Combined Effects of Sodium Chloride and Hydrochloric Acid on Wheat Flour Strength[1]

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ABSTRACT

The combined effects of salt (sodium chloride) and acid (hydrochloric) on wheat flour strength were studied by measuring physical dough properties and baking quality. The combined effects increased mixing time and stability and slightly increased loaf volume. When optimum potassium bromate was used in doughs treated with different combinations of salt and acid, over-oxidized dough characteristics appeared and decreased loaf volume. When salt and acid were in dough, no oxidant was required because of the two reagents' marked strengthening effect. The combined effect of salt and acid on the balance between resistance to extension and extensibility of dough was highly important in determining loaf volume and crumb characteristics. Cysteine hydrochloride improved extensibility of doughs treated with salt and acid, and the strengthening effects of salt and acid were more pronounced, as measured by loaf volume potential. The amount of cysteine required to improve the extensibility of the dough was quite constant, regardless of the stiffness or strength of the dough.

Salt increases the mixing time and stability of dough (Hlynka 1962, Hoseney and Finney 1974), but acid decreases mixing time and stability (Hoseney and Finney 1974, Tanaka et al 1967).

The effect of combined salt and acid in dough is less clear. Tanaka et al (1967) reported that farinograph consistency of unsalted doughs decreased as the pH was lowered with acetic acid and that the consistency further decreased with salt. Galal et al (1978) found that combinations of organic acids and salt greatly increased farinograph mixing time and dough stability. Earlier, Bennett and Ewart (1965) indicated that the extensibility and resistance of dough, as measured by the Simon Research extensometer, decreased when salt and acid were present. None of these studies included baking evaluations. We therefore studied the combined effects of salt and acid on wheat flour strength as measured by mixograph properties and baking tests.

MATERIALS AND METHODS

Materials

Untreated hard red winter (HRW) and soft red winter wheat flours were used. HRW wheat was milled on the Kansas State University pilot flour mill and had 10.6% protein and 0.39% ash. Farinograph water absorption and mixing time were 58% and 3.5 min, respectively. Mixograph mixing time was 4.5 min. An amylograph value of 520 BU was obtained by adding 0.15 g of malted barley flour per 100 g of flour. All data were expressed on a 14% moisture basis and were obtained by AACC (1976) methods.

The soft wheat flour, supplied by the Pillsbury Company, had 9.73% protein and 0.39% ash. Farinograph water absorption and mixing time were 53% and 2.5 min, respectively. Mixograph mixing time was 3.5 min. An amylograph value of 500 BU was achieved by adding 0.20 g of malted barley flour for 100 g of flour. Because the flours had a fairly short mixing requirement, they were suitable to use with additives, which lengthen mixing. Primarily because they contained only marginal protein, their farinograph and mixograph characteristics were weak.

The salt was sodium chloride supplied by Fischer Scientific Company. The salt was dissolved in distilled water and added as a solution of desired concentrations. The pH of a 5% salt solution at 25°C was 5.9. Hydrochloric acid 2*N* solution was supplied by Fischer Scientific Company. L-Cysteine hydrochloride was obtained from Sigma Chemical Company. Potassium bromate was obtained from Mallinckrodt Chemical Works. All chemicals were of reagent quality.

Methods

A 10-g mixograph was used to measure mixing time and stability of doughs by the method of Finney and Shogren (1972). Two series were run, the first under normal conditions, the second under a nitrogen atmosphere to eliminate dough oxidation by air. In the latter experiment, the mixograph was placed in a glove bag and flushed with nitrogen.

A straight dough method was followed, with a formula of 2.5% yeast, 6% sugar, 3% shortening, 2% commercial milk replacer, 0.25% dough strengthener (sodium stearoyl lactylate), all on a 100% flour basis. Enough malted barley flour was used to achieve an amylograph value of 500 BU. Salt and acid were added as previously indicated.

