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DEVELOPMENT OF A LIQUID STARTER FOR CRACKER SPONGES AND FACTORS AFFECTING CRACKER FLOUR QUALITY

by

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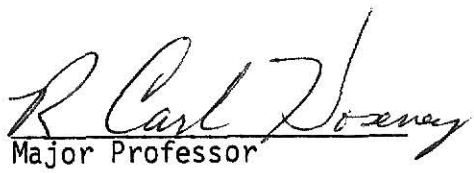

Major Professor

TABLE OF CONTENTS

THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH THE ORIGINAL
PRINTING BEING
SKEWED
DIFFERENTLY FROM
THE TOP OF THE
PAGE TO THE
BOTTOM.

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INTRODUCTION

Bacterial fermentation has been thought to play a vital role in the long time sponges (18 hrs) used in making soda crackers. Attempts to produce crackers using a higher percentage of yeast and shorter sponge time have not been successful. The finished product was different in texture and flavor from those made by the traditional procedure (Micka 1955a).

Soda cracker fermentation may be similar to sour dough bread production where overnight sponges are used. The process is perpetuated by rebuilding a starter (mother sponge) with fresh flour and water. This starter sponge, when developed, serves as an inoculum of microorganisms for subsequent batches of dough (Sugihara et al 1971).

When crackers are produced in a laboratory no starter sponge is kept and sterile equipment is used. Fermentation is greatly retarded under these conditions so that the dough has a high pH and the cracker has an undesirable flavor (Micka 1955a).

When cracker sponges are fermented, significant changes in rheology occur. Strength of the cracker sponge decreases as fermentation time increases and the pH decreases. In recent studies this effect was attributed to a proteolytic enzyme native to the flour. Its optimum activity was believed to be in the 3.8 - 4.15 pH range (Pizzinatto and Hoseney 1980a).

Modification of the gluten proteins is believed to be a necessary part of cracker sponge fermentation. Without proper modification, the dough is difficult to sheet and may not be readily handled by the factory equipment.

Little is known about cracker flour quality. A shipment of flour which is not like previous batches may mean several days work lost. If the product breaks during processing, it must be sold or used as cracker meal.

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REVIEW OF LITERATURE

Cracker doughs are prepared by the sponge and dough process, which covers a twenty-two to twenty-six hr time period (Heppner 1959). The lengthy fermentation is deemed necessary to modify the gluten and to develop the unique flavor and texture of this product (Howard 1956).

Although several reviews on the role of ingredients are available, the chemistry of cracker doughs is very complex and is not fully understood (Pizzinatto and Hoseney 1980a, Heppner 1959, Al-Zubaydi 1975). The cracker formula itself has not been standardized. Matz (1968) gives several formulas for soda crackers and ranges for each ingredient.

Both hard and soft wheat flours are used for crackers. Generally, the type depends upon the location of the bakery. Bakeries in soft wheat areas will use all soft wheat or a combination of hard and soft wheat flour. Those in hard wheat areas may use all hard wheat. Sponge flours are generally stronger than dough flours.

Sponge flours generally have protein contents in the 8.5 to 10.5 percent range, 0.38 to 0.42 percent ash, and 60° to 90° MacMichael viscosity. Dough flours generally have 8.0 to 9.0 percent protein, 0.38 to 0.42 percent ash, and 40° to 60° MacMichael viscosity (Heppner 1959, Johnson and Bailey 1924). Some bakers will use a medium strength flour for both the sponge and dough. Flours differ in their behavior during fermentation so the process must be carefully monitored (Heppner 1959).

According to Micka (1944), cracker flours are usually blended. Typically, two brands are blended for the sponge and one or two for the dough. Nearly every cracker baker uses different criteria for blending; some use origin of the wheat, while others use protein content. Little uniformity exists so that blends are made based upon preference, past

experience, or for some other reason.

Testing the performance of flours for cracker-making has received attention in the literature (Dunn 1933, Bohn 1934, Micka 1934, Bohn 1935, Reiman 1936, Reiman 1938, Brown 1939, Simmons 1940, Simmons 1941, Loving 1942, Tarnutzer 1942, Hanson 1943a, Hanson 1943b, Micka 1955b). Dunn (1933) attempted to develop a procedure for the production of experimental crackers to test flour quality. He found that crackers from the same batch varied widely in quality, and concluded that commercial crackers could not be produced in a laboratory.

Other investigators collected analytical data to help predict the usefulness of cracker flours. Tarnutzer (1942) reported that ash analyses and hydrogen ion concentration were not useful in predicting utility of a given flour. Protein content and viscosity seemed to be statistically significant as a measure of flour quality.

Bohn (1935) indicated that viscosity was related to strength as determined by shop practice. Baking small loaves of bread was found to be valuable in testing flours for cracker use, specially when used in combination with the acidulated viscosity test (Bohn 1934, Bohn 1935, Reiman 1936, Reiman 1938, Simmons 1940, Simmons 1941, Tarnutzer 1942).

Brown (1939) questioned the usefulness of bread baking tests to predict flour performance. He found that the quality of crackers was more dependent upon the type of sponge flour than the type of dough flour used in the formula. Loaves of bread baked from the same flour in different laboratories did not resemble one another.

Micka (1955b) investigated the utility of bread baking tests in evaluating cracker flours. He found a positive relationship between

bread volume and the volume of commercially baked soda crackers. The relationship held for flours milled from various wheat varieties, except for hard red spring wheat flours. Hard red spring wheat flours produced bread with large volume, but soda crackers with low volume and lacking tenderness.

In other studies, Micka (1955b) investigated the interrelationship of relative soda cracker volume, tenderness, bloom, and flour apparent viscosity. Very tender crackers could be baked from flours of low apparent viscosity, milled from either winter or spring white wheat. However, those crackers lacked volume (oven spring) and bloom. Crackers of good volume and bloom could be produced from flours of relatively high apparent viscosity, milled from either soft or hard winter wheat, but those crackers lacked tenderness. Flours with very high apparent viscosities gave hard, flinty crackers.

Studies by Micka (1958) concerning the effect of flour aging on the quality of soda crackers were inconclusive. Laboratory tests for cracker flours were only of limited value because the commercial processing of soda crackers involves many variables which can't readily be duplicated, under laboratory conditions. Bloom was found to be the most important factor for evaluating the quality of the finished product.

MATERIALS AND METHODS

Ingredients

Two flours were used in the preparation of slurries: KSU flour (12.1% protein, 0.46% ash) and Ross flour (11.6% protein, 0.46% ash). Eleven different flours obtained from commercial cracker producers were used for cracker sponge production, physical dough tests, and cracker baking. The flours were supplied by Nabisco, Keebler, Sunshine, Frito-Lay, Bremmer, and Lance. All flours had protein contents in the 8.6 - 11.5% range, and 0.4 - 0.59 % ash (Table 1).

Compressed yeast from Anheuser-Busch, St. Louis, Missouri was used. The yeast was aged three weeks at 4°C before use. Hydrogenated vegetable shortening (Crisco, Proctor & Gamble, Cincinnati, Ohio) was used in sponges prepared for physical dough tests. Lard (Armour, Phoenix, Arizona) was used in cracker doughs prepared for baking tests. Sodium dodecyl sulfate (99% pure) was obtained from Polysciences, Warington, PA. Tenox (20% BHA, 20% BHT, 60% corn oil) was obtained from Eastman Kodak, Kingsport, Tennessee. All other chemicals were reagent grade.

Slurry Preparation

All ingredients were mixed by hand. Flour to water ratio was varied with a 1:2 ratio being used for most experiments. Yeast was used at 0.62% of the flour weight. In some slurries, sucrose was added at 1, 2, or 3% based on the flour weight.

All slurries were fermented uncovered for 18 hrs at 30°C with 90% relative humidity in a proof cabinet (National Mfg., Lincoln, Nebraska). A feed of flour or sucrose was then added and the slurries given a second 18 hr fermentation.

Table 1. Specifications of Commercial Cracker Flours

Commercial Cracker Flour	Protein (%)	Moisture (%)	Ash (%)
1	8.6	14.1	0.45
2	9.7	14.7	0.45
3	8.6	12.3	0.46
4	11.5	14.1	0.52
5	9.5	13.0	0.59
6	10.0	13.7	0.53
7	9.4	13.4	0.39
8	9.9	13.1	0.43
9	10.3	12.6	0.56
10	9.6	13.6	0.51
11	9.8	13.4	0.48

Hydrogen ion activity was measured directly (no dilution) with a Beckman Expandomatic IV pH meter. Titratable acidity was measured by dispersing 15 g slurry in 85 ml distilled water and titrating with 0.1253 N NaOH to a phenolphthalein endpoint.

To test the effectiveness of the slurries in lowering the pH of sponges, slurries were used at 5, 10, and 15% of the total sponge weight in a cracker formula from Faridi-Araghi (1975) and Pizzinatto and Hoseney (1980b). Flour and water were removed from the sponge formula to compensate for the flour and water present in the slurry. Sponges were mixed by hand, placed in greased 250 ml beakers, and fermented uncovered in a proof cabinet for 18 hrs at 30°C and 90% relative humidity.

Samples were prepared for pH determination by blending 15 g of sponge with 85 ml distilled water for one min at high speed in a Waring blender. Hydrogen ion activity was measured with a Beckman pH meter.

Slurries were stored in a refrigerator at 40°F. Once a week 20% flour based upon slurry flour weight was added and the slurry fermented 18 hrs at 30°C, 90% relative humidity and then refrigerated for further use.

Cracker Sponge and Dough Preparation

Cracker sponges used for viscosity tests and rheological tests were prepared based upon the formula given in table 3. The slurry for these sponges was prepared by fermenting flour, water, yeast, and sucrose (100:200:0.62:3.0) for 18 hrs, adding 20% flour, based on sponge flour weight, and fermenting an additional 18 hrs.

Sponges were mixed 2 min, followed by scraping and an additional one min of mixing. The mixer used was a pin mixer with 1 lb. mixing bowl from National Mfg., Lincoln, Nebraska. Speed was modified to 32 rpm by changing pulley size. Sponges were transferred to lightly greased

Table 2. Cracker Formula

Ingredients[a]	Sponge (%)	Dough (%)
Flour	65	35
Water	25	--
Yeast	0.4	--
Shortening	--	11
Salt	--	1.8
Soda	--	0.45

[a]Ingredients based on flour weight

Table 3. Modified Cracker Formula Including Slurry

Ingredient[a]	Sponge (%)	Dough (%)
Flour	63.50	35
Water	22.00	--
Yeast	0.36	--
Slurry[b]	4.52	--
Shortening	--	11.0
Salt	--	1.8
Soda	--	0.45

[a] Based on flour weight

[b] Slurry is 5% of total sponge weight

1000 ml beakers. They were covered with a plastic bag and fermented for 18 hrs at 30°C and 90% relative humidity.

At the dough mixing stage, shortening was placed in a bowl followed by the soda, salt, and the fermented sponge. The last 35% of the flour (dough flour) in the formula was not added. Sponges were given 4 min mixing followed by scraping and an additional one min mixing.

Viscosity Determination

Sponge preparation. Sponges were prepared as described above from eight commercial cracker flours. For each flour 2 sponges were prepared; one was given no fermentation while the second was fermented 18 hrs. Following mixing, all sponges were frozen and lyophilized, then stored at 4 °C.

Protein extraction. A one gram sample of each lyophilized sponge was weighed into a small beaker, and 30 ml of 1% (w/v) SDS added. The mixture was stirred gently for two hrs at room temperature (25°C) on a magnetic stirring plate, then transferred to centrifuge tubes. The mixtures were centrifuged 10 min at 10,000 x g (25°C). The supernatant was decanted to another tube and recentrifuged 20 min at 17,000 x g, 25°C (Danno and Hoseney 1982). Flour of known protein content was extracted in the same manner to generate a standard curve.

Protein determination. The clear supernatant from centrifuging was diluted 1:20 with 1% (w/v) SDS. Protein was determined by the Lowry method (Lowry et al 1951). Solutions were diluted to 1.5 mg/ml protein with 1% SDS for viscosity measurement.

Viscosity measurement. Viscosities of extracts were determined by measuring flow time in a Connon-Fenske capillary flow viscometer (size 50).

For each measurement, 5 ml of extract was placed in the tube and allowed to equilibrate 5 min in a constant temperature bath set at 31°C. The sample was drawn up and flow time through the capillary was recorded. The relative viscosity from the mean of three determinations was calculated.

Rheological Measurements

Extensigraph. A Brabender extensigraph was used to measure the rheological characteristics of fermented sponges. The sponges had all dough ingredients except the last 35% flour (dough flour) added. Three 150 g test pieces were scaled from each 500 g sponge. The test pieces were given 20 revolutions in the extensigraph rounder, moulded into a cylindrical shape, then clamped in dough holders. After a 45 min rest period in a humidified chamber, dough pieces were tested. The instrument records resistance to extension and extensibility.

Mixograph studies. A National Mfg. 10 g. mixograph was used to study changes in the strength of fermenting sponges. Sponges were given 0, 2, 3 and 4 hrs fermentation. Dough ingredients were not added. Fifteen grams of sponge was placed in the mixograph bowl along with enough water to bring the sample to 58% absorption. Samples were mixed for 8 min.

Instron studies. An Instron Universal Testing Machine was used to study rheological characteristics of fermenting dough. Sponges were prepared as for the extensigraph studies. Fifty gram dough samples were run through sheeting rolls twice, set at 3/8" gap. The sheeted samples were placed on an aluminum foil-lined cookie sheet, then covered to prevent drying. Samples were transferred to the Instron by cutting the foil around each dough piece.

The test procedure used in this study was based upon a stress-relaxation method described by Peleg (1979). The Instron was run in the compression mode using a 2000 g load cell with a flat plunger having 3.5 cm diameter base. Samples were compressed 1/2", the crosshead was halted, and decay was allowed to proceed for 5 min. Force readings were taken at 0.5 min intervals. Data was normalized into straight line for analysis.

