

Effects of Fermentation in Saltine Cracker Production¹

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ABSTRACT

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Yeast was found to be necessary in cracker sponges. Stack weight decreased with increased yeast fermentation because of the decreased dough density. In addition, the cracker cell structure was finer and more uniform. The starter slurry inoculated the system with bacteria and was required to decrease the pH. The lower pH allowed the flour proteases to modify the flour proteins. Stack height decreased when slurry was included in the cracker formula, but the textural strength of the cracker increased.

During the 18-hr sponge fermentation, gas was produced, the pH declined, and the flour proteins were enzymatically modified. With the total starter system, cracker stack height and stack weight decreased as sponge fermentation time increased. At the same time, the texture of the crackers changed from extremely tender and fragile to strong with increasing sponge fermentation time. The 4-hr rest period following dough-up was essentially a proof period and allowed equilibration of moisture.

Saltine crackers are produced with a procedure that requires a total of approximately 24 hr of fermentation. Pizzinatto and Hoseneý (1980a) showed that as fermentation time increased, the strength and the pH of the cracker sponges decreased.

The role of a starter system, as developed for laboratory production of saltine crackers by Doescher and Hoseneý (1985), is generally ignored in the literature. Piepner (1971) mentioned the use of a "buffer" or sponge, which could be added to cracker sponges to enhance fermentation. Most authors, however, simply mention the variability in sponge pH and cracker quality that arises from the fluctuation in material adhering to the troughs (Johnson and Bailey 1924; Micka 1955; Heppner 1959; Matz 1968, 1984; Smith 1972). The assumption can be made that adventitious bacteria play an important role in the fermentation process (Sugihara 1978).

Pizzinatto and Hoseneý (1980a) also suggested that the reduction of pH during fermentation brings the sponge to the pH optimum (approximately 4.1) of the native proteolytic enzymes of flour. Wu (1987) showed that the resulting enzymatic action is responsible for the rheological changes in cracker sponges. Salgo (1981) studied wheat proteases and found two enzymes with similar pH optima, 3.8 and 4.2, which were stable in the pH 2.5-5.0 range.

Saltine crackers are unique baked products with a peculiar

texture. This texture, although readily recognizable to consumers, is difficult to describe or define objectively. Most reported instrumental texture evaluations of crackers, biscuits, or other pastry products use methods based on breaking strength. Samples are suspended across a bridge, and the force required to snap the test specimen is recorded (Swartz 1943, Stinson and Huck 1969, Bruns and Bourne 1975, Zabik et al 1979, Katz and Labuza 1981).

Katz and Labuza (1981) examined crispness of four different snack foods, including saltine crackers. Samples were equilibrated at one of 10 relative humidities for three weeks before testing. A critical water activity, above which the product was unacceptable, was determined using sensory techniques. A snap test was used to measure cracker texture, with the initial slope of the force deformation curve taken to indicate crispness (a technique also used by Bruns and Bourne 1975).

The objectives of this study were to determine the effects of yeast and starter on cracker quality and to determine what changes occur in the system during phases of fermentation.

MATERIALS AND METHODS

Materials

Two commercial cracker flours provided by Lance Inc. and Dixie-Portland Flour Mills Inc., and one flour milled from soft wheat at Kansas State University were used in this study (Table I). These flours were selected to represent the range of proteins and flour qualities available from several commercial sources.

Compressed yeast (Anheuser-Busch, St. Louis, MO, or Red Star, Universal Foods, Milwaukee, WI) was aged two to four weeks at 4°C before being used. Minor dry ingredients were supplied by Nabisco Brands, Inc. Hydrogenated vegetable shortening (Crisco, Proctor & Gamble, Cincinnati, OH) was used in the cracker baking.

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Absorption Determination

Optimum absorption was determined by the mixograph procedure described by Rogers and Hosenev (1987).

Cracker Baking

Crackers were baked using a procedure slightly modified (Rogers and Hosenev 1987) from that developed by Pizzinatto and Hosenev (1980b) and Doescher and Hosenev (1985). For the study on ingredient effects, the fermentation time remained constant. Sponges were set with flour and water plus yeast alone, yeast plus slurry (control), slurry alone, or no starter at all (flour and water). When "mock" systems were made, 5 ml of the water was held back and sponges were mixed for only 2 min. After the desired yeast fermentation, which varied from 1 to 8 hr, approximately 1.3 ml 85% lactic acid (quantity of acid needed varied slightly between flours) was diluted to 5 ml and mixed into the sponge for 1 min. This was followed by fermentation times varying from 8 to 14 hr. In other experiments, sponge dough-up fermentation times or dough-up rest times were varied, holding ingredients and the other fermentation time constant.

Gassing Power

Samples of cracker sponge and dough were prepared as for baking. A 10-g sample of sponge or a 50-g sample of dough was placed into a half-pint reaction bottle in a gasograph (Coghill Corp., Hayden Lake, ID) (Rubenthaler et al 1980).