To ensure constant yeast activity in all doughs, we used a

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modified mixing procedure. All ingredients except the yeast were incorporated with the desired amounts of acid and salt for 1 min at low speed in a Hobart A-200 mixer. Then yeast was added, and the dough was mixed another 30 sec at the same speed. The procedure was used to prevent any direct contact between the yeast and either acid or salt. Doughs were mixed to optimum development as determined by visual observation at second speed with mixograph mixing time as a guide. At two thirds of the mixing time, an amount of sodium bicarbonate equivalent to the acid was added to restore the pH of the doughs to the normal and constant pH level, regardless of the different treatments. The amounts of salt formed by the reaction of acid and sodium bicarbonate was calculated and deducted from the salt added as a dough ingredient; thus, the quantity of salt from dough to dough was constant.

The added acid affected neither yeast activity nor gas production, which was confirmed by checking dough gassing power. Thus, differences in loaf volume and grain quality resulted primarily from differences in gas retention, not gas production. Dough temperatures after mixing were controlled at 81 ± 1° F. The doughs were divided immediately after mixing into two pieces (539 g per piece), rounded, placed on a greased pan, and fermented 2½ hr in a cabinet adjusted to 86° F and 85% rh. The dough pieces were punched, rounded, rested for 20 min in the fermentation cabinet, then molded, panned, and proofed to height (1.5 cm above pan) at 86° F and 85% rh. The loaves were baked at 425° F for 25 min. Loaf volume and weight were measured immediately after baking. Loaf volume was determined by rapeseed displacement. Specific loaf volume was calculated by dividing volume by weight (cc/g).

Every experiment was replicated at least once, and the data were analyzed statistically by response surface methodology, described by Cochran and Cox (1957).

TABLE I
Mixing Time and Stability as Affected by the Amount of Acid Added at 2% Sodium Chloride (Flour Basis)

	Mixing Time (min)		Stability[b]	
Acid[a]	Air	Nitrogen	Air	Nitrogen
···	6.0	6.0	163	163
10	7.0	7.0	166	166
20	8.5	8.5	171	171
30	11.5	11.5	172	172
40	15.0	15.0	174	184

[a] Hydrochloric acid, µmole/g.
[b] Angle in degrees between the ascending and descending slopes.

RESULTS AND DISCUSSION

Combined Effects on Mixograph Mixing Time and Stability

Any combination of acid and salt increased mixing time (Fig. 1) and stability (Fig. 2) of the HRW flour studied. Both mixing time and stability were increased by increasing both acid and salt.

At a constant amount of salt (2%), increasing the acid increased both mixing time and stability (Table I). Mixing time increased by more than 100% when 40 µmole of acid was added (Table I).

By increasing either the acid or salt and decreasing the other, the same mixing time could be obtained. For example (Fig. 3), adding 2% salt (control) gave a 6-min mixing time; decreasing the salt to 1% and adding 10 µmole of acid gave the same mixing time (6 min). Also 2% salt plus 20 µmole of acid, 2.2% salt plus 15 µmole of acid, and 1.5% salt plus 22 µmole of acid gave the same mixing time (8.5 min). These combinations appear to have a complementary effect on mixing time. All mixings were under normal conditions in air.

Similar results were obtained when dough was mixed under a nitrogen atmosphere (Table I). No differences were found in mixing time or stability when doughs were mixed in either air or nitrogen, which indicates that the increases in mixing time and stability resulted from the combined effects of acid and salt on dough structure rather than from any oxidation reaction.

These results indicate that acid and salt combined in the dough produced a synergistic effect on mixing time and stability.

Tanaka et al (1967) and Galal et al (1978) postulated that the combination of salt and acid produced a very compact and insoluble protein aggregate. Smith and Mullin (1965) indicated that additives that decrease protein solubility markedly increase