Cracker Baking

Crackers were baked from doughs prepared from the modified cracker formula shown in Table 3. Lard was used instead of hydrogenated shortening at the dough-up stage. Soda was increased to 0.75%. Sponge and dough mixing was the same as for rheology and viscosity tests. The fully mixed dough was given a 6 hr fermentation, so that total fermentation time was 24 hrs.

After fermentation, the dough was flattened by hand into a rectangularly shaped frame (3-1/2 x 11 x 1"), giving the dough piece uniform thickness. This dough piece was cut in half prior to sheeting given 2 pieces 3-1/2 x 5-1/2 x 1" each. The dough was sheeted by passing 10 times through the rolls of an Anets pie-sheeter. The dough was gradually reduced in size from an initial thickness of 25 mm (1") to 0.30 mm (0.076") final thickness. During the first four passes, the dough was reduced from 25 mm to 5.65 mm (0.225") by passing through the following sheeter openings: 16.12 mm (0.635"), 12.30 mm, (0.485"), 9.50 mm (0.375"), and 5.65 mm (0.225"). At this point, the dough was folded upon itself in the direction of its length, and was passed through the 5.65 mm setting. After a reduction to 2.88 mm (0.114"), the dough was folded upon itself

again and passed through rolls set at 2.88 mm. After a pass at 1.25 mm (0.050"), the dough was folded upon itself and turned 90° prior to a second pass at 1.25 mm. The final reduction of the dough was to 0.30 mm (0.076").

The sheeted dough was placed on cookie sheets and covered on all sides with bakery parchment paper to prevent drying. The sheeted doughs were cut with a small cutter-docker having 21 cells (7 x 3) of 52 x 48 mm each. The sheeted dough was placed onto the cutter-docker which was inverted with pins and cutting edges exposed. A rolling pin was used to press the dough onto all of the pins. The dough piece could be visually inspected to ensure complete cutting.

After docking, the cutter-docker was inverted and the dough piece was released onto a pressed board 9 x 17 x 1/4". The board served as a support for the dough so that it could be transferred to the oven onto a pre-heated baking sheet. An expanded metal sheet (gauge 20-22) measuring 8-1/2 x 17" with 3" legs was used for baking. The sheet was heated for one min at 510°F. The cut and docked crackers were slid from the pressed board onto the heated sheet for baking. Crackers were baked approximately 3' 15" having the oven door open the last 20 seconds to control browning. A 1/2-3/4" border of dough was left to prevent the cracker edges from over-browning.

Baked crackers were cooled on metal racks at room temperature for about 30 min. They were stored overnight in plastic bags, then broken into individual crackers. Ten representative crackers were selected and measured for stack height and weight. Height was determined using a dial caliper manufactured by Mitutoyo.

RESULTS AND DISCUSSION

Slurry

Slurries with flour to water ratios of 1:4, 1:3, and 1:2 had similar drops in pH over an 18 hr fermentation period. However, quality of all slurries prepared without yeast deteriorated by developing an intense odor. Slurries with the same flour to water ratios as above but containing yeast were stable, and gave lower pH (Table 4).

In all cases, the most rapid drop in pH occurred during the first nine hrs of fermentation. According to Micka (1955a), the growth of acid-producing bacteria proceeds rapidly during the first ten hrs of fermentation, then slows as the nutrient supply is exhausted. The data generated in this experiment supports that theory (Fig. 1).

Because the flour to water ratio made relatively little difference in the pH after fermentation, the slurry with a 1:2 flour to water ratio, plus yeast, was chosen for use based upon consistency and ease of incorporation into the sponge. Sponges were inoculated at the 5, 10, and 15% level (sponge weight basis) and change in pH during fermentation was noted (Table 5).

Although significant drops in sponge pH occurred, the final pH was not in the 3.8-4.15 range which is typical for a cracker sponge. Presumably, the nutrient supply was exhausted and a new source needed to be added to the slurry.

Slurries which had readily fermentable nutrients added after the 18 hr fermentation were given a second 18 hr fermentation. This resulted in lower slurry pH's. Sponges produced from these slurries reached a pH in the desired range (Table 6).

Table 4. Changes in pH During 18 hr Fermentation of Slurries

Slurry (Flour:H_2O)	Initial pH	Final pH
1:4	6.10	4.35
1:3	6.10	4.55
1:2	6.05	4.35
1:4, Yeast	6.05	3.93
1:3, Yeast	6.09	4.00
1:2, Yeast	6.05	4.25

Figure 1. Change in pH as a function of time for fermenting slurries.

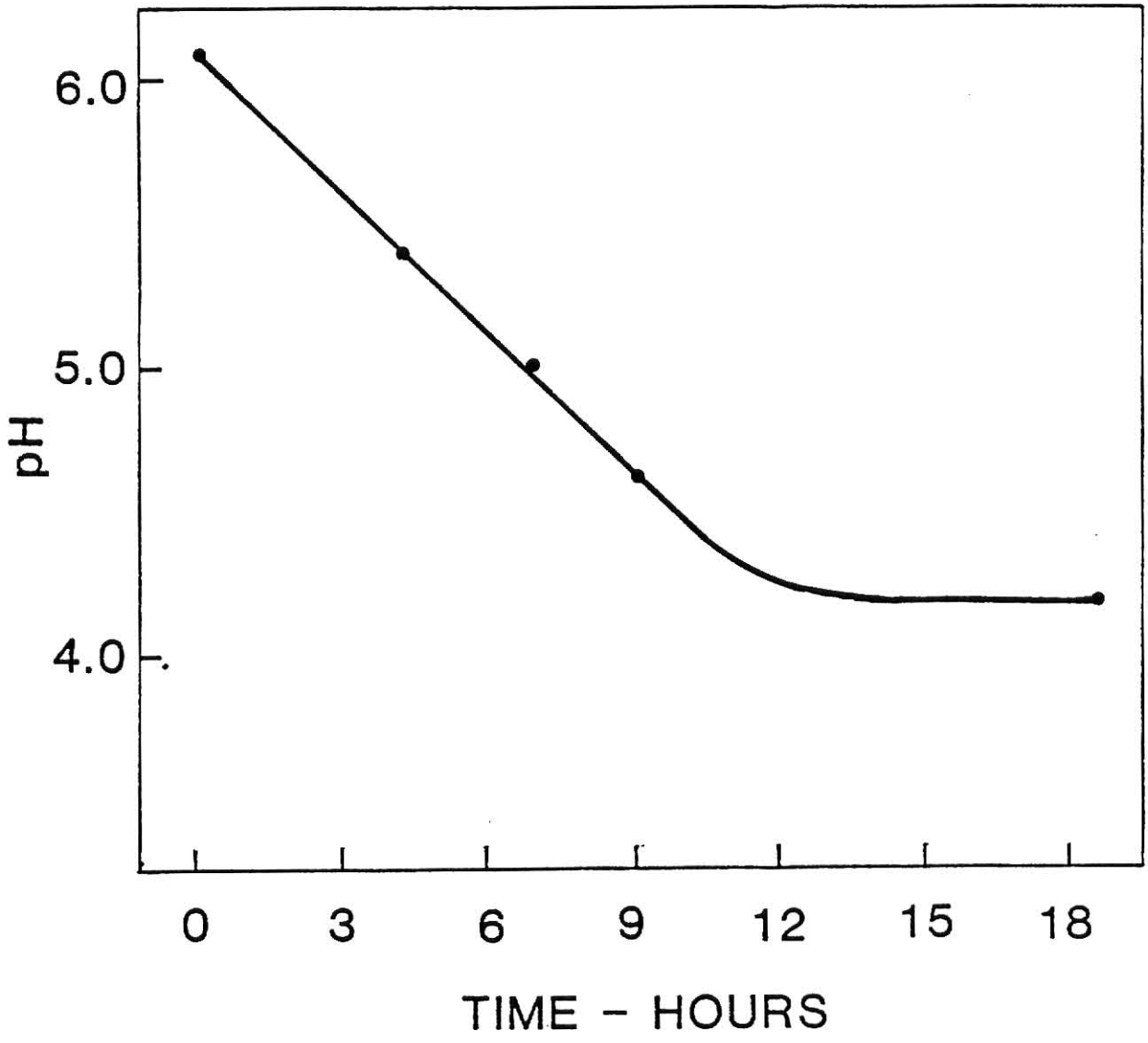

6.0
5.0
4.0
pH
0
3
6
9
12
15
18
TIME - HOURS

Table 5. Effect of Inoculum on Sponge pH During 18 hr Fermentation

Sponge	Initial pH	Final pH
Control	6.15	5.10
5% Inoculum	6.03	4.38
10% Inoculum	5.90	4.27
15% Inoculum	5.80	4.20

Table 6. pH of Slurries and Sponges After 18 hr Fermentation

		pH
Slurries:	25% Flour	3.85
	50% Flour	3.92
	25% Sucrose	3.72
	50% Sucrose	3.75
Sponges:	5% Sucrose Slurry	3.95
	10% Sucrose Slurry	3.80
	5% Flour Slurry	3.95
	10% Flour Slurry	3.95

Since both sucrose and flour were effective in lowering slurry and sponge pH, attempts were made to determine the least possible amount of nutrient to be added to the slurry. All levels of sucrose added to the slurries showed similar results (Table 7). Slurries with a pH below 3.65-3.70 had undesirable odors and were not suitable for further experimentation. It is possible that the lactic acid bacteria stopped acting and putrefactive bacteria took over at the low pH. Putrefactive bacteria could be responsible for the odors.

To determine whether the type of nutrient added affects putrefaction, sucrose, and flour were added to slurries. Amount of fermentable carbohydrate added to each slurry was equal. Differences in final pH were noted, yet no difference in total titratable acidity appeared (Table 8). The slurries with sucrose added as a nutrient source has a putrid odor while those with flour did not. This suggests that flour has a buffering effect on the system and keeps it out of the pH range where putrefactive bacteria become active.

When a new flour source was used, slurry and sponge pH shifted to higher levels. This suggested that fewer fermentable carbohydrates were present. Small amounts of sucrose were then added to the slurry before fermentation to compensate for that difference. After the 18 hr fermentation and addition of nutrient (20% flour) with a second fermentation, differences in pH were noted. Greater amounts of sucrose added resulted in lower slurry and sponge pH (Table 9).

Since slurries with 2% sucrose reached a pH near that where putrefactive bacteria appear to be active, the slurries with 0.5% or 1.0% sucrose should be used with that flour. When a new shipment of the same flour

Table 7. Effects of Sucrose on Slurry and Sponge pH After 18 hrs Fermentation

Sucrose Level[a] (%)	Slurry pH	Sponge pH
25	3.55	4.02
12.5	3.50	3.98
6.25	3.52	4.10
3.0	3.55	3.98

[a] Based on flour weight

Table 8. Effect of Nutrient Source on pH and Total Acidity After 18 hrs Fermentation

Slurry	pH	Titratable Acidity (meq/ml)
20% Flour	3.82	1.14×10^{-2}
6% Sucrose	3.65	1.14×10^{-2}

Table 9. Effects of Sucrose Added to Flour on Slurry and Sponge After Fermentation

Slurry	pH	Sponge pH
0% Sucrose	3.98[a]	
20% Flour	3.92[b]	4.13
0.5% Sucrose	3.98[a]	
20% Flour	3.85[b]	3.93
1.0% Sucrose	3.90[a]	
20% Flour	3.75[b]	3.92
2.0% Sucrose	3.85[a]	
20% Flour	3.70[b]	3.90

[a]pH after first 18 hrs

[b]pH after second 18 hrs

was used, it was necessary to use 3% sucrose to get the desired slurry pH. The slurry containing 3% sucrose gave sponge pH's in the desired range for all cracker flours.

When slurries reach a pH in the 3.75-3.90 range, sponges reach a pH between 3.8-4.15. Thus, use of a slurry seems to be an effective means of producing cracker sponges with sterile equipment or without a starter sponge.

Viscosity

In recent studies, changes in the rheology of fermenting cracker sponges were attributed to a proteolytic enzyme native to the flour. Its optimum activity was in the 3.8-4.15 range (Pizzinatto and Hoseney 1980a).

Subsequent studies tend to support this theory since proteases have been found active at the low pH's. Kawamura and Yonezawa (1982) found that changes in gluten proteins were stopped with known enzyme inhibitors.

If proteins are cleaved by a proteolytic enzyme, extracts from fermented sponges should have lower relative viscosity. Therefore, viscosity was used to measure changes in the proteins.

Extracts of the doughs varied greatly in protein concentration so that dilution to 1.5 mg/ml was necessary. About 90% of the total nitrogen was extracted from the sponges, while 93% was extracted from the flour used to generate a standard curve.

Results of viscosity tests are presented in Table 10. Six of the eight flours exhibited a decrease in viscosity as a result of fermentation. This would tend to support the theory that a proteolytic enzyme is acting at the low pH during fermentation to cleave some of the peptide bonds.

Table 10. Effect of Fermentation on the Viscosity of SDS Extracts from Cracker Sponges

Commercial Cracker Flour	Fermentation (hrs)	Relative Viscosity
1	0	1.262 ± .004
	18	1.202 ± .010
2	0	1.105 ± .009
	18	1.164 ± .006
3	0	1.159 ± .004
	18	1.136 ± .008
4	0	1.142 ± .012
	18	1.158 ± .002
5	0	1.164 ± .008
	18	1.125 ± .001
6	0	1.166 ± .005
	18	1.059 ± .006
7	0	1.176 ± .006
	18	1.106 ± .006
8	0	1.177 ± .011
	18	1.069 ± .003

However, the viscosity of extracts from two of the flours increased after fermentation. This suggests that our theory regarding the action of a proteolytic enzyme is wrong. It is also possible that the theory is correct, but more than one phenomenon was occurring during the 18 hour fermentation of the sponge, perhaps for all flours. The increase in viscosity could have been the result of oxidative gelation, which has long been known to occur in flour water solubles (Durham 1925).

