

# Rheological Changes in Cracker Sponges During Fermentation<sup>1</sup>

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## ABSTRACT

Cereal Chem. 57(3):185-188

The 18-hr cracker sponge fermentation is an important step in conditioning dough for production of good quality crackers. Changes in the physical characteristics of cracker sponges during fermentation were measured by the Brabender extensigraph. Sponges were prepared in a low speed mixer (32 rpm) using a 500-g mixing bowl and fermented in a proof box at 86° F (30° C). The effects of sodium bicarbonate (soda), salt, yeast, mixing time, and pH were evaluated alone and in combination. Dough strength decreased as fermentation time increased. Salt increased dough

resistance to extension, whereas soda and mixing time tended to increase extensibility. Yeast appeared to be responsible for the drop in pH during fermentation. Results with sponges at different pH levels, obtained by addition of lactic acid, showed that the decrease in resistance to extension during fermentation was pH dependent. The lower pH levels appeared to favor the activation of proteolytic enzyme. A pH of 4.0 was optimum for the presumed proteolytic enzyme action.

Commercially, crackers are prepared by a sponge and dough process requiring up to 24 hr. Prolonged sponge fermentation is generally believed to be necessary for the unique textural properties of saltine crackers. Cracker sponge fermentation is undoubtedly important, but the 18-hr fermentation constitutes approximately 75% of cracker production time.

The chemistry of cracker doughs is complex and incompletely understood. Although many attempts have been made to deal with the subject in a practical way, few references in the literature deal with it scientifically (Heppner 1959, Matz 1968, Pieper 1971). Analytical data are helpful in determining the usefulness of a particular flour for cracker production but are not sufficient to reliably indicate which flours will give a good quality finished product (Dunn 1933, Johnson and Bailey 1924).

The purpose of the present investigation was to study physical changes during saltine cracker sponge fermentation as the first and necessary step to understanding what is required of a good quality cracker flour.

## MATERIALS AND METHODS

### Ingredients

Soft wheat flour with 9.2% protein and 0.44% ash on a 14% moisture basis was obtained from Acme-Evans Co., Indianapolis, IN. Compressed yeast produced by Anheuser-Busch, Inc., St. Louis, MO, and a vegetable shortening (Crisco) made from hydrogenated vegetable oil by Procter and Gamble, Cincinnati, OH were used. Other chemicals were reagent grade.

### Equipment

A pin mixer with a 1-lb mixing bowl (National Manufacturing Co., Lincoln, NE) was modified by changing the pulleys to mix at 32 rpm. The fermentation cabinet was also from National Manufacturing Co., Lincoln, NE. Physical tests on cracker sponge were performed with a Brabender Extensigraph from C. W. Brabender Instruments, Inc., South Hackensack, NJ.

### Cracker Formula

The cracker formula (Table I) used in this study was based on Faridi and Johnson's (1978).

### Cracker Dough

All ingredients were scaled on the basis of 500 g of flour and used at room temperature. Yeast was weighed and was dispersed

immediately before use in the amount of water called for in the formula. Sponge temperature was controlled by placing the mixing bowl in a freezer for 7-10 min before mixing to give a sponge temperature of approximately 73° F (23° C).

The sponge ingredients were mixed in a low speed pin mixer using a 500-g mixing bowl. After 2 min of mixing, the mixer was stopped for 1 min, and adhering pieces were scraped from the side of the bowl; mixing was continued for 1 min. After a total of 3 min of mixing, the sponge was transferred to a 2,000-ml beaker covered with a plastic bag previously soaked in hot water. With this procedure, a relative humidity of about 90% was maintained, and after fermentation the sponge had a relatively wet surface with no skin formation. Sponge samples were allowed to ferment at 86° F (30° C).

To facilitate mixing at the dough stage, shortening was the first ingredient placed into the mixing bowl, followed by the previously hand-mixed dry ingredients and the fermented sponge. The dough was mixed for 4 min at 32 rpm in the modified pin mixer. The mixer was then stopped so that adhering dough pieces could be scraped from the side of the bowl; mixing was continued for 1 min.

### Extensigraph

The extensigraph was used to measure changes in the rheology of cracker sponges. Three 150-g test pieces were scaled off from an approximately 500-g sponge. The test pieces were given 20 revolutions in the extensigraph rounder, rolled into a cylindrical shape on the shaping unit, and clamped in lightly greased dough holders. The test pieces in the holders were stored in a humidified chamber for 45 min before being stretched on the extensigraph. The instrument records load extension (resistance to extension) and extensibility.