Cracker Texture Analysis

To adjust the water activity before texture analysis, crackers were placed on screens suspended over trays of sulfuric acid solutions diluted with water to produce an equilibrium relative humidity of 20%. The chambers were sealed and crackers were equilibrated for a minimum of five days. Water activity of the samples was measured with a thermocouple psychrometer (Decagon Devices Inc., Pullman, WA).

The universal testing machine (UTM) (Instron model 1132) was used in the compression mode for instrumental texture analyses. For breaking strength determinations, the 2-kg load cell was used with a crosshead speed of 5 cm/min and a chart speed of 25 cm/min. An individual cracker, top side down, was placed over a 2.5-cm bridge. A blunt chisel probe, placed parallel to the direction of the last sheeting, was lowered until the cracker broke. The peak force, or force required to break the cracker, was recorded. This test was designed to simulate the initial force required to bite, or break, a cracker.

The 50-kg compression load cell was used for the crushing test, with a crosshead speed of 2.5 cm/min and a chart speed of 50 cm/min. A 1.27-cm diameter, flat, circular probe was centered over the middle dock hole of an individual cracker placed top side down on a flat plate. The cracker was measured for thickness and then compressed to 50% of its original thickness. The curves generated were examined for their general shape, including the angle to the first break, the degree of failure, the average force of the curve, and the final force. This test was designed to simulate the shattering of the cracker in the mouth during chewing with the molars. Organoleptic analysis was also carried out on most samples.

RESULTS AND DISCUSSION

Cracker Texture Analysis

An untrained organoleptic panel was used to survey five brands

TABLE I
Analytical Data for Flours Used for Cracker Baking

Flour Sample	% Protein (14% mb)	% Ash (14% mb)
1	9.37	0.45
2	7.82	0.42
3	10.08	0.48

of commercial crackers. Panel results revealed distinct differences in cracker texture. The first bite of cracker, with the incisors, indicated the hardness/tenderness of the cracker. Continued mastication with the molars indicated the friability of the cracker. To account for those differences, two separate but related cracker texture tests were performed.

Typical UTM crushing curves are depicted in Figure 1. A tender, friable cracker (Fig. 1A) requires a moderate amount of force to cause the first failure, yet the angle to the first break is steep. After the first failure, the cracker has many minor and major failures. The resistance to force remains fairly constant throughout the test period.

A cracker judged to be tough and pasty, shown in Figure 1B, has a lower slope to the first break and continues to build resistance to force throughout the entire testing period. Few, if any, major failures are noted.

Effect of Sponge (Starter) Ingredients

The sponges made with no yeast or slurry produced doughs that were nonuniform or mottled in appearance and crackers that had uneven puffing. Because of the uneven puffing, the measured stack height (Table II) was not a good guide to the inner structure of the crackers. These crackers had excessive shelling (separation of external layers), poor lamination, poor cell structure, and were very tender. The extreme tenderness made it very difficult to obtain 10 unbroken cells from the sheet of 21 cells. When tested organoleptically, the initial bite was overly tender. However, there was a pastiness that remained around the molars during several compressions. The UTM compression procedure showed a building of resistance, with large variability within the treatment.

The crackers baked from sponges containing flour, water, and yeast showed a slight decrease in stack height and a decrease in stack weight when compared with crackers made from sponges containing only flour and water (Table II). Increased gas production and/or increased gas retention would change the

TABLE II
Effect of Varying Starter on Baking Performance^a

Starter	Sponge pH	Stack Ht ^{b,c} (mm)	Stack Wt ^{b,c,d} (g)	Ht/Wt Ratio
None	5.41	72.55 a	35.36 a	2.05
Yeast	4.88	71.51 a	33.36 ab	2.14
Slurry	3.63	63.88 b	36.49 a	1.75
Yeast + slurry	3.77	68.40 ab	31.63 b	2.16

^aBaked using flour 1; average of four replicates.

^bStack of 10 crackers.

^cDifferent letters denote significant differences at the 0.05 level.

^dDry basis.

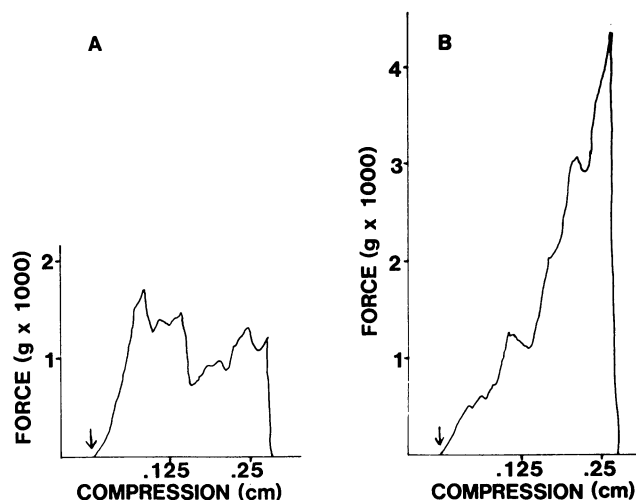


Fig. 1. Universal testing machine compression curves of crackers, using a 1.27-cm diameter flat circular probe. A, tender, friable cracker; B, tough and pasty cracker.

density of the dough, resulting in a reduced weight for the constant volume being examined. The crackers also had a more uniform cell structure than crackers made with no yeast or slurry, although the actual stack height was less. The crackers were noticeably paler in top color than the crackers from the other treatments, indicating the depletion of fermentable carbohydrates (reducing sugars needed for browning) by the yeast.