In a bread system yeast is known to create protein thiyl radicals. These thiyl radicals can add to the activated double bond of ferulic acid which is esterified to an arabinoxylan portion of a pentosan. The linkage creates a high molecular weight, crosslinked entity which imparts an increase in viscosity to the water soluble fraction. This phenomen is referred to as oxidative gelation (Hoseney and Faubion 1981).

Since the pH of a cracker sponge is the same range as that of bread during the early hrs of fermentation, it is possible that oxidative gelation occurs. As the pH drops during fermentation the yeast becomes inactive, and the proteolytic enzyme begins to act. An increase or decrease in viscosity might result depending upon which phenomenon was the strongest.

To test that theory, doughs were treated with ferulic acid. Adding ferulic acid has been shown to stop the increase in viscosity caused by oxidative gelation (Hoseney and Faubion 1981).

Addition of ferulic acid (200 to 300 ppm) did result in decreased viscosity of the extracts. This suggests that the proteolytic enzyme was active in the sponge, but the effect of the enzyme was overshadowed by oxidative gelation (Table 11).

The effects of fermentation at the optimum pH for the enzyme were studied. The pH of a sponge prepared without yeast was dropped to

Table 11. The Viscosity of SDS Extracts of Sponges Containing Added Ferulic Acid

Ferulic Acid (ppm)	Fermentation (hrs)	Relative Viscosity
0	0	1.105
0	18	1.164
200	18	1.109
250	18	1.098
300	18	1.080

4.1 by addition of lactic acid and allowed to "ferment" for 18 hrs. Viscosity was compared to the same flour at zero and 18 hrs of fermentation with yeast. A significant reduction in viscosity was noted for the pH modified sponge (Table 13). This further supports the theory that a proteolytic enzyme is acting at a pH near 4.1, and is responsible for changes in viscosity.

Rheology

Studies by Pizzinatto (1978) indicated that the extensigraph could be used as a tool to study rheological changes in fermenting dough. The extensigraph reveals changes in resistance to extension and extensibility but does not show changes in elasticity. Since elasticity is an important property that cracker doughs possess, a test was sought to measure changes in the elasticity of the dough during fermentation.

Several sources in the literature suggested stress-relaxation models to define and describe changes in the elasticity of dough (Glucklich and Shelef 1962). Peleg (1979) described a stress-relaxation method to measure viscoelastic properties of solid foods using an Instron Universal Testing Machine. Food samples were compressed and allowed to relax following deformation. When the resultant curves were normalized into straight lines, an elastic solid would appear as a vertical line while an inelastic material would appear as a horizontal line along the x-axis. Rate of relaxation could be determined by slope of the line.

Cracker sponges were tested according to the method described by Peleg in an attempt to measure changes in elasticity after fermentation. Plots of normalized data show that the relaxation rates of sponges fermented zero, 6 and 18 hrs did not differ (Fig. 2). Increasing crosshead speed had no effect on the rate of relaxation (Figs. 3, 4, 5).

Table 12. The Viscosity of SDS Extracts of Sponges Set at Different pHs

Flour #1	Fermentation (hrs)	Relative Viscosity
Regular Sponge	0	1.262
Regular Sponge	18	1.202
Acid-Adjusted pH	18	1.119

Figure 2. Effect of fermentation time on the relaxation rate of cracker sponges. Sponges were fermented zero (·), 6 (▲) and 18 (x) hrs. Crosshead speed was 5 cm/min.

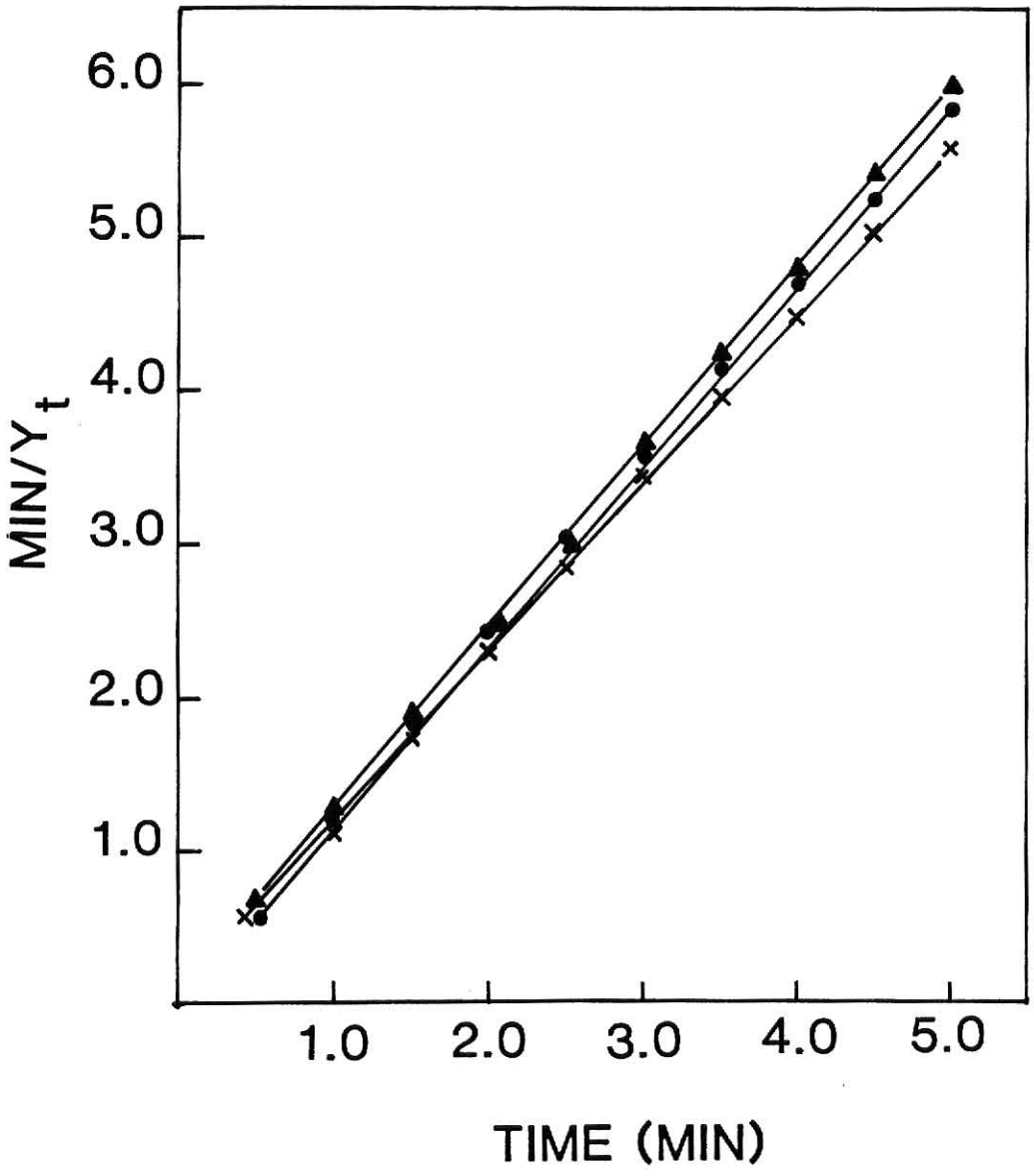

6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y t
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 3. Effect of fermentation time of the relaxation rate of cracker sponges when crosshead speed was increased to 10 cm/min. Sponges were fermented zero (·), 6 (▲) and 18 (x) hrs.

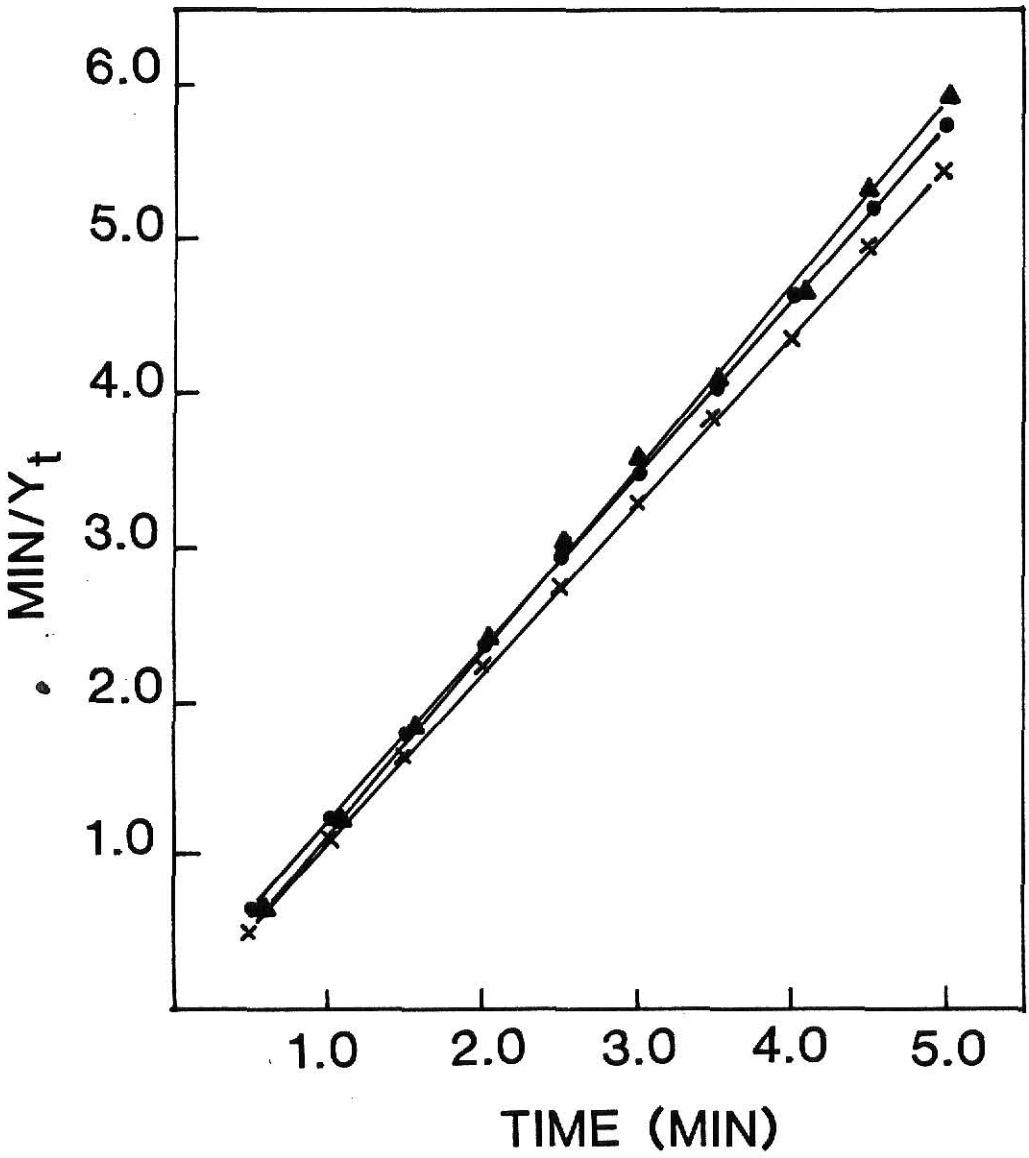

6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y$_t$
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 4. Effect of fermentation time of the relaxation rate of cracker sponges when crosshead speed was increased to 20 cm/min, sponges were fermented zero (·), 6 (▲) and 18 (x) hrs.