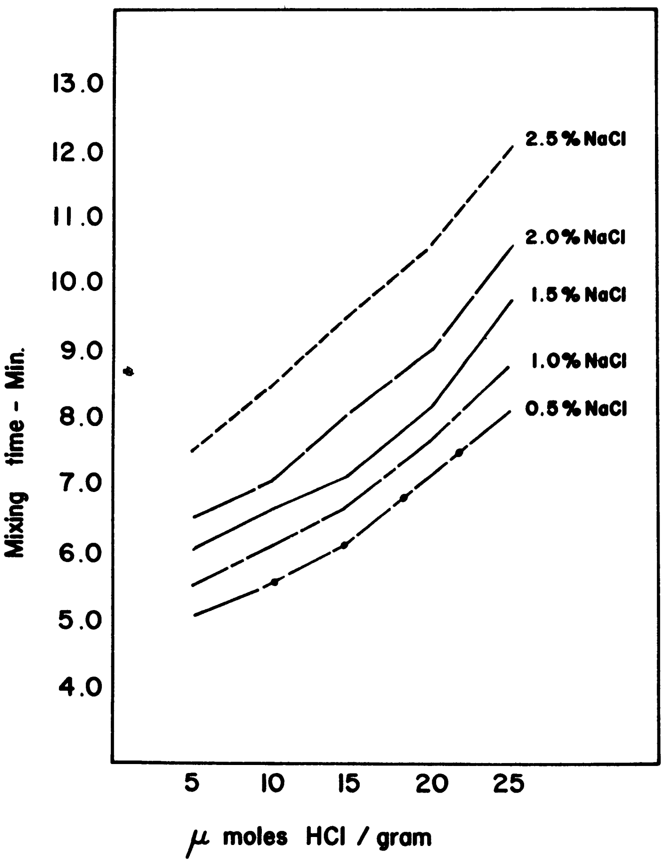

Fig. 1. Mixograph mixing time as affected by combinations of salt and acid.

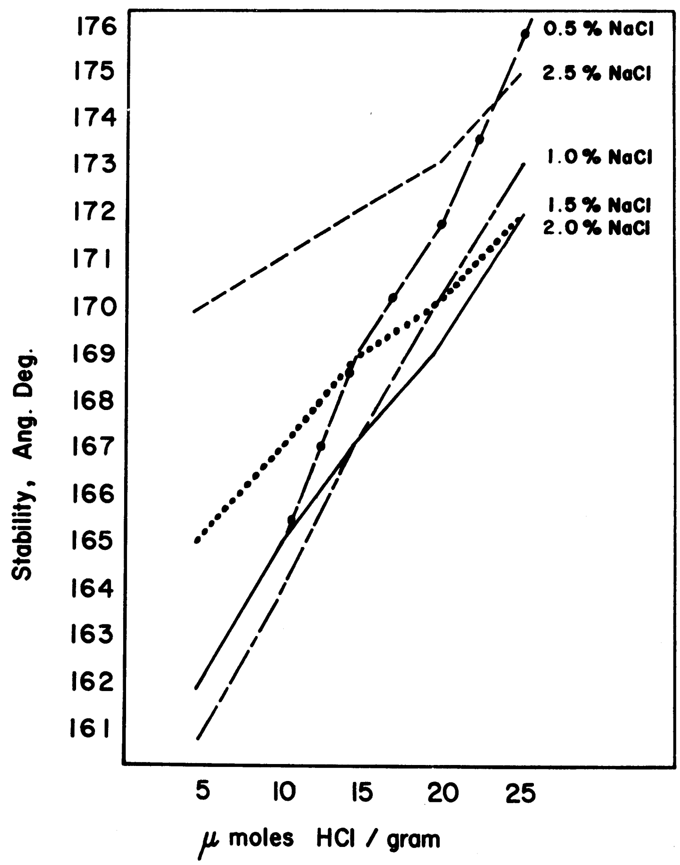

Fig. 2. Mixograph stability as affected by combinations of salt and acid.

mixing requirement. Also, Kasarda et al (1971) reported that the insoluble proteins impart strength to wheat flour doughs, whereas more soluble proteins have a weakening effect. From those investigations and our results, the synergistic effect of acid and salt on the dough appears to be strengthening.

Combined Effect on Loaf Volume

Figure 4 shows the combined effects of salt and acid on loaf volume without oxidant in the formula. Loaf volume increased with various levels of salt (except 2.5%) as the amount of acid increased to a certain level; then loaf volume started to decrease. At high levels of salt, a small amount of acid was needed to obtain the increase and vice versa. Above 15 μmole of acid, loaf volume decreased with all levels of salt. The loaves obtained from doughs treated with 25 μmole of acid and 2.5% salt were the least in volume and had round corners, indicating poor dough flow.