### pH Determination

The hydrogen ion activity of cracker sponges was determined by placing 15 g of sponge in an 8-oz, wide-mouth glass jar containing 80 ml of distilled water. Ten drops of formaldehyde was added to stop fermentation. The jar was sealed and shaken for 30 min at high speed (200 rpm) in a reciprocating shaker. If necessary, additional shaking was used until the sponge sample had been completely

TABLE I  
Cracker Formula<sup>a</sup>

Ingredients	Sponge (%)	Dough (%)
Flour	65	35
Water	25	...
Yeast	0.4	...
Shortening	...	11
Salt	...	1.8
Soda	...	0.45

<sup>a</sup>Ingredients based on flour weight.

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dispersed. The sample was transferred to a 250-ml beaker with 20 ml of distilled water, and the hydrogen ion activity was determined.

## RESULTS AND DISCUSSION

Preliminary studies showed that both the mixograph and the extensigraph were inadequate to measure rheological changes in cracker doughs because the doughs were too tough. Al-Zubaydi (1975) reported a similar problem when using a farinograph with cracker doughs.

Two alternatives were apparent: to work with cracker sponges or to work with cracker doughs at higher water-to-flour ratios. Because most of the reactions take place during sponge fermentation, we decided to work with cracker sponges. When dough ingredients were added to the sponges after fermentation, the dough flour was always left out; consequently, the cracker sponge water-to-flour ratio was kept constant. After preliminary experiments, the Brabender extensigraph was selected to measure the changes in physical characteristics of cracker sponges. The extensigraph gave much larger differences in the physical properties of doughs as a result of fermentation than did either the mixograph or the farinograph.

Sponges (500 g) were prepared in the pin mixer and fermented in a fermentation cabinet at 86° F (30° C). The effects of fermentation time, soda, salt, yeast, mixing time, and pH were evaluated alone and in certain combinations. Shortening was considered an indispensable ingredient affecting the physical characteristics of doughs; it was therefore used in all doughs. The shortening facilitated the incorporation of dry ingredients added in the second mixing. The effects of adding shortening at the sponge or the dough mixing steps (before or after 18 hr of fermentation) were evaluated.

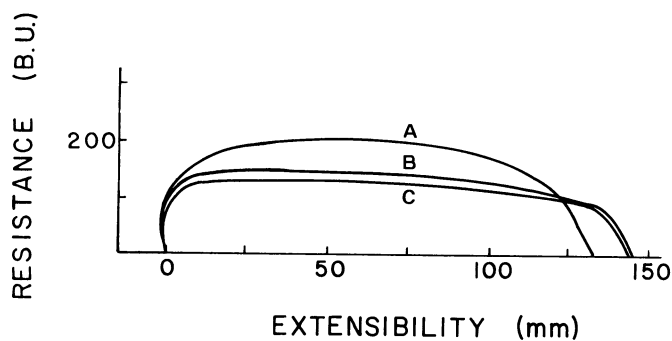


Fig. 1. Effect of dough mixing time on the extensigraph properties of cracker sponges. All doughs had soda and salt added at mixing, 18 hr of fermentation, and a pH of 6.90. Doughs were mixed for: A, 4 min; B, 5 min; C, 6 min.

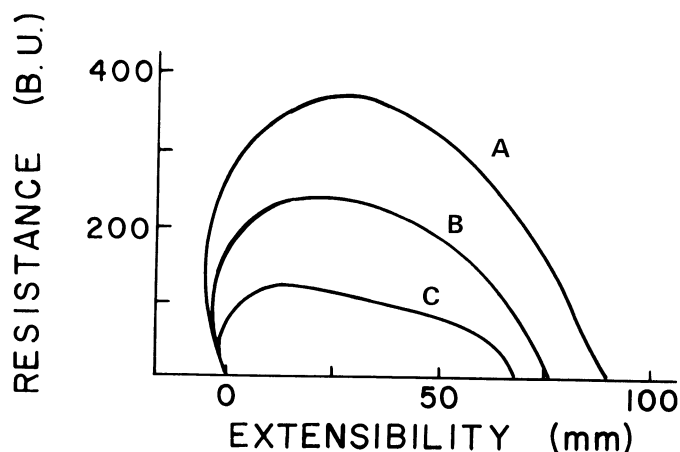


Fig. 2. Effect of fermentation time on the extensigraph properties of cracker sponges. No soda or salt was added. A, 0-hr fermentation, pH 5.35; B, 9-hr fermentation, pH 4.90; C, 18-hr fermentation, pH 4.15.