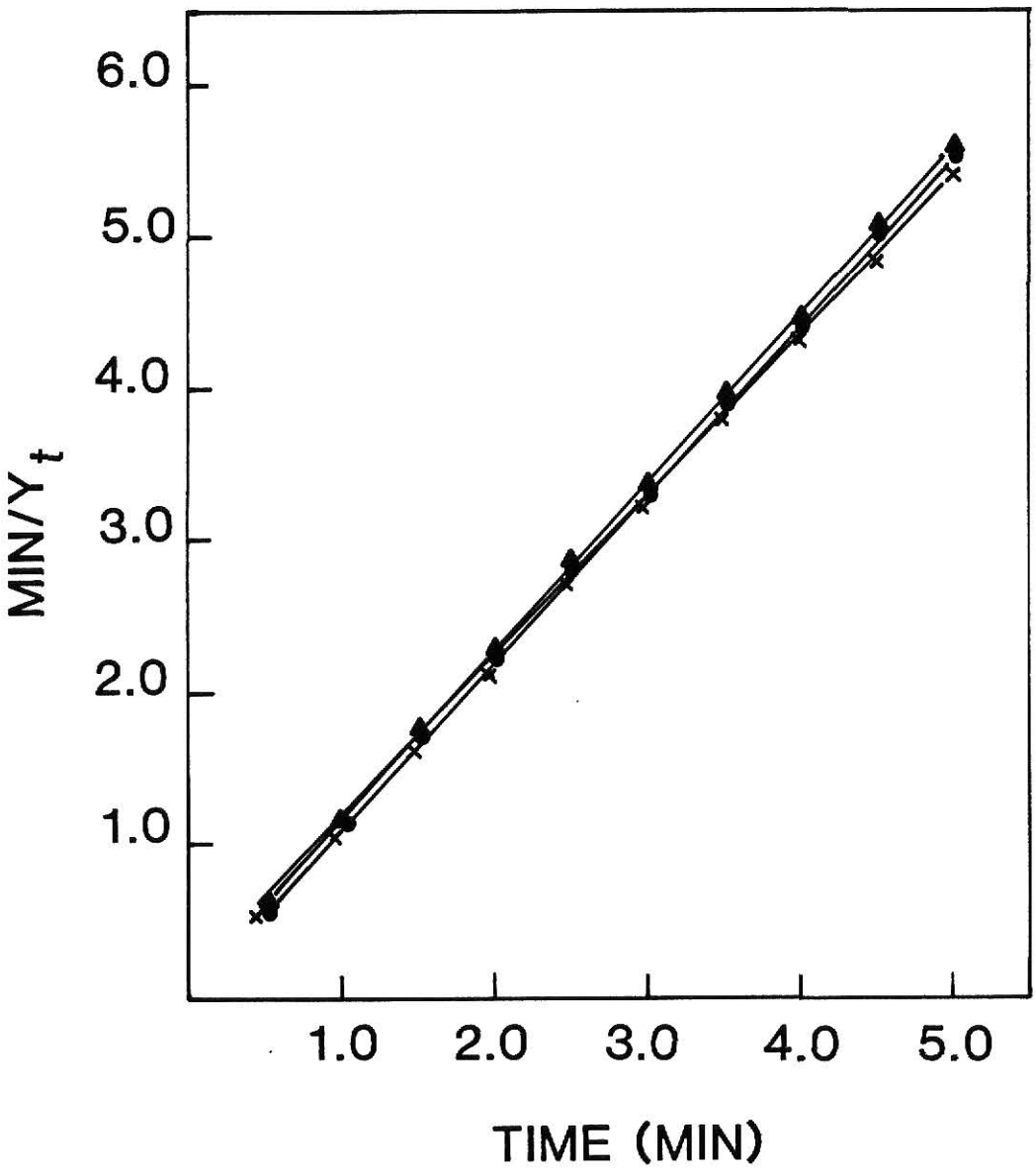
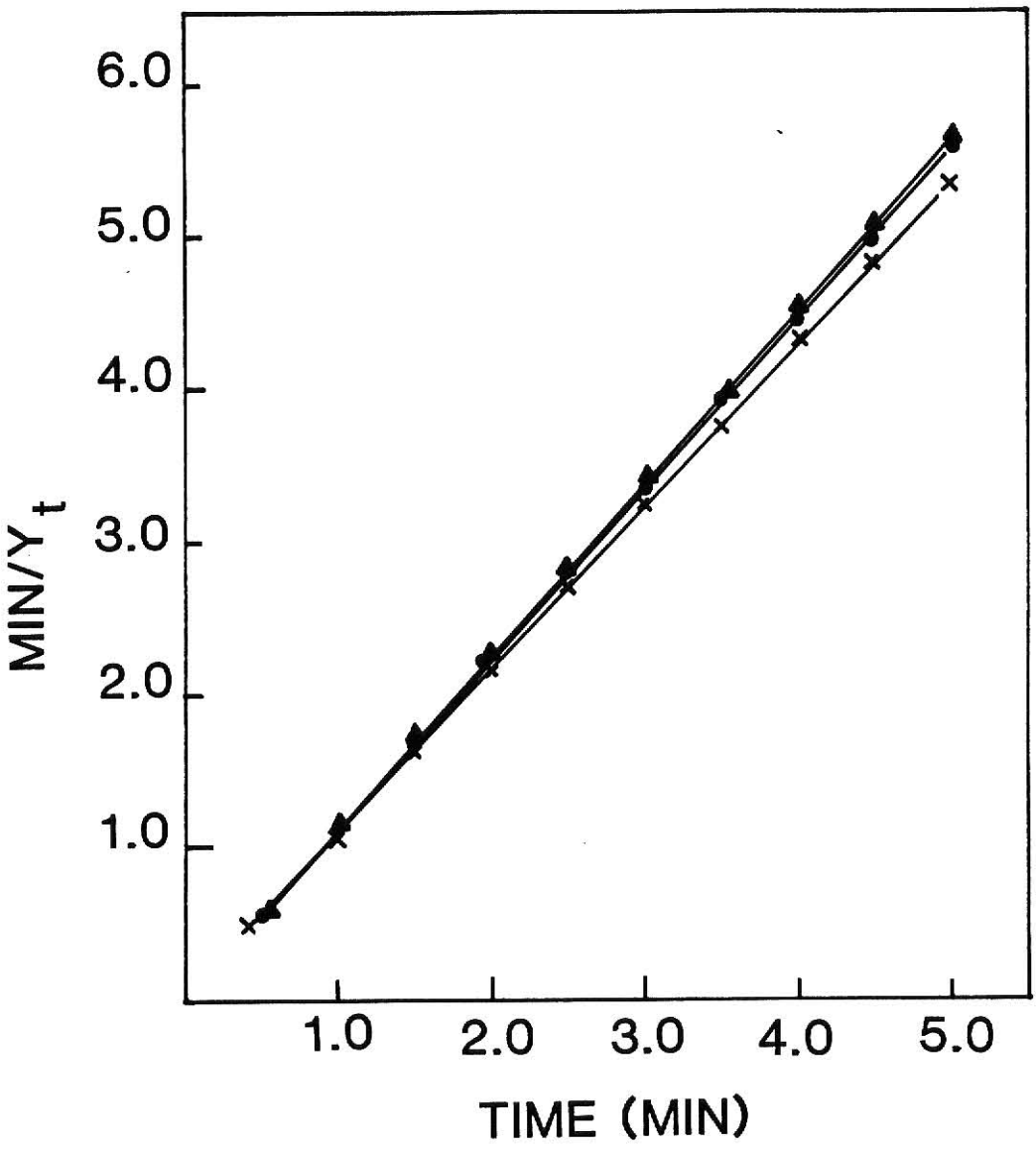

6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y$_t$
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 5. Effect of fermentation time of the relaxation rate of cracker sponges when crosshead speed was increased to 25 cm/min. Sponges were fermented zero (·), 6 (▲) and 18 (x) hrs.


6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y$_t$
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Sponges tested after a short fermentation period did not differ from nonfermented samples (Fig. 6). Fermenting 4 hrs in the presence of acid had no effect on the relaxation rate (Fig. 7). Samples which were made up into doughs after 0, 2, 4, and 6 hrs fermentation had similar relaxation rates (Fig. 8).

Since relaxation rates for all samples were similar, and lines were congruent in most cases, little could be learned about differences in elasticity. The usefulness of this test procedure was questioned and it was abandoned.

Although a test to study elastic properties of fermenting doughs was not found, studies on changes in the dough's physical properties were still pursued. The extensigraph was chosen since it had been shown useful for studies on cracker sponges (Pizzinatto 1978, Faridi-Araghi 1975). The mixograph was chosen as well based upon its usage in bread systems.

Results of extensigraph studies on eleven different cracker flours showed that all sponges changed with fermentation. Resistance to extension and extensibility decrease for all flour (Fig 9). Weak flours did not provide enough resistance to drive chart on the extensigraph after 18 hrs of fermentation.

Extensigraph studies revealed a progressive change throughout the fermentation period (Fig. 10). When compared with the pH change during fermentation, it is clear that much of the rheological change occurs at relatively high pH. Clearly, this is not totally the result of the proteolytic enzyme active at pH 4.1.

To learn more about the changes occurring early in the fermentation period, systems of flour/water and flour/water/yeast were studied along with the regular system. Sponges of flour/water reach a pH of 5.2 to 5.7

Figure 6. Effect of a short fermentation period on the relaxation rate of cracker sponges. Sponges were fermented zero (·) and 4 (x) hrs. Crosshead speed was 0.25 cm/min.

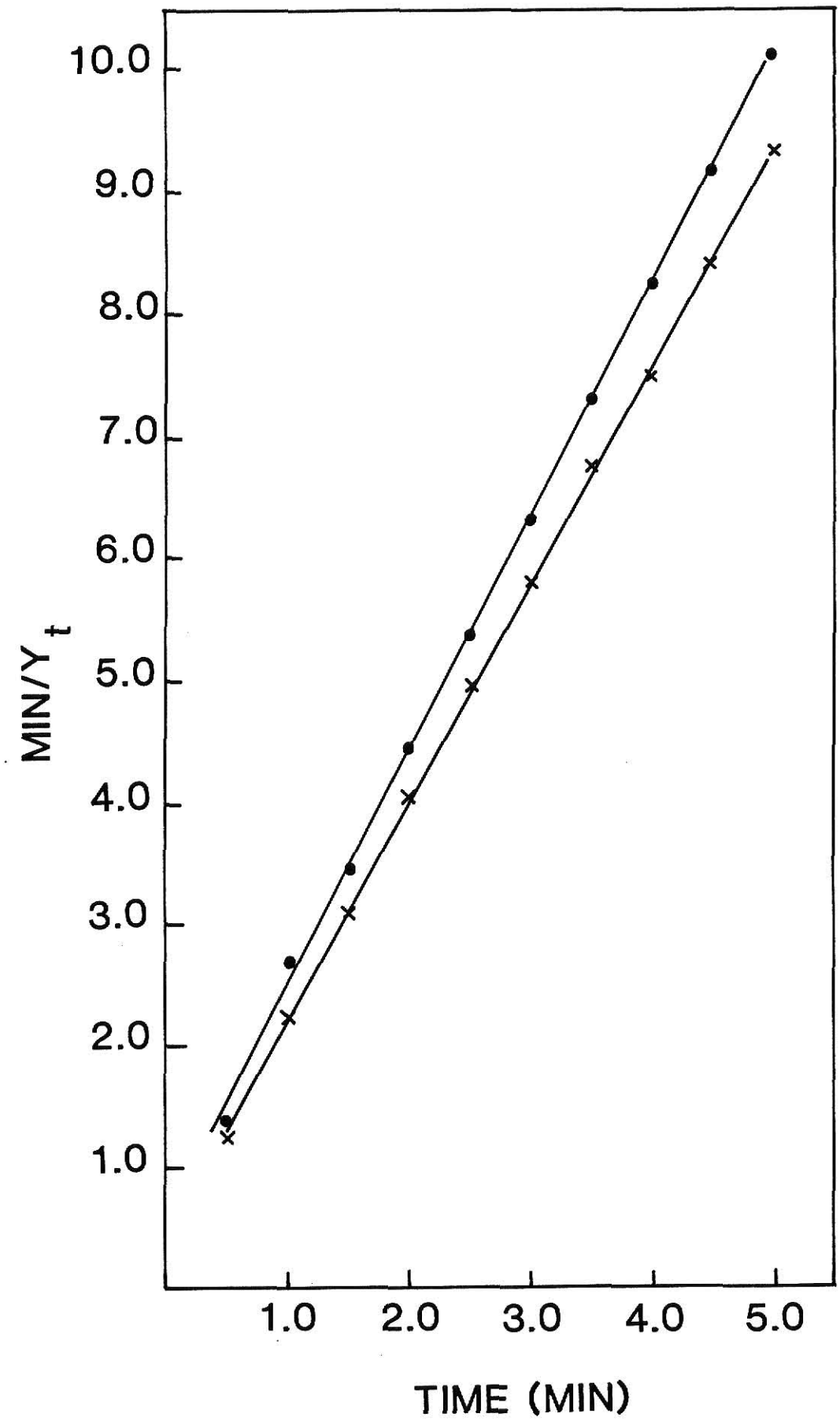

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y t
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 7. Effect of fermenting at low pH on the relaxation rate of cracker sponges. Sponges had pH dropped to 4.1 with lactic acid, were fermented zero (·) and 4 (x) hrs, then neutralized. Crosshead speed was 0.25 cm/min.

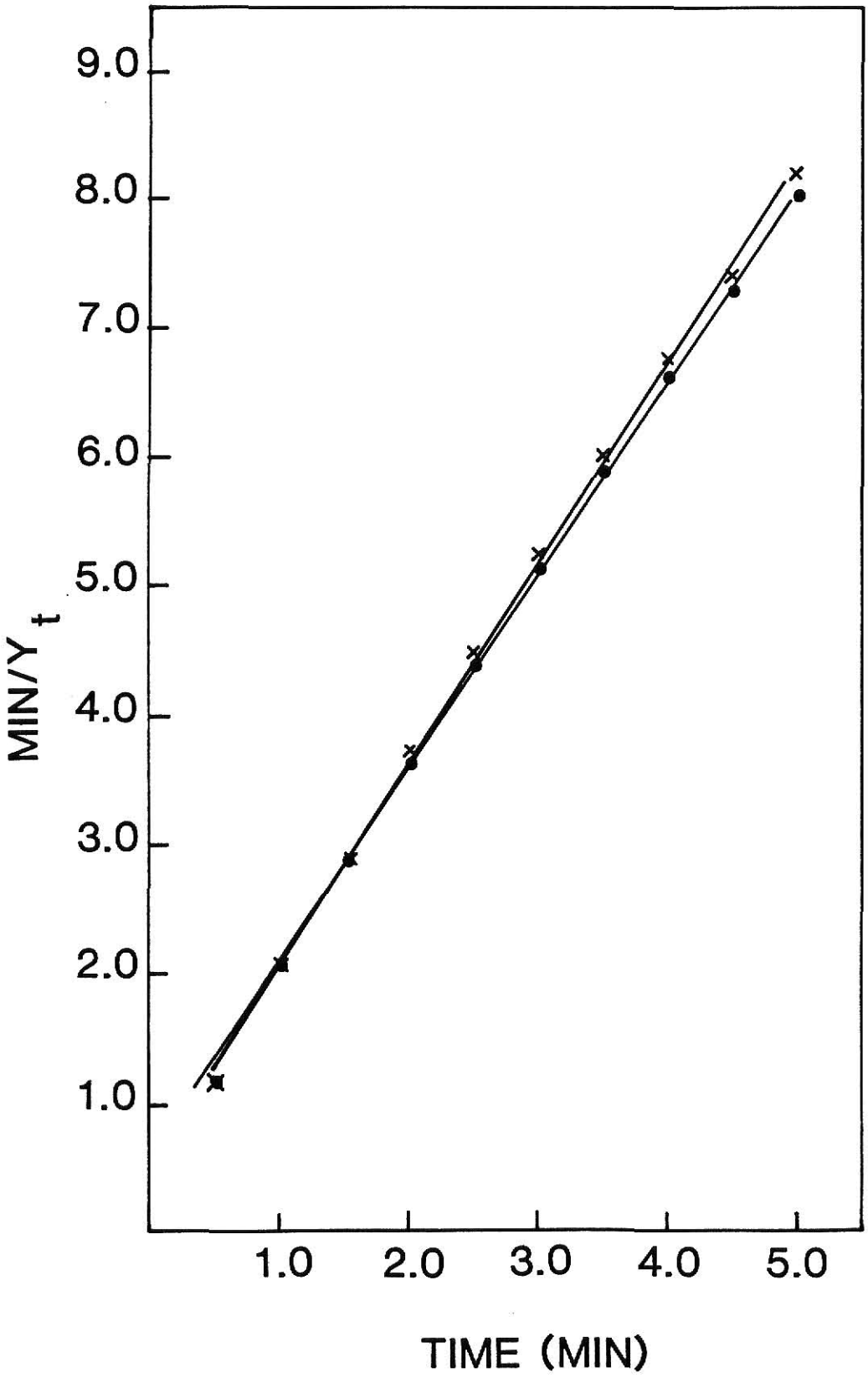

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y t
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 8. Effect of dough flour on the relaxation rate of cracker sponges. Sponges were fermented zero (·), 2 (▲), 4 (■) and 6 (x) hrs. Dough flour was added along with usual dough stage ingredients. Crosshead speed was 0.25 cm/min.

