study, although, as shown in Table IV, longer mixing times might be required.

Effects of Fermentation Time and Sponge Salt on Canadian Wheat Flours

Table V shows the effect of fermentation time and sponge-salt levels on total baking scores and loaf volumes obtained from Canadian spring wheat flours representing a range in quality and flour protein. With the standard 4.5-hr fermentation and 0.15% sponge-salt procedure, the two higher-protein grade 1 CWRS wheat flours gave high baking scores and loaf volumes. For the two lower-protein grade 1 CWRS wheat flours and grade 3 CWRS wheat flour, total baking scores were lower as a result of reduced loaf volumes. These results are consistent with previous studies (Finney and Barmore 1948) showing the close relationship between protein content and loaf volume. The CWRW wheat sample gave a low total bread score and loaf volume, which is probably related to both its lower protein content and its inability to withstand long fermentation. All samples gave optimum baking scores with approximately 15 ppm bromate.

As in the case of flour A, bread scores and loaf volumes of the six flours showed large decreases when fermentation time was reduced to 2.5 hr with 0.15% sponge salt. However, in the presence of 1% sponge salt and a 2.5-hr fermentation, all flours gave baking scores and loaf volumes superior to those produced with the standard procedure. Even though the CWRW wheat flour did not give a particularly high baking score and loaf volume for the 2.5-hr fermentation and 1% salt method, values were significantly higher than with the 4.5-hr fermentation and 0.15% salt method. This result suggests that high sponge-salt levels may be particularly useful in improving the baking quality of flours with low fermentation tolerances.

In addition, the six wheat flours were processed with sponge absorptions 4% above final dough absorptions to determine whether increased water levels would improve baking quality as a result of higher yeast activity. With the 1% sponge salt and 2.5-hr fermentation procedure, three of the flours showed some improvement in baking score (three to seven units) over values obtained at sponge absorptions 2% below final dough absorption; the remaining flours showed no change (data not shown). Thus, in some cases, increased sponge absorption levels with 1% sponge salt may improve bread quality. At the higher sponge absorption, sponge heights and sponge handling properties were not adversely affected. Recent studies in our laboratory[4] indicate that higher sponge absorptions may be particularly useful in improving bread quality with very strong flours.

Related Considerations

In commercial sponge-and-dough procedures, salt is normally withheld during the sponge stage and added at dough-up (Pyler 1968). However, under some circumstances the addition of salt to the sponge appears to be beneficial. For example, during warm weather, if control over temperature is lacking, addition of salt to the sponge has been reported to control sponge fermentation (Garnatz 1957). In our experience, some Canadian bakeries also add low levels of salt (0.15%) to the sponge, presumably to control sponge height. However, as far as we are aware, no in-depth studies have been published concerning the effects of various levels of sponge salt on bread properties with respect to fermentation times and bromate requirements.

The results of the present study suggest that the addition of 1% sponge salt, based upon total flour, offers several advantages over the normal commercial practice of withholding salt until dough-up. First, with the normal 4.5-hr sponge time, the use of 0.5 or 1% sponge salt resulted in substantially improved bread quality, in terms of total bread scores and loaf volumes, in comparison to that obtained with 0 or 0.15% sponge salt. Second, the presence of 0.5 or 1% sponge salt appeared to be effective in reducing oxidation requirements, as evidenced by the reduction (by 10–15 ppm) in optimum bromate requirements. In fact, with 1% sponge salt, bread of good quality was produced with no bromate. At present, the reasons for this effect are not known. However, it may be related to the "toughening" effect of salt upon the gluten proteins,

[4]Unpublished data.

TABLE V
Effects of Fermentation Time and Sponge Salt Level on the Baking Properties of Canadian Wheat Flours[a]

Procedure	Flour Grade and Type					
	No. 1 CWRS[b]-15.0	No. 1 CWRS-13.5	No. 1 CWRS-12.5	No. 1 CWRS-11.5	No. 3 CWRS	No. 1 CWRW[c]
4.5-hr Fermentation and 0.15% salt						
Total bread score	79	86	67	50	49	30
Loaf volume, cc	2,010	2,180	1,860	1,800	1,740	1,660
2.5-hr Fermentation and 0.15% salt						
Total bread score	48	60	50	32	43	29
Loaf volume, cc	1,800	1,960	1,770	1,680	1,740	1,650
1.0% Salt						
Total bread score	80	91	79	70	76	62
Loaf volume, cc	2,080	2,130	1,990	1,930	1,925	1,880

[a]Results obtained at optimum bromate level (approximately 15 ppm).
[b]Canada Western red spring; official designation includes grade and guaranteed protein level.
[c]Canada Western red winter.

which is to some degree similar to the effects of oxidizing agents, as evidenced by farinograph and extensigraph studies (Fisher et al 1949, Meredith and Bushuk 1962).

The most important finding of the present study is the apparently successful reduction in sponge time from 4.5 to 2.5 hr obtained by including 1% salt in the sponge with no significant changes in overall ingredient levels or processing conditions. Six of the seven wheat flours tested gave highly acceptable bread in terms of total bread scores and loaf volumes with the 1% sponge salt and 2.5-hr fermentation procedure, and the seventh, the winter wheat flour, showed improved baking quality compared to that achieved with the standard 0.15% sponge salt and 4.5-hr fermentation procedure.

Although the results appear very promising, at present we do not know whether the approximately 1% salt in the sponge will prove successful in reducing sponge times and/or oxidation requirements with commercial sponge-and-dough procedures. However, the increased mixing requirements at dough-up with 1% sponge salt do not appear to present any difficulties for commercial mixers. Recent studies in conjunction with a Canadian milling company[5] also suggest that the mechanical abuse imparted to doughs by commercial dividers, rounders, molders, and sheeters does not present any processing problems. In addition, reduction of yeast activity by the addition of sponge salt does not appear to be a factor. In fact, previous studies by Walden and Larmour (1948) showed that the gassing rates of doughs were not seriously affected with up to 1.5% salt, and recent studies in our laboratory[6] have shown that gassing power after 6 hr is not significantly affected with up to 1.0 *M* sodium chloride. Currently, research is being conducted in our laboratory to determine the possible effects of other ingredients such as surfactants, the effects of sponge temperature rise, and the keeping qualities of bread produced with the 1% sponge salt and 2.5-hr fermentation procedure.

[5]Unpublished data.
[6]Preston and Kilborn. Unpublished data.

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