Figure 5 shows the combined effects on loaf volume with the optimum oxidant in the formula. Loaf volume decreased when acid was increased at all levels of salt, but no combination of salt and acid increased loaf volume. All the breads were characterized by round corners and the appearance of having been made from over-oxidized doughs.

Thus, better bread was obtained with oxidant than with any combination of salt and acid. When oxidant was used in combination with salt and acid, loaf volume decreased and the bread exhibited some over-oxidized characteristics.

Our results probably are related to the interplay of two dough properties: resistance to extension and extensibility. Doughs of good quality must show enough resistance to extension to retain gas in cells and enough extensibility so the gas cells can expand during proofing and baking without extensive rupture of the membranes between cells. This means that good gas retention in dough depends on a balance between these two properties (Bloksma 1971). Evidently, salt with acid affects this balance if the dough is optimally matured.

Optimum amounts of oxidants improve gas retention and loaf volume, whereas larger amounts lead to excessive dough rigidity and subsequent loss of gas retentive properties (Bloksma 1971). Thus, in the present instance, when doughs were optimally oxidized, the further strengthening effect due to salt and acid led to excessive dough rigidity, somewhat similar to over-oxidation.

Line \ Column	A	B
1	0 + 2.0	20 + 2.0
2	10 + 1.0	15 + 2.2
3	7.9 + 1.5	22 + 1.5

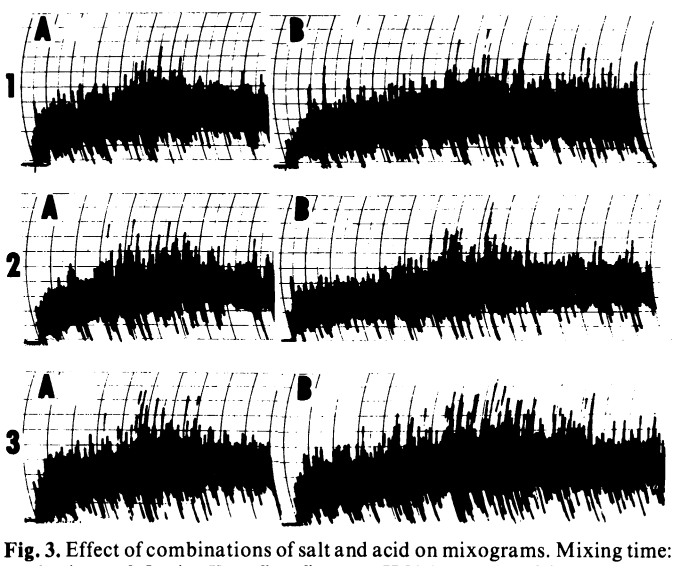

Fig. 3. Effect of combinations of salt and acid on mixograms. Mixing time: **A,** 6 min; **B,** 8.5 min. Key: first figure = HCl (μmole/g of flour), second figure = NaCl (% flour basis).

Combined Effects of Salt and Acid in the Presence of Cysteine

The previous experiments indicated a dough-strengthening effect due to combined salt and acid. We were therefore interested