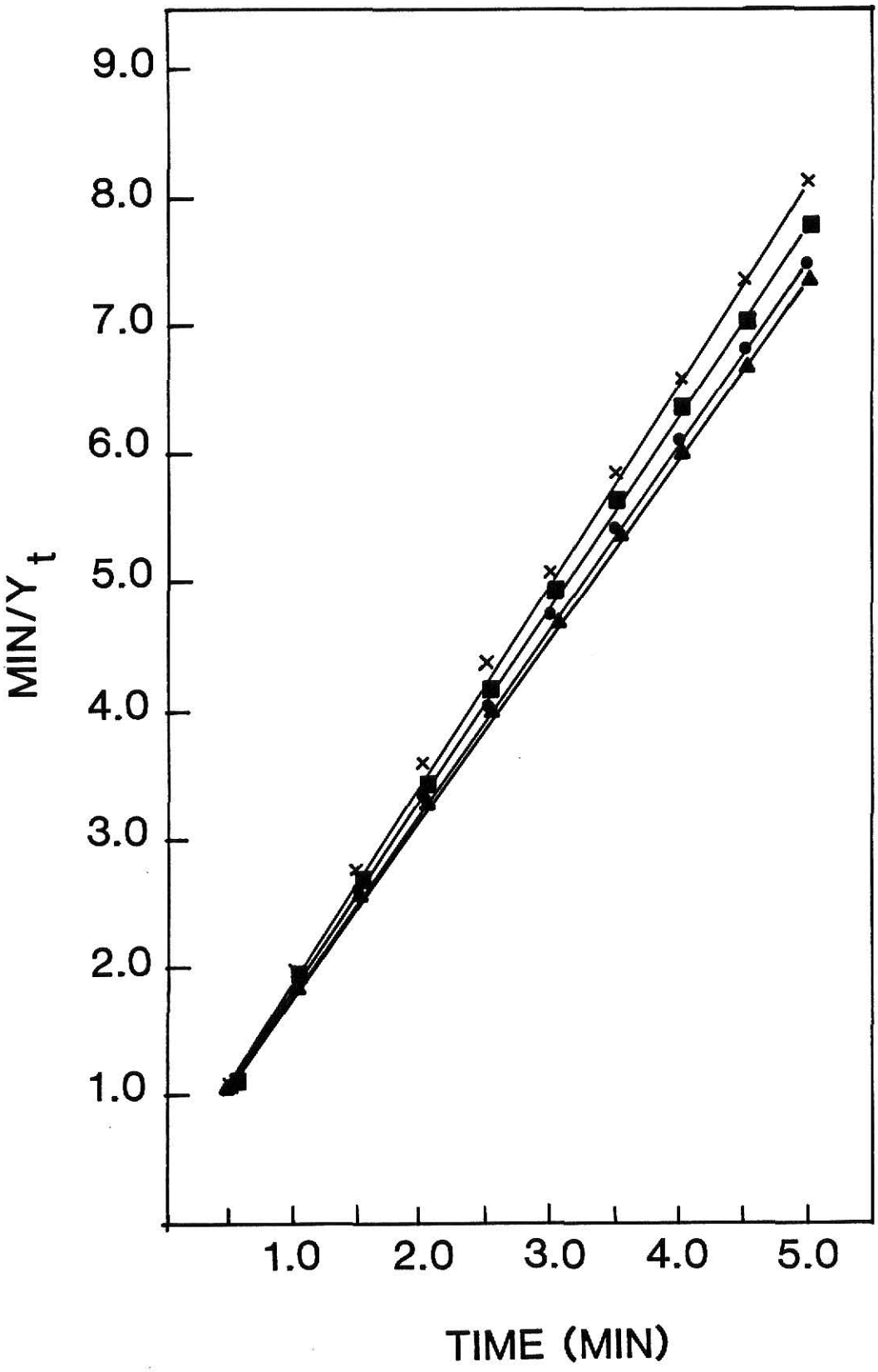

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
MIN/Y t
1.0
2.0
3.0
4.0
5.0
TIME (MIN)

Figure 9. Effect of fermentation on the extensigram properties of cracker sponges. Sponges were fermented zero and 18 hrs.

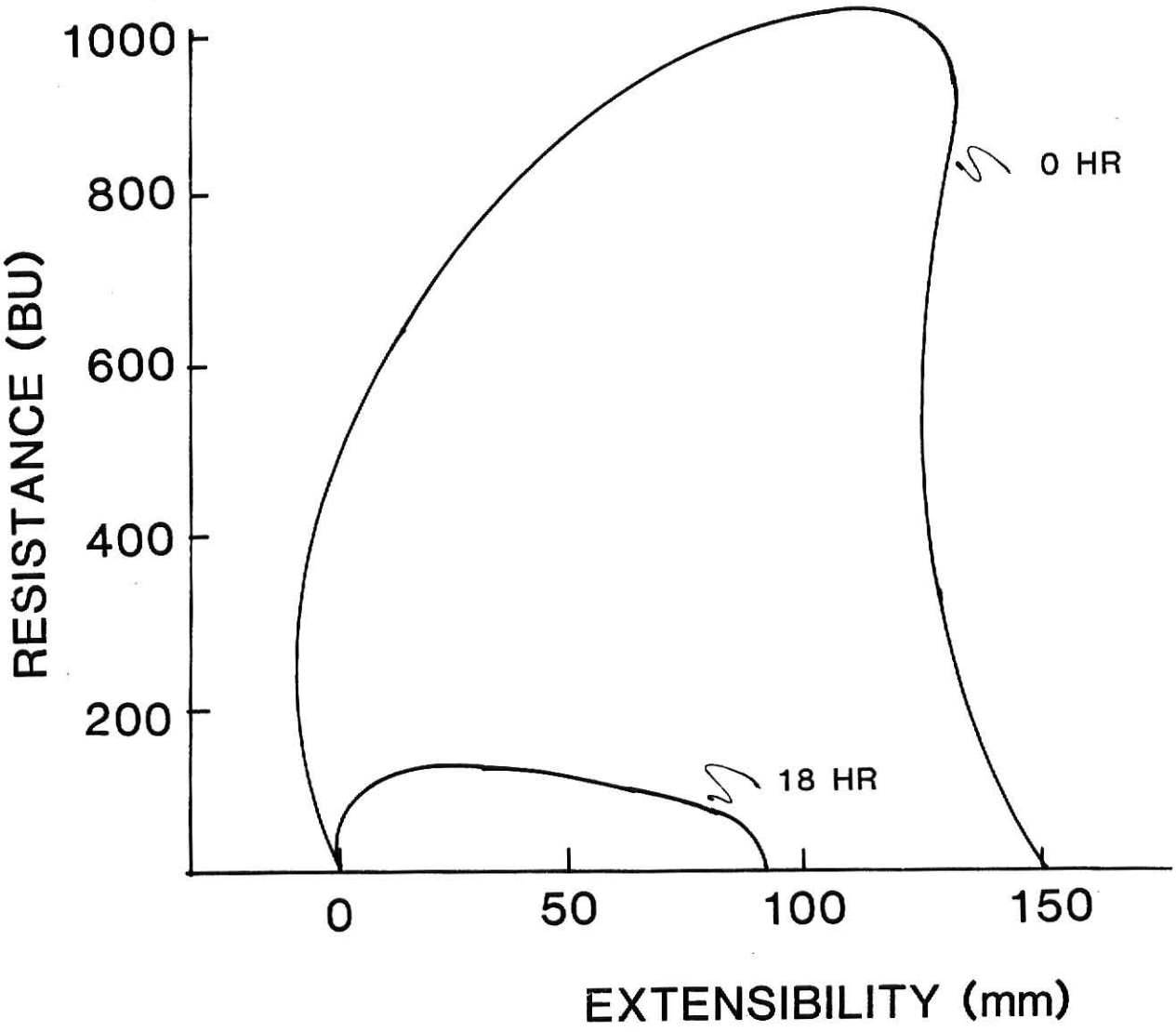
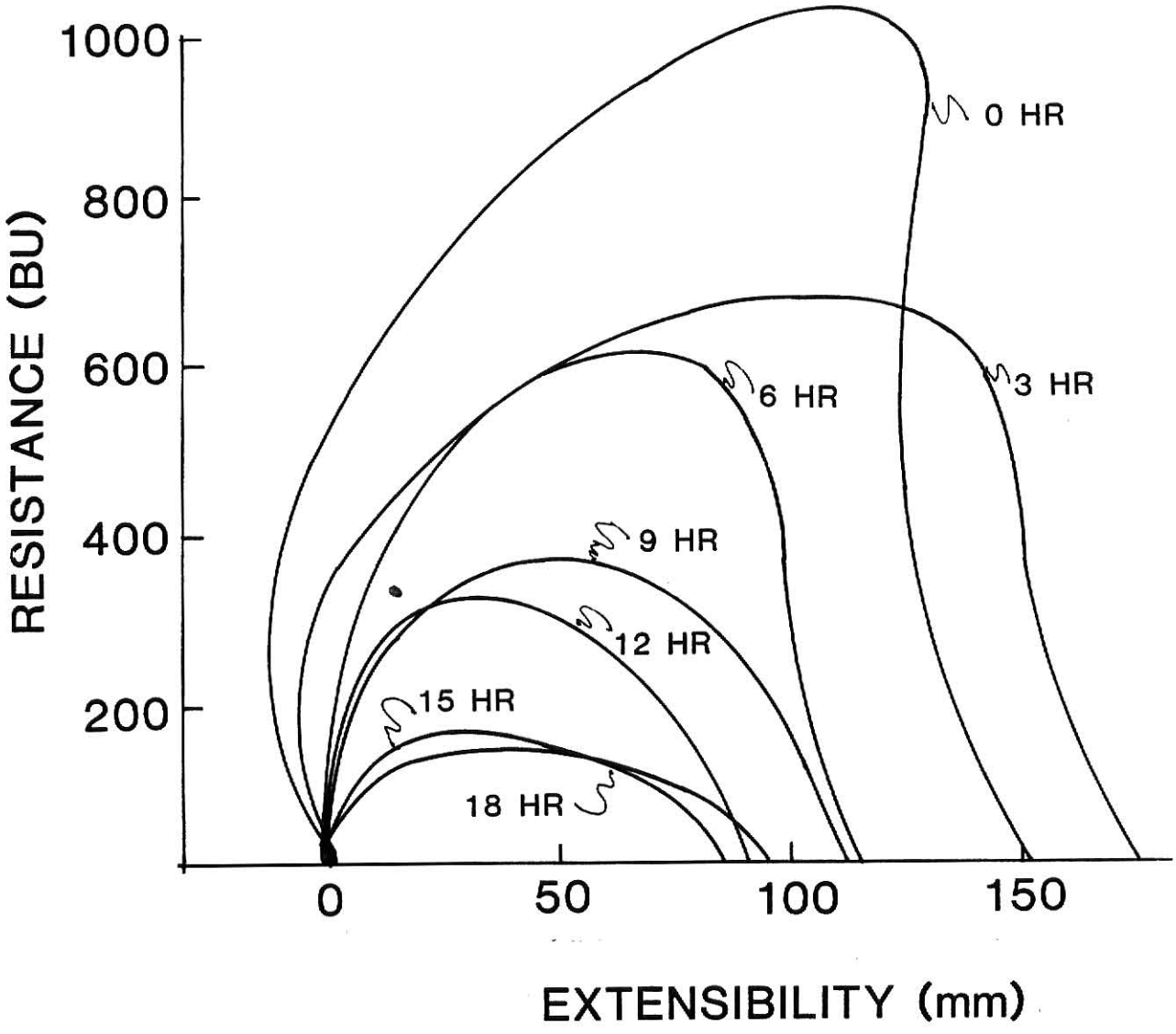

1000
800
600
400
200
RESISTANCE (BU)
0 HR
18 HR
0
50
100
150
EXTENSIBILITY (mm)

Figure 10. Effect of fermentation time on the extensigram properties of cracker sponges. Each sponge was adjusted to pH 7.0 with soda.


1000
800
600
400
200
RESISTANCE (BU)
0 HR
3 HR
6 HR
9 HR
12 HR
15 HR
18 HR
0
50
100
150
EXTENSIBILITY (mm)

after 18 hrs while those of flour/water/yeast reach pH's in the 4.5 to 4.7 range.