Organoleptically, the crackers made from the yeasted sponge were tender, although not as fragile as the crackers made without starter. The pasty sensation lingering around the molars during mastication was still evident. The UTM compression curves showed a continual building of resistance throughout the compression, with one or two major breaks in the compression curve.

After 18 hr of fermentation (Table II), the pH of the sponge set with flour, water, and yeast, although lower than that of the flour and water sponge, was still higher than the optimum pHs (3.8 and 4.2) of the proteolytic enzymes reported in flour (Salgo 1981). The major changes, thus, could not be attributed to increased protein modification occurring in the sponge. Therefore, it appeared that the yeast was necessary for gas production.

The gas produced by yeast lowers the dough density. Thus, for a given area (docker cell), fermentation would lower the dough weight and subsequent cracker weight. In addition, bubble nucleation is required for uniform puffing between the lamellae of the finished product. The large bubbles are subdivided during dough mixing and during sheeting. Those smaller, finer air cells create the even, flaky puffing preferred in saltine crackers.

Sponges containing the slurry, flour, and water produced crackers with stack weights slightly greater than those of the flour and water sponges but with greatly reduced stack height (Table II).

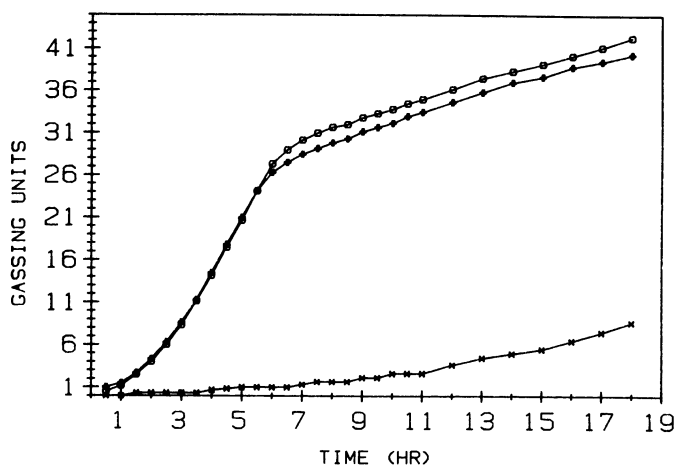


Fig. 2. Gasograph curve of fermenting sponges. Sponge containing slurry (—x—), sponge containing yeast (—+—), sponge containing slurry and yeast (control) (—o—).

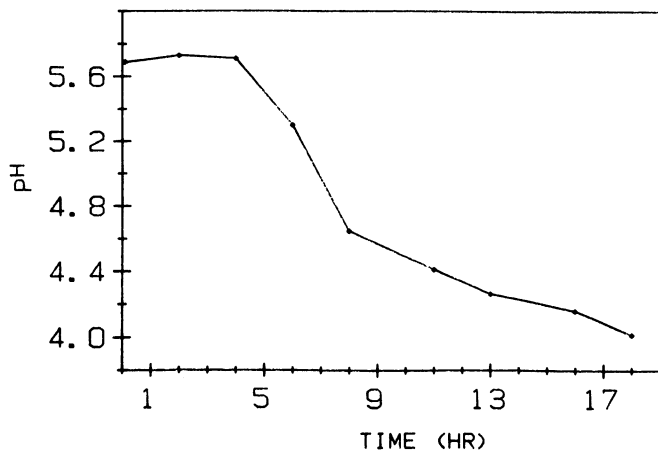


Fig. 3. Change in sponge pH as a function of fermentation time.

The dough was both more extensible and more developed (more cohesive) than normal. The improved puffing between laminations of those crackers compared to the flour and water crackers indicated that some gas was produced, even in the absence of added yeast.

The texture of the crackers made with slurry, determined organoleptically, was similar to that of the control crackers. The crackers were strong yet not tough and did not build up around the molars during mastication. The UTM compression curves were fairly level in force, with mainly minor failures.

A sponge set with yeast and slurry (the standard or control cracker) appeared to have a combination of the individual effects of yeast and slurry (Table II). The control sponge yielded crackers that were reduced in both stack height and stack weight when compared to the flour and water sponge crackers. The texture was strong without being pasty. The UTM compression curves showed fairly constant resistance during the compression. They showed two to three major failures, along with several minor breaks. Based on these data, we concluded that the yeast was necessary for gas production, and the starter was required to lower the pH