The extensigrams were very similar, showing that the time at which shortening was added was not a critical factor. Addition of shortening to the sponge did not have any apparent detrimental effect on fermentation. The pH was essentially the same whether the sponge contained shortening or not. Bohn and Bailey (1937) suggested that the effect of shortening on doughs was physical (lubrication).

Extensigrams of cracker sponges (Fig. 1) showed that as mixing time increased, extensibility increased and resistance to extension decreased. The effect was the same in the presence and absence of soda and salt. Mixing clearly had an effect on the extensigraph properties of cracker sponges. Excess mixing was detrimental, causing sticky doughs that were difficult to handle. Optimum mixing time was 8 min (3 min sponge mixing and 5 min dough mixing).

### Effect of Fermentation

Extensigrams showed that as fermentation time increased, the strength of cracker sponges decreased (Fig. 2). After fermentation, the extensigrams showed less resistance to extension and less extensibility, consequently less area or strength. The weakening of cracker sponge could be attributed to many factors, for example,

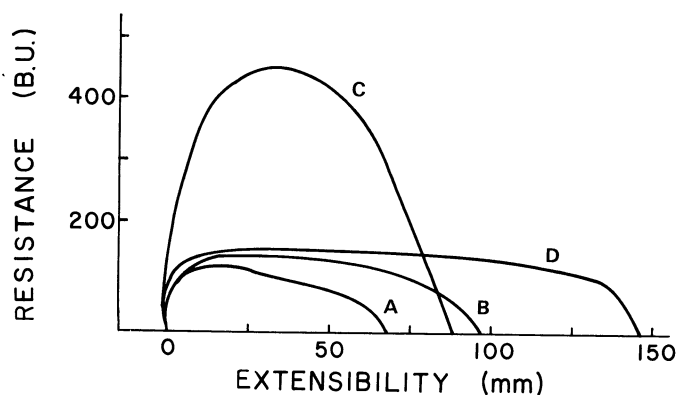


Fig. 3. Effect of addition of soda and salt, alone and in combination, on the extensigraph properties of cracker sponges fermented for 18 hr. A, neither soda nor salt added (control), pH 4.15; B, soda added, pH, 6.90; C, salt added, pH 4.30; D, soda and salt added, pH 6.90.

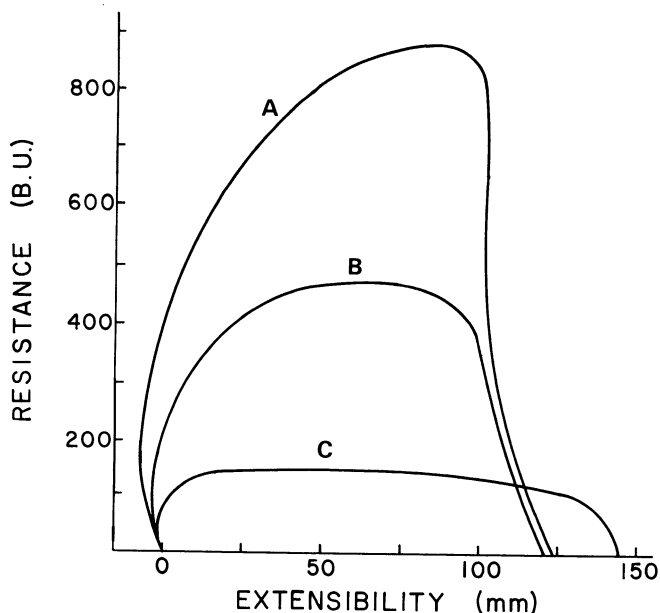


Fig. 4. Effect of fermentation time on the extensigraph properties of cracker sponges. Both soda and salt were added at dough mixing. A, 0-hr fermentation, pH 7.10; B, 9-hr fermentation, pH 7.10; C, 18-hr fermentation, pH 6.90.

the production of organic compounds, mainly acids, during fermentation. The pH of the dough dropped from 5.35 before fermentation to 4.15 after 18 hr of fermentation. The mechanism by which acid could weaken a cracker sponge is uncertain. Acid is generally believed to disrupt gluten structure, however. Researchers have postulated that the breakdown of protein is caused by the cleavage of protein salt linkages by the action of either the hydrogen ion or the anionic acid residue (Bennett and Ewart 1962, Tanaka et al 1967).