Both the extensigraph and the mixograph were used. In the mixograph, all samples tested showed rapid breakdown during the early hours of fermentation. The curve became narrow during the first few min of mixing. At zero time, the flour/water sample appeared the strongest (Fig. 11). As fermentation proceeded, all doughs weakened. Doughs containing yeast appeared to be stronger while doughs containing added slurry were weak. Doughs containing both yeast and slurry were weaker than either of the two used alone. At the end of 4 hrs, all the doughs were very weak (Fig. 12).

To determine whether compounds with sulfhydryl groups were being generated during fermentation and were responsible for the weakening, several oxidizing agents were added to a fermented dough. Addition of 50 and 100 ppm of KIO_3 to a dough sample fermented 4 hrs had no strengthening effect. However, addition of 1% and 2% Tenox had a marked strengthening effect (Fig. 13). A combination of KIO_3 and 1% Tenox showed strengthening of the curve similar to Tenox alone (Fig. 13). Thus, Tenox appears to be responsible for the strengthening effect. Tenox is an anti-oxidant and functions as a free radical scavenger. This infers that the changes occurring early in the system are caused by a free radical reaction. The nature of the reaction is obscure.

Extensigraph studies showed that changes in resistance to extension were similar for all systems. Initial strength differed, but all came to the same point after 15 hrs of fermentation (Fig. 14). The extensibility of all sponges increased during the first 3 hrs, then decreased in yeasted systems. The flour/water system became very extensible, increasing up to the 9th hr of fermentation (Fig. 15). The flour/water dough remained extensible through the last 9 hrs of fermentation.

Figure 11. Effect of ingredients on the mixogram properties of cracker sponges. Sponges were given 0 hr fermentation. Sponges contained flour/water (control), flour/water/yeast (yeast), flour/water/slurry (slurry) and flour/water/yeast/slurry (yeast and slurry).

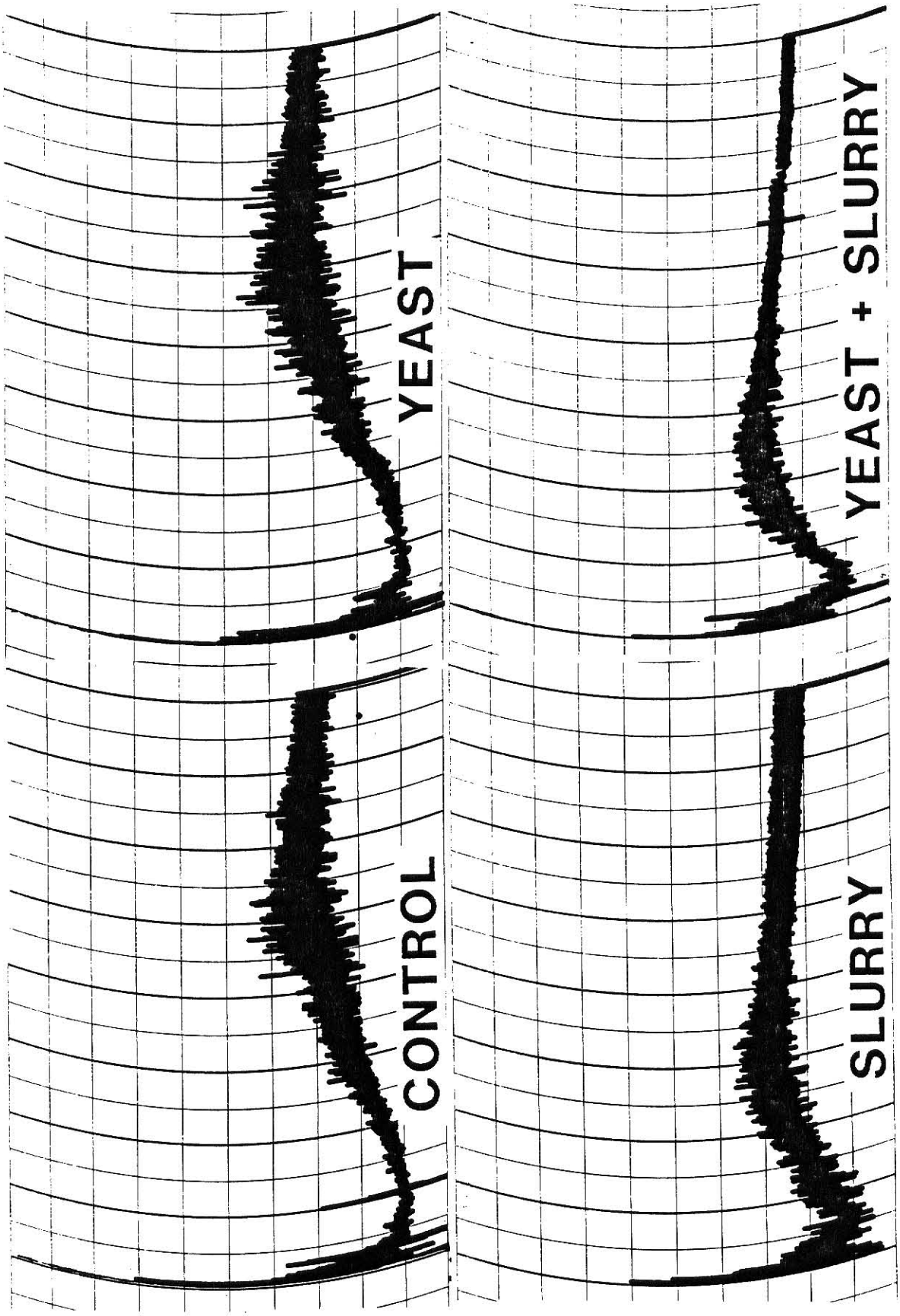

CONTROL
YEAST
SLURRY
YEAST + SLURRY

Figure 12. Effect of ingredients on the mixogram properties of cracker sponges. Sponges were given 4 hr fermentation. Sponges contained flour/water (control), flour/water/yeast (yeast), flour/water/slurry (slurry) and flour/water/yeast/slurry (yeast and slurry).

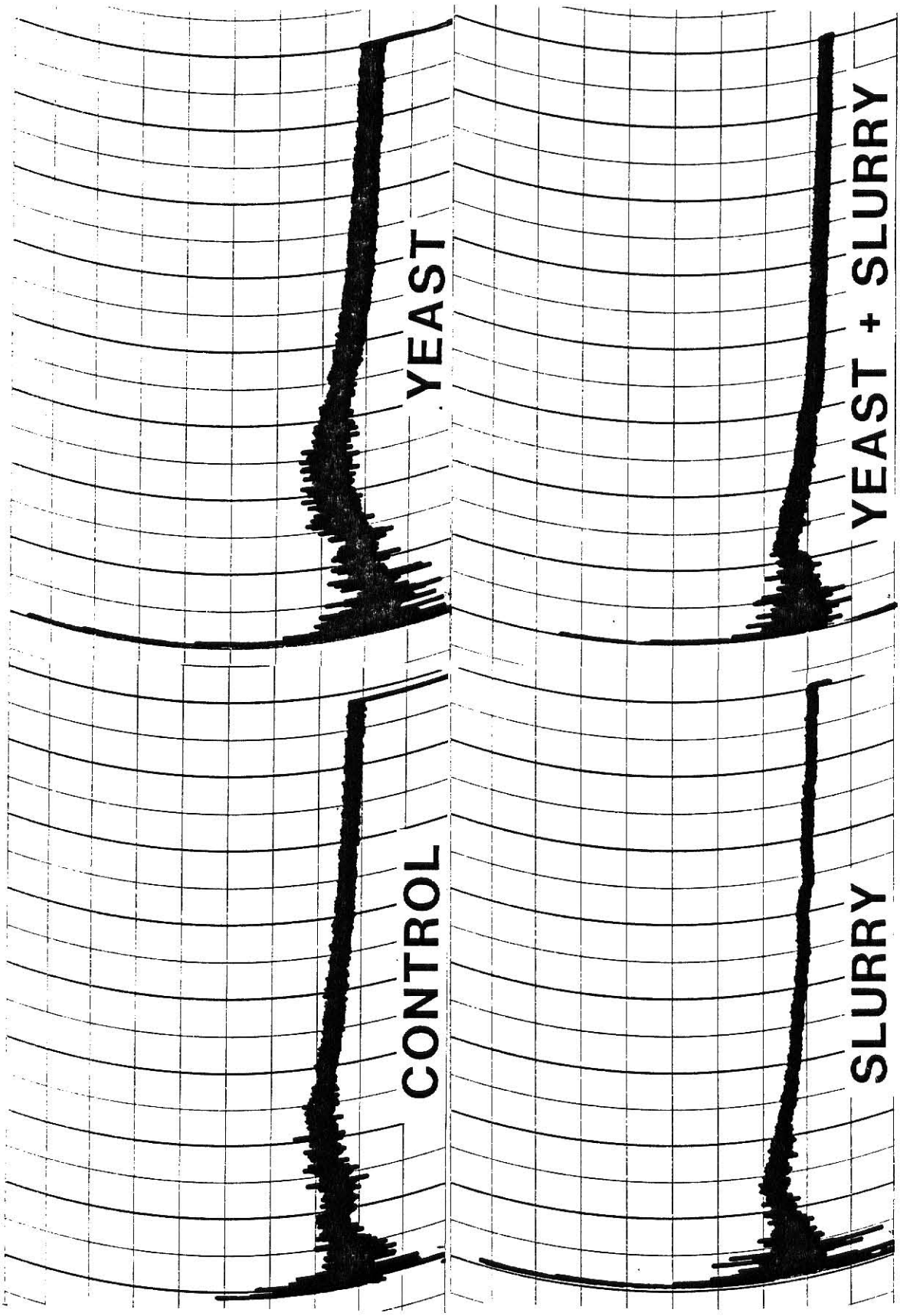

CONTROL
YEAST
SLURRY
YEAST + SLURRY

Figure 13. Effect of KIO_3 and Tenox on the mixogram properties of cracker sponges. Sponges of flour/water were fermented 4 hrs. Tenox was used at 1% and 2%. A combination of 1% Tenox and KIO_3 was used (50 ppm KIO_3 and 100 ppm KIO_3, respectively).

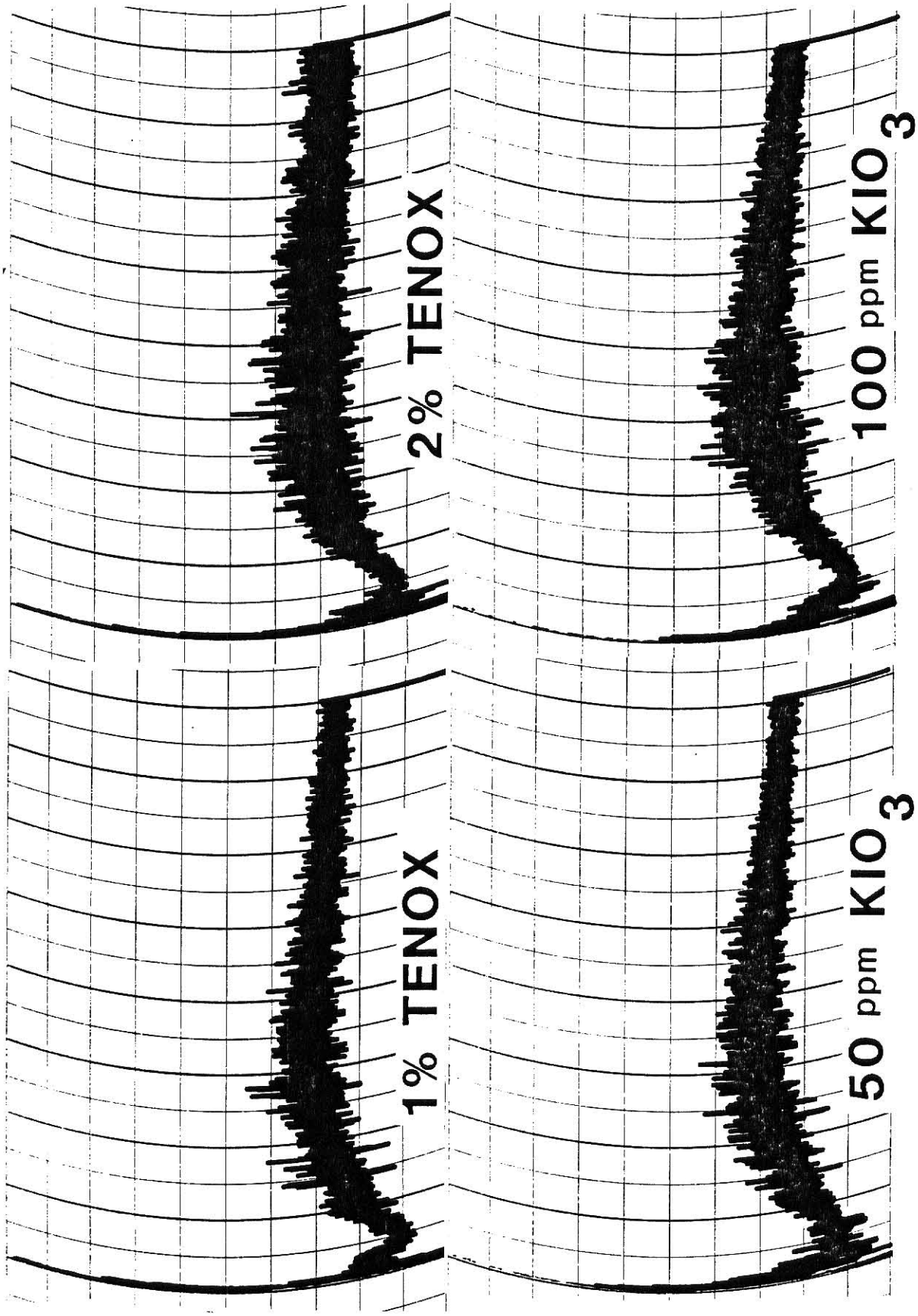

1% TENOX
2% TENOX
50 ppm KIO3
100 ppm KIO3

Figure 14. Effect of ingredients on the resistance to extension of fermenting sponges. Sponges containing flour/water (·), flour/water/yeast (▲), flour/water/yeast/slurry (■) were produced from a weak flour, #10. A sponge containing flour/water/yeast/slurry was produced from a strong flour, #9 (x).