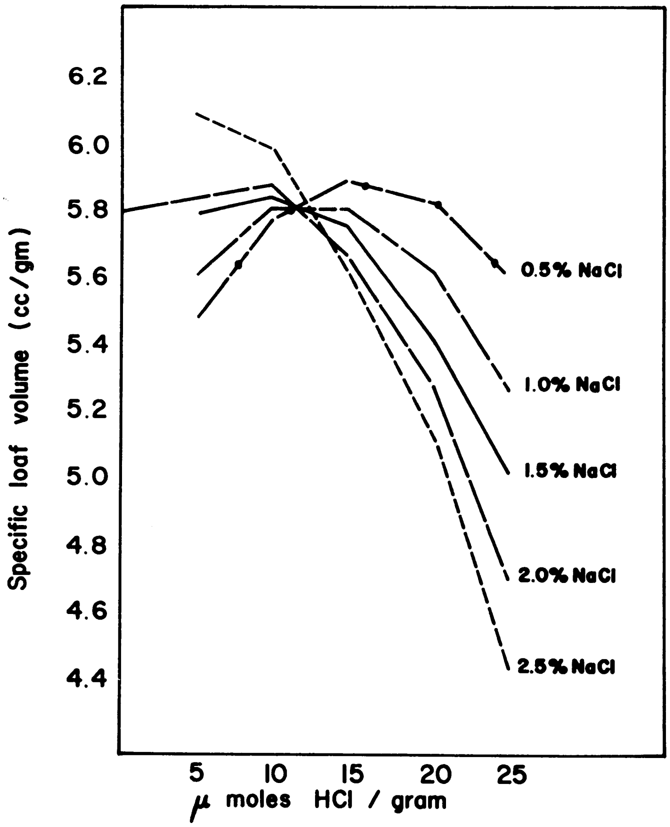

Fig. 4. Specific loaf volume as affected by combinations of salt and acid without oxidant in the formula.

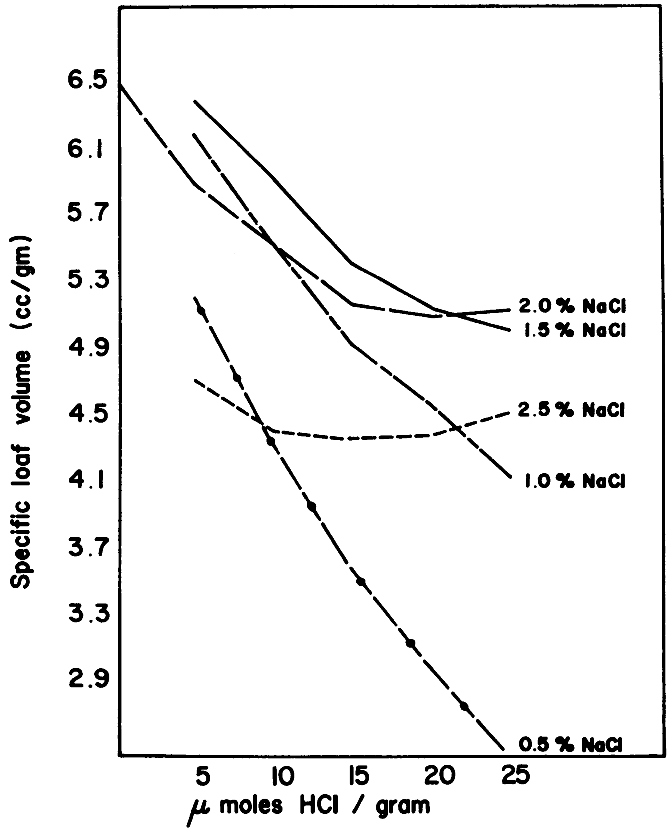

Fig. 5. Specific loaf volume as affected by combinations of salt and acid with optimum oxidant ($KBrO_3$) in the formula.

TABLE II
Effects of Acid and Cysteine on Mixing Time and Stability in Doughs with 2% Sodium Chloride

Acid[a]	L-Cysteine HCl (ppm flour basis) 0	20	30	40	50
	Mixograph Mixing Time (min)				
10	6.5	4.5	3.5	3.5	3.0
20	8.0	6.5	5.5	5.5	4.0
30	11.0	7.5	7.0	7.0	6.0
	Mixograph Stability[b]				
10	170	168	163	163	161
20	171	169	165	165	162
30	172	170	168	168	167

[a]Hydrochloric acid, μmole/g.
[b]Angle in degrees between ascending and descending slopes.