### Effects of Soda and Salt

Soda and salt are normal ingredients in crackers. Soda is added at the dough stage to neutralize the acids produced during sponge fermentation and to establish the pH of the finished product. A color too light or too dark is due to lack or excess of soda, respectively. Salt is also added at the dough stage. Besides its seasoning action, it controls yeast fermentation and has a direct effect on dough rheology. The effect of soda or salt and their combination on extensigrams was evaluated (Fig. 3). Soda increased extensibility of cracker sponges, whereas salt mainly increased resistance to extension. The effect of salt is thought to be due to changes in gluten hydration. Bushuk and Hlynka (1964) explained the phenomenon with the concept of "free" and "bound" water, suggesting that salt in a dough system increases the amount of free or mobile water in the system by altering the gluten so that

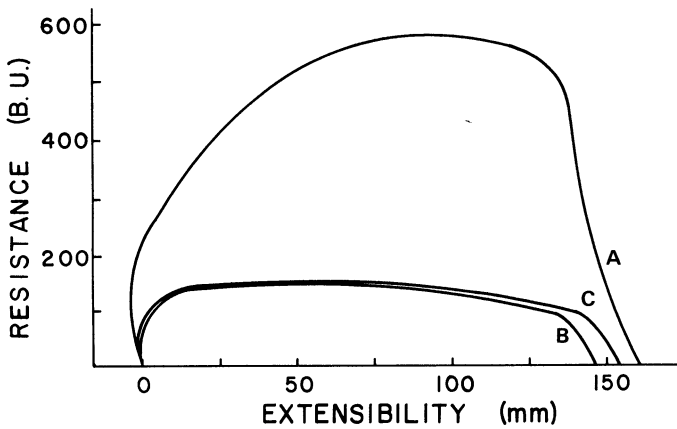


Fig. 5. Effect of different yeast concentrations after 18-hr fermentation on the extensigram properties of cracker sponges. Each dough contained both soda and salt. A, no yeast, pH 7.30; B, normal amount of yeast, pH 6.90; C, twice the normal amount of yeast, pH 6.90.

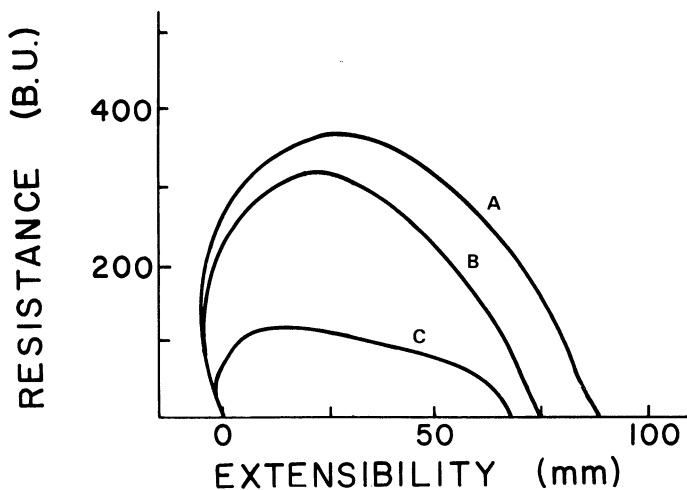


Fig. 6. Effect of pH on the extensigram properties of cracker sponges. No soda or salt was added. A, normal sponge, 0-hr fermentation, pH 5.35; B, normal sponge, 0-hr fermentation, pH adjusted to 4.15 with lactic acid; C, normal sponge, 18-hr fermentation, pH 4.15 after fermentation.

salt occupies the sites once occupied by bound water. Thus the theory explains the toughening or strengthening effect of salt. A theory to explain the effect of salt at low pH has been given by Galal et al (1978). When soda and salt both were added to the sponge, a large increase in extensibility was found (Fig. 3). In addition, the resistance to extension was less than that from the addition of salt alone. Addition of soda had a marked effect on the final dough pH, whereas salt did not affect pH. In general, soda and salt strengthened cracker sponges.