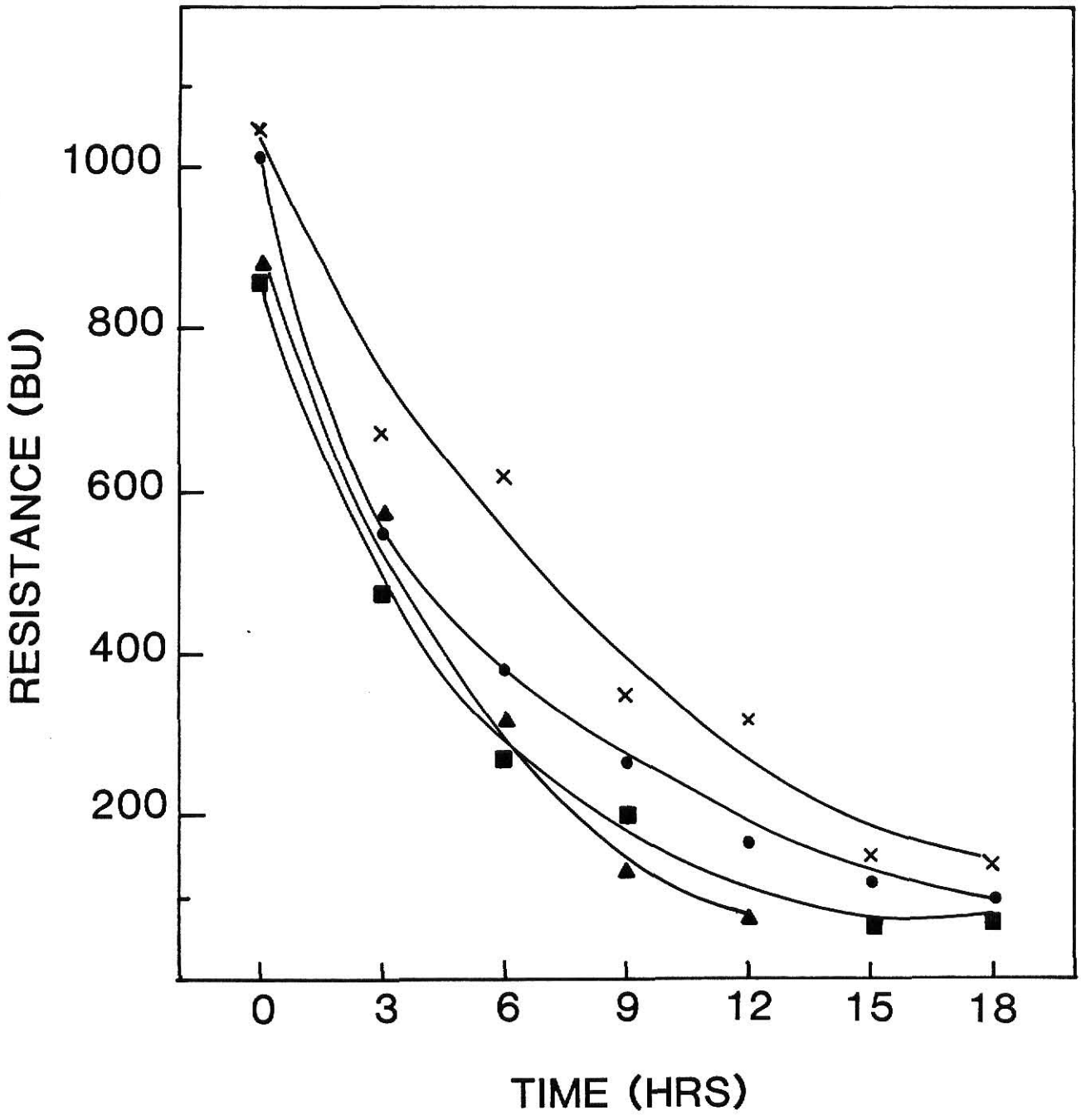
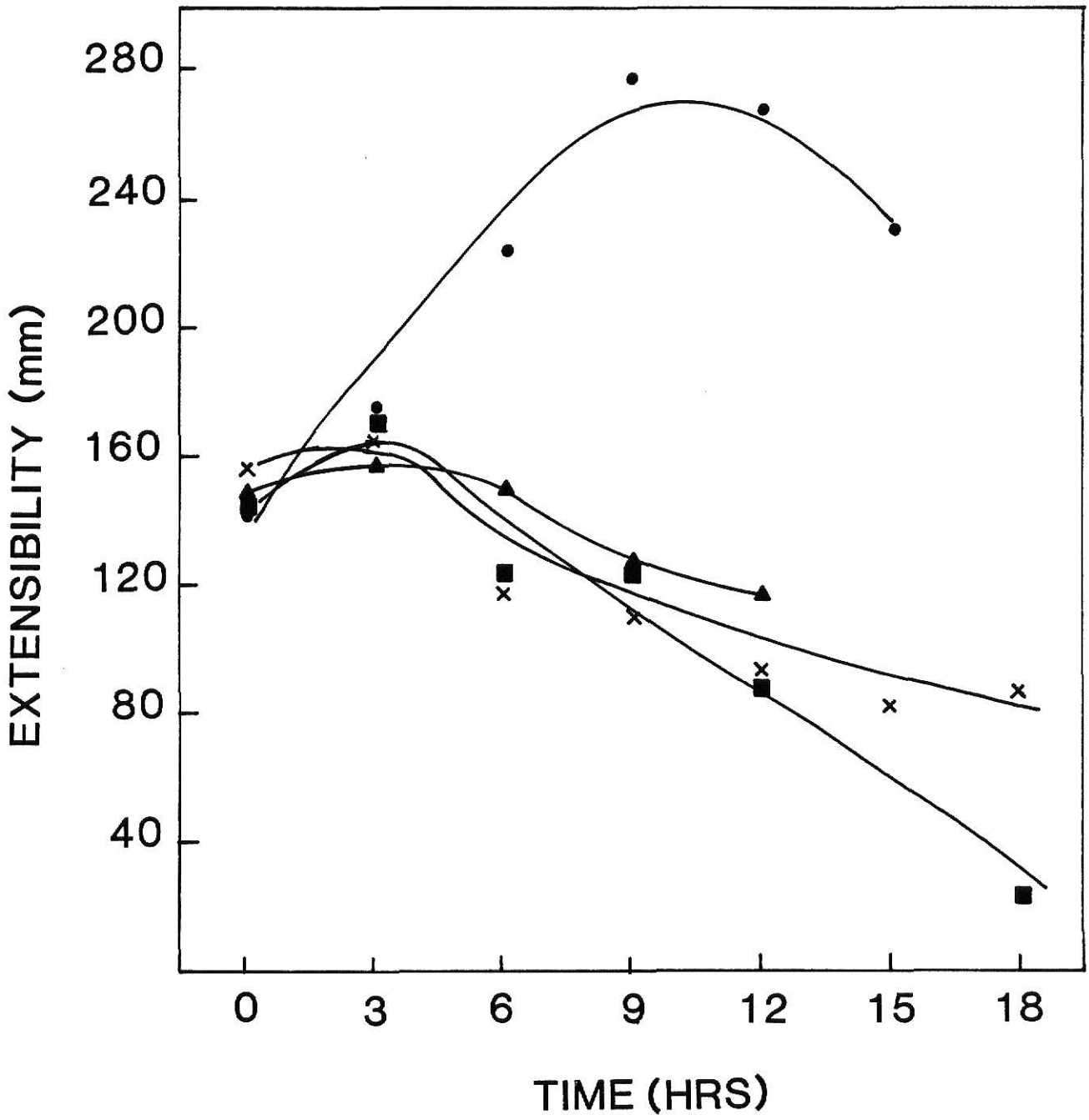

RESISTANCE (BU)
1000
800
600
400
200
0
3
6
9
12
15
18
TIME (HRS)

Figure 15. Effect of ingredients on the extensibility of fermenting sponges. Sponges containing flour/water (·), flour/water/yeast (▲), flour/water/yeast/slurry (■) were produced from a weak flour, #10. A sponge containing flour/water/yeast/slurry was produced from a strong flour, #9 (x).


280
240
200
160
120
80
40
EXTENSIBILITY (mm)
0
3
6
9
12
15
18
TIME (HRS)

Based upon the results of the viscosity studies, changes in the rheological character of the dough had been attributed to the action of a proteolytic enzyme specific to pH 4.1. If the proteolytic enzyme were solely responsible for the changes, none should occur until it became active. Since a fermenting dough does not reach pH 4.1 until the 9th-12th hr, another system is clearly at work.

If a proteolytic enzyme native to the flour is responsible for changes which occur late in the fermentation period, then its action should be evident in a system when the pH is dropped to the optimum level for its activity. Samples "fermented" 6 hrs at pH 4.1 showed decreased resistance to extension. Both strong and weak flours had less resistance to extension when fermented 6 hrs at pH 4.1 than 6 hrs of normal sponge fermentation. The weak flour showed a more rapid drop in resistance to extension than did the strong flour (Fig. 16). Both strong and weak flours showed increased extensibility when fermented at low pH (Fig. 17).

Although the results of these studies do provide some evidence that a proteolytic enzyme acts in the system, other systems must be at work. Clearly, this is an area that requires further study.

Cracker Baking

Results of the physical dough tests indicated that the cracker flours we had differed in their strength both before and after fermentation. Crackers were baked to determine whether those differences reflected the quality of cracker flours.

A laboratory method for the production of saltines had been developed by Pizzinatto and Hoseney (1980b). In his work only a few cracker flours were used. Thus, we wanted to evaluate how effective the method was for flours of varying strength.

Figure 16. Effect of fermenting at low pH on the resistance to extension of cracker sponges. Sponges produced from a strong flour (x) and a weak flour (•) had pH dropped to 4.1 with lactic acid. Sponges were neutralized with soda before testing.

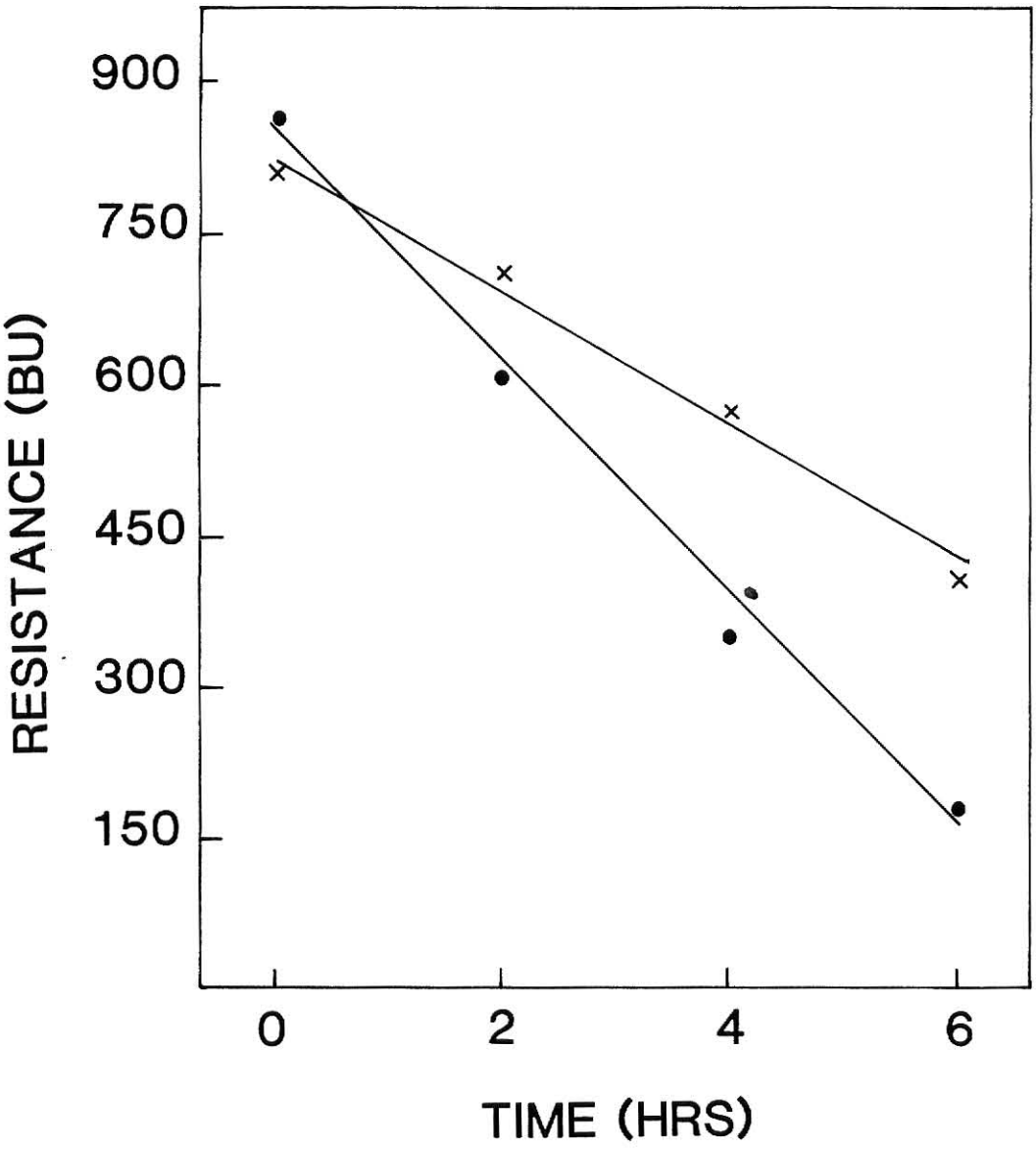
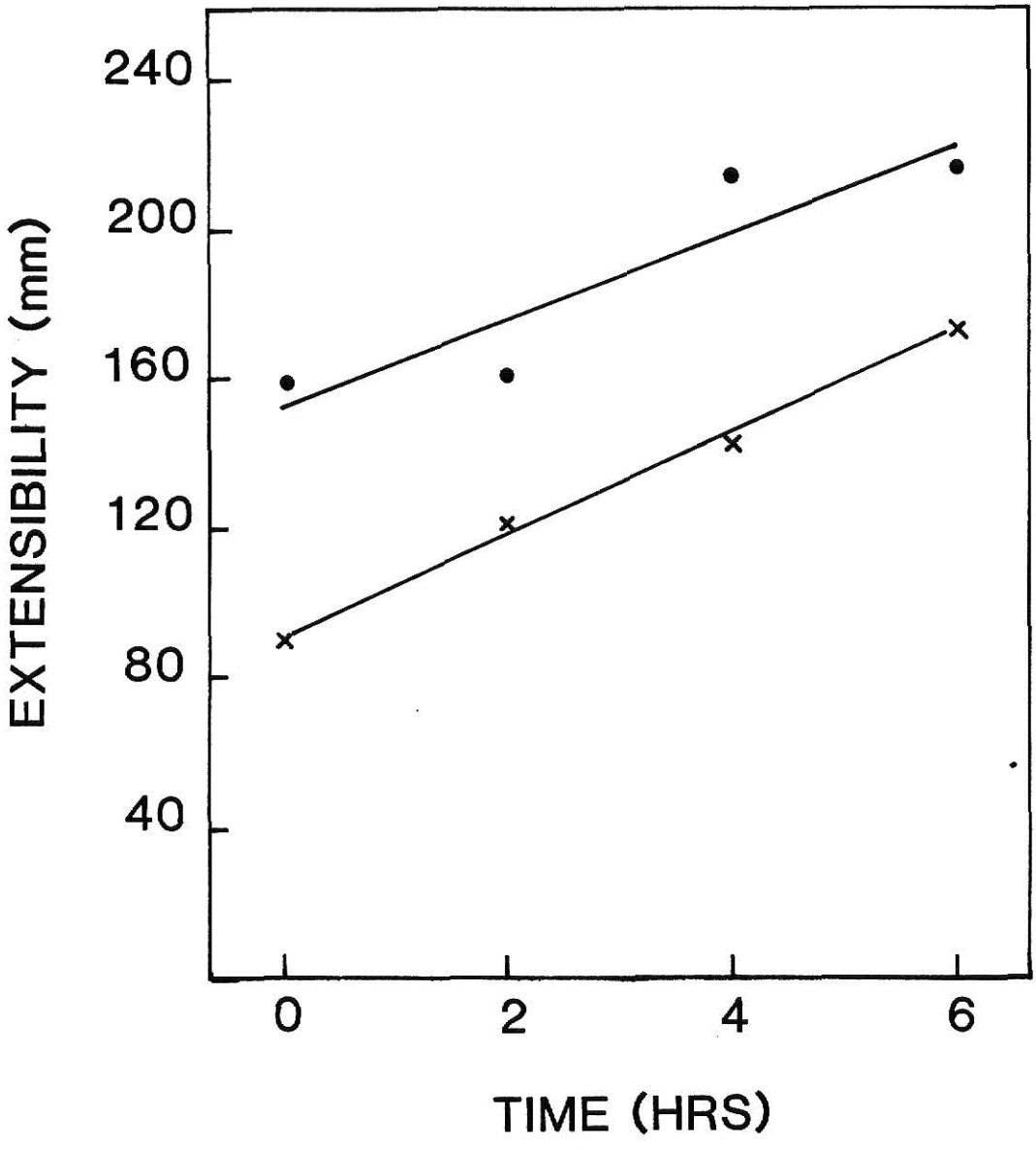