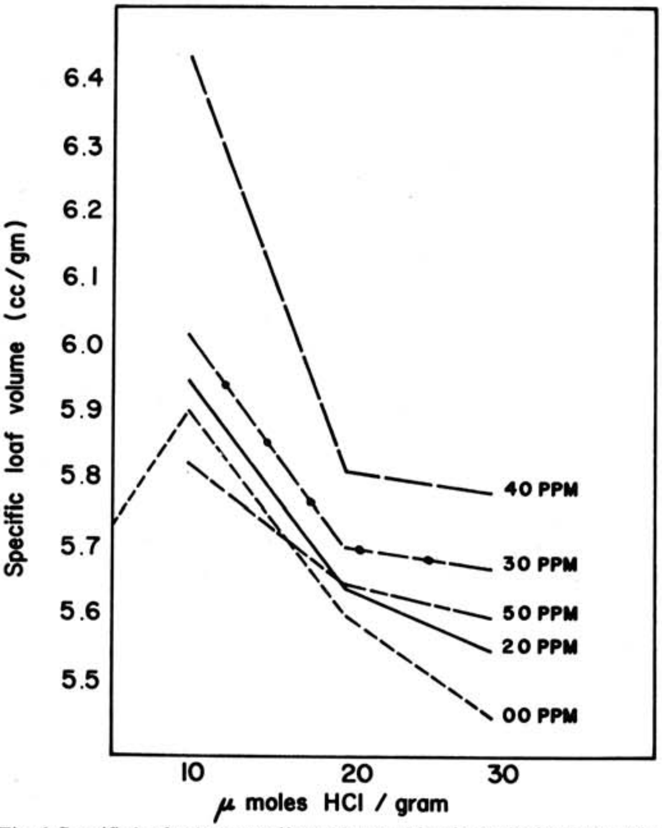

Fig. 6. Specific loaf volume as affected by combinations of acid and cysteine at 2% salt.

in determining the effect of adding more cysteine, a well-known dough reducing agent, in conjunction with salt and acid. Experiments were conducted with a soft wheat flour to provide a system more sensitive to dough-strengthening effects.

Table II indicates that increasing cysteine at any level of acid in doughs made with 2% salt decreased both mixing time and stability. Levels of 30 and 40 ppm cysteine had identical effects on both dough variables. At any level of cysteine, increasing the amount of acid (in the presence of 2% salt) increased mixing time and stability of dough.

Baking results presented in Fig. 6 indicated that at any level of acid, increasing cysteine to 40 ppm increased loaf volume. Increasing cysteine above 40 ppm decreased loaf volume. The increase in loaf volume from adding cysteine up to 40 ppm probably resulted from improved dough extensibility. Above that

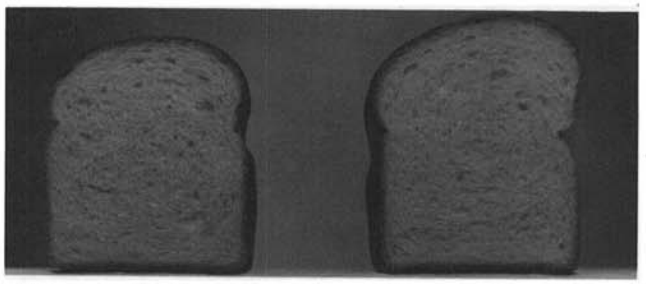

Fig. 7. Loaves baked from soft wheat flour: **left,** control (2% salt); **right,** 10 μm of HCl, 40 ppm cysteine, plus 2% salt.

level, dough becomes slack and more extensible; the cells expand more readily and become porous, lose gas, and finally break. Thus, gas retention and loaf volume decrease.

At any level of cysteine, increasing acid decreased loaf volume, probably because resistance increased and extensibility decreased. Optimum cysteine (40 ppm) gave the largest loaf volumes of all the treatments, regardless of differences in the amount of acid added or dough stiffness. Thus, cysteine required to improve the extensibility of the dough is quite constant regardless of the dough's stiffness or strength. The extent to which extensibility was improved depended on dough strength, which explains why the largest loaf volumes were obtained at 10 μmole of acid with different levels of cysteine (Fig. 6).

Similar results with different cysteine and bromate levels were reported by Henika and Rodgers (1965), who used bromate with cysteine to improve loaf volume and grain quality. Finney et al (1971) also showed improving effects with cysteine in dough.

The best loaf volume and grain quality with short mixing time were obtained with 40 ppm cysteine and 10 μmole of acid (Fig. 7).

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