Extensigrams (Fig. 4) in the presence of both soda and salt showed that as fermentation time increased, strength (area) of cracker sponges decreased. Extensigrams presented in Figs. 2 and 4 show that of cracker sponges with the same fermentation time, those containing both soda and salt were always stronger. The effect of different soda concentrations on the extensigrams of cracker sponge was slight in the presence of the normal salt concentration. A small increase in extensibility was observed as soda content increased. Increased salt content, with soda held constant, strengthened cracker sponges, giving extensigrams with more extensibility and more resistance to extension.

### Effect of pH

Extensigrams of cracker sponges prepared with normal yeast content and with twice the normal content were similar (Fig. 5). Extensigrams of cracker sponges with no yeast showed a much greater resistance to extension than did cracker sponges with normal yeast content. The cracker sponge containing no yeast but given an 18-hr "fermentation" (Fig. 5A) showed a large reduction in

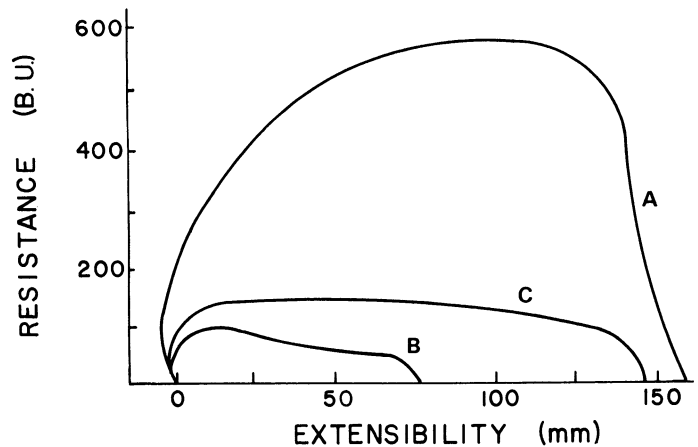


Fig. 7. Effect of pH on the extensigram properties of cracker sponges after 18-hr fermentation. Each dough contained both soda and salt. A, no yeast, sponge pH 5.35, dough pH 7.30; B, no yeast, sponge pH adjusted to 4.15 with lactic acid, dough pH 7.10; C, containing yeast (control).

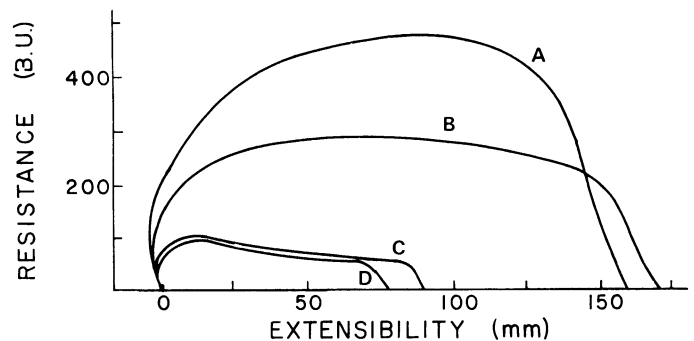
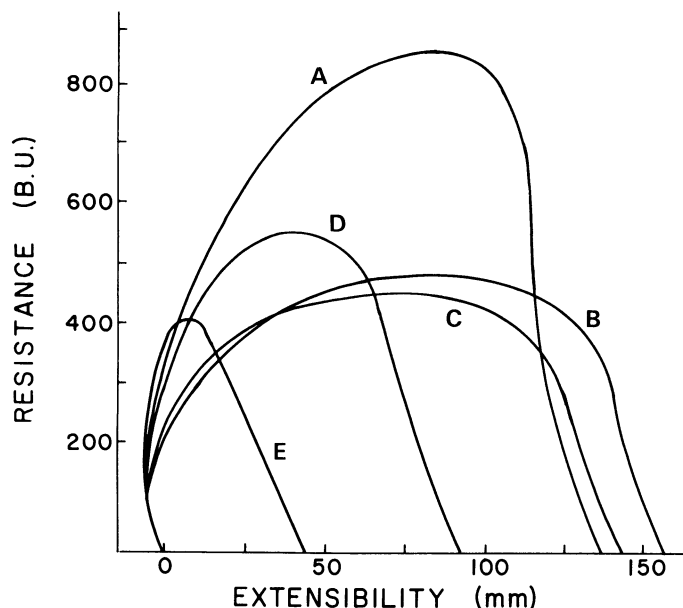


Fig. 8. Effect of "fermentation" time on the extensigram properties of cracker sponges. Sponges contained no yeast and had sufficient lactic acid added to give a pH of 4.15. Each dough contained both soda and salt and had a pH of 7.10. "Fermentation" times were A, 9 hr; B, 12 hr; C, 15 hr; D, 18 hr.



**Fig. 9.** Effect on cracker sponge extensigram properties of 9 hr of "fermentation" at different pH levels. Sponges contained no yeast; both soda and salt were added at dough mixing. The sponge pH levels (with final dough pH level in parentheses) were: **A**, 4.45 (7.35); **B**, 4.15 (7.05); **C**, 3.85 (7.05); **D**, 3.50 (6.45); **E**, 3.00 (3.90).

resistance to extension and a considerable increase in extensibility compared to a cracker sponge with yeast that was not fermented (Fig. 4A). Because the pH of the cracker sponge containing no yeast remained constant at 5.35, the effect was presumably caused by native flour enzymes working on the cracker sponge. Although the effect of enzyme action on cracker sponge rheology was considerable, it was much less than that obtained when yeast was present. Elkassabany and Hosney (1980) have reported evidence of enzyme activity in flour that alters the rheology of dough at a pH optimum of 5.2.

Adjusting the pH of cracker sponges to 4.15 by addition of lactic acid gave extensigrams (Fig. 6) showing that the final pH was not the only factor responsible for changes in extensigram properties. Addition of lactic acid decreased resistance to extension and extensibility slightly. Cracker sponge adjusted to a pH of 4.15 and given no fermentation time (Fig. 6B) had much stronger rheological properties than did the normal cracker sponge fermented for 18 hr to a pH of 4.15 (Fig. 6C), indicating that factors besides pH were working on the cracker sponge.

The effect of lowering the pH to 4.15 and giving the cracker sponge prepared without yeast an 18-hr "fermentation" period is shown in Fig. 7. The "fermentation" time at pH 4.15 had a large effect on the extensigram properties, as shown by the comparison of a sponge at pH 4.15 given no fermentation (6B) and one given 18 hr of "fermentation" (7B). This suggested that the pH-lowering action of yeast brings the sponge to the optimum pH (4.15) of the native proteolytic enzymes of flour, which are then responsible for the rheological changes in cracker sponges. Because the rheological changes were greater at pH 4.15 than with a yeasted system, the next step was to evaluate how long a "fermentation" time was necessary to match the properties of normal sponges. Extensigrams in Fig. 8 show that as "fermentation" time increased, the strength of the cracker sponge decreased. On the other hand, extensibility stayed essentially constant during the first 12 hr but decreased dramatically between 12 and 15 hr of "fermentation."

The final step in this study was an attempt to evaluate the

optimum pH for the presumed proteolytic enzyme activity. Extensigrams in Fig. 9 show that sponges with different pH levels had different extensigram properties. If we assume that the most important function of pH is to promote proteolytic enzyme activity, then the optimum pH is between 3.85 and 4.15. That pH agrees well with the pH of normal cracker sponges and with reports in the literature (Reed 1975) that pH 4.00 is the optimum for native flour proteolytic enzymes. The effect of pH 3.00 on the properties of cracker sponges appears to be a direct effect of acid action rather than of proteolytic enzyme action. This effect occurred immediately after the mixing of cracker sponges and no "fermentation" time was required. Addition of soda to raise the pH did not reverse the acid's action even when it was added immediately after mixing without any "fermentation" time. Also, salt did not strengthen the cracker sponge, again showing that acidic action was not reversible.

## CONCLUSIONS

As fermentation time increases, the pH and the strength of cracker sponge both decrease. Yeast is required and appears to be responsible for the lowering of pH by the production of organic acids during fermentation. The lower pH levels are optimum for native flour proteolytic enzymes. A second enzyme with a pH optimum around 5.2 is possible. Its action is not enough to mellow the cracker sponge in 18 hr, however. Salt has a marked effect, strengthening cracker sponge by increasing resistance to extension. Soda appears to increase extensibility. Mixing has a considerable effect on sponge rheology by increasing extensibility and decreasing resistance to extension up to certain limits. Excessive mixing is detrimental to cracker sponge, however, causing stickiness. Salt plus soda has a synergistic effect, increasing extensibility and strengthening the cracker sponge, although salt alone strengthens cracker sponge more than does salt plus soda.

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[Received August 2, 1979. Accepted December 10, 1979]