900
750
600
450
300
150
RESISTANCE (BU)
0
2
4
6
TIME (HRS)

Figure 17. Effect of fermenting at low pH on the extensibility of cracker sponges. Sponges produced from a strong flour (x) and a weak flour (·) had pH dropped to 4.1 with lactic acid. Sponges were neutralized with soda before testing.


240
200
160
120
80
40
EXTENSIBILITY (mm)
0
2
4
6
TIME (HRS)

Bakers are concerned most with stack height and weight, heights and weights of 10 crackers were used to evaluate the product. A height to weight ratio was calculated as an indication of oven spring.

Crackers from three different commercial producers were weighed and measured to establish targets for stack height and weight. Commercial crackers were found to vary from batch to batch as periodic checks were made. Crackers produced using a 48 x 52 mm cell should weigh 29-32 g per ten based upon the commercial crackers.

A cracker flour identified by the supplier as one that made good saltines (flour #10) was selected for the tests to evaluate sheeting method. This flour was used at both sponge and dough stages. Sheeting according to the method outlined by Pizzinatto resulted in crackers with very low weights and poor oven spring (Table 13).

The commercial flours in this study appeared to be much weaker than the flours used by Pizzinatto and Hoseney (1980b). It appeared that the weak doughs were being damaged by the sheeting procedure, thus giving low dough weights and low oven spring.

Based upon visual observation, the physical character of the dough changed when the dough was sheeted at the 1.25 mm gap. Passes made at that setting or at smaller gaps appeared to affect the strength of the dough. Therefore, the number of passes at 1.25 mm were reduced. Weights of the resulting crackers still fell below the target weight.

When passes at settings less than 1.25 mm were eliminated, and two passes at 1.25 mm were left in, doughs appear stronger. The resulting crackers had weights above the target weight.

The last step was to find a final reduction (gap) which would give crackers with weights in the desired range. One pass at 0.30 mm was

Table 13. Baking Data, Pizzinatto's Method

Trial	Ht (mm)	Wt (g)	Ht/Wt
1	41.75	23.68	1.763
2	44.10	23.20	1.901
3	41.78	22.74	1.837

Data for stack of 10 crackers.

found to be the proper setting. Doughs which were sheeted according to the modified procedure gave crackers with suitable baked weights (Fig. 18).

From this work, it appeared that the number of passes at a small gap was more important than the total number of passes. Moving the steps where the dough was folded did not appear to significantly affect the cracker. Again, the number of passes at a small gap seemed to be the key.

The new sheeting method produced crackers with the correct weight. However, the stack height or oven spring was low. We believe that the rate of heating of the crackers when first placed in the oven was too slow. Thus, we developed a procedure to transfer the docked cracker dough directly onto a heated expanded metal baking sheet. The puffing was much more uniform and crackers with improved height to weight ratios resulted (Table 14). The method was quite reproducible.

Cracker doughs do not become fully developed during mixing. The development occurs during the sheeting process. It follows that stronger flours would require a more rigorous sheeting to become fully developed. Weak doughs would need less mechanical work for development and would be susceptible to damage by overdevelopment. If all doughs were sheeted according to a method developed for a weak dough, one would expect weights of crackers baked from weak flours to be on target. However, crackers produced from strong flours would not become fully developed. They would retain more elasticity and shrink back after passing through the final reduction rolls, giving higher weights. Results of the baking tests tend to support this theory (Table 15).

The developed procedure was used to evaluate the 11 commercial cracker flours. In the baking tests flour #10 was used for the dough-up so that

Figure 18. Sheeting procedure developed for cracker doughs. The procedure was used for baking tests for all flours.

MODIFIED SHEETING PROCEDURE

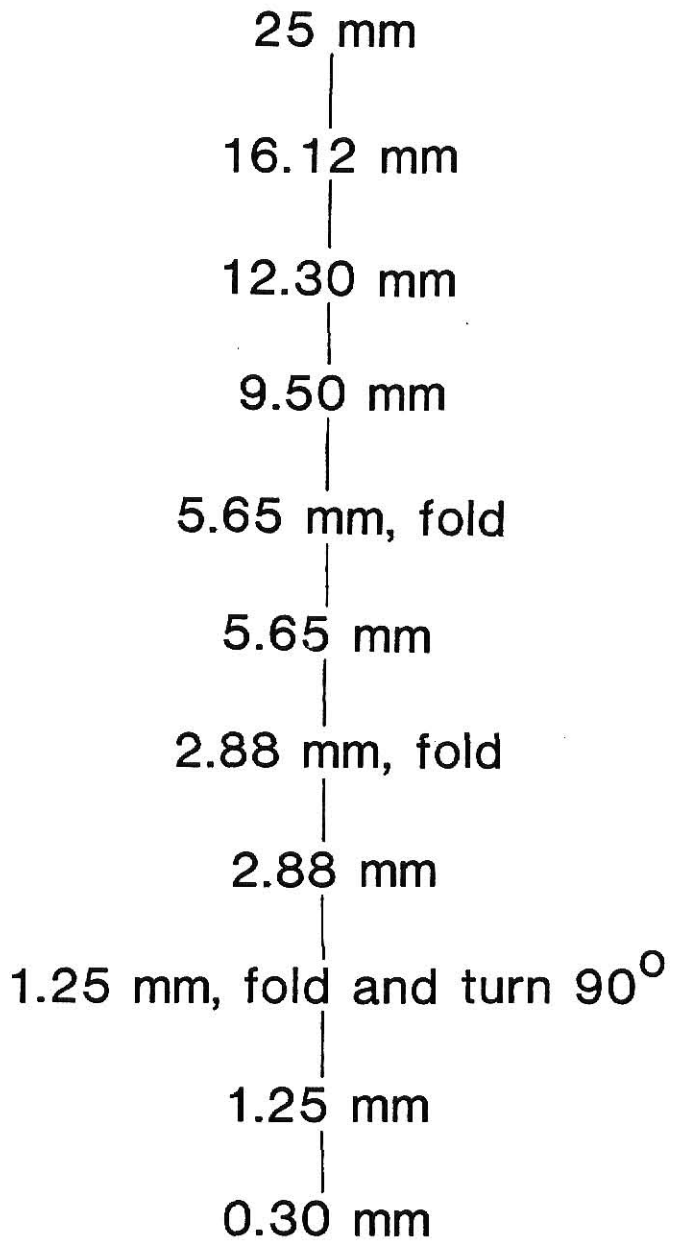


Table 14. Results Using the Modified Baking Procedure with Commercial Cracker Flour #10[a]

Trial	Ht (mm)	Wt (g)	Ht/Wt
1	63.20	29.40	2.150
2	63.40	27.67	2.291
3	63.40	29.47	2.151
4	64.10	32.43	1.976
5	62.35	31.50	1.977
6	60.90	30.18	2.018
7	60.05	26.78	2.242
8	60.40	30.36	1.989
9	62.90	30.57	2.057
10	65.90	31.05	2.122
11	63.30	32.41	1.953
Mean	62.72	30.16	2.084
Stnd. Dev.	1.717	1.780	0.115

[a] Data for stack of ten crackers

Table 15. Baking Data for Commercial Cracker Flours[a]

Commercial Cracker Flour	Ht (mm)	Wt (g)	Ht/Wt
1	69.20	37.70	1.836
2	50.53	25.42	1.988
3[b]	67.55	36.56	1.848
4	74.85	35.15	2.129
5	70.33	37.20	1.890
6	61.83	29.55	2.092
7	66.75	30.02	2.224
8	61.72	30.40	2.030
9	70.70	36.92	1.915
10	62.72	30.16	2.084
11	61.18	30.53	2.004

[a]Data for stack of ten crackers

[b]An extra 10 ml of water/yeast mixture was needed to make up a good dough.

the effect of fermentation on each sponge flour could be studied. Flours which remained relatively strong throughout the fermentation period gave crackers with high weights. They were the same flours that appeared strong on the extensigraph. In general, the strong flours had less puffing or more uneven puffing. Flours which weakened during fermentation gave crackers with acceptable weights. Degree of puffing was similar for all samples made from weak flours.

Only one flour gave crackers with unacceptable appearance and puffing. It had low weights, suggesting that the sheeting method was too rigorous. The flour had weakened enough during fermentation that it could not be tested on the extensigraph.

In conclusion, the modified baking method is quite reproducible and appears to be suitable for a variety of flours. It seems to be well suited for the flours commonly used in the cracker industry. Flours which are strong need and can tolerate more rigorous sheeting before they lose their elasticity.

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DEVELOPMENT OF A LIQUID STARTER FOR CRACKER SPONGES AND FACTORS AFFECTING CRACKER FLOUR QUALITY

by

LINDA CATHERINE DOESCHER

B.S., Iowa State University, 1981

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE
FOOD SCIENCE

Department of Grain Science and Industry

Kansas State University
Manhattan, Kansas

1983

ABSTRACT

A liquid starter (inoculum) for use in cracker sponges was developed. Slurries of only flour and water were not stable. When yeast was added, the system was stable but did not produce sponges with the desired pH (4.1). To produce the most desirable inoculum, a flour-water-yeast-sucrose mixture (100:200:0.62:3) was fermented 18 hours, and then fed with 20% flour and fermented another 18 hours. The sponges produced with a 5% inoculum of that mixture reached pH's in the 4.1 range in 18 hours.

The 18 hour cracker sponge fermentation is a critical step in the production of good quality crackers. Changes in the doughs' rheological properties were measured throughout the fermentation period using a Brabender extensigraph. Dough strength decreased as fermentation time increased. Significant changes in rheological properties occurred during the early hours of fermentation. During the latter part of the fermentation period, when pH was low, a proteolytic enzyme native to the flour appeared to act. Protein extracts from doughs showed decreased viscosity after fermentation, indicating cleavage of the proteins.

Baking tests were conducted to relate flour strength to baking properties. Height, weight, and oven spring (height/weight) were evaluated. The amount of mechanical work done to the dough appeared to be a critical factor. Weak flours which went through rigorous sheeting gave crisp crackers with little puffing. When weak flours were given less mechanical work during sheeting, crackers with even puffing and light texture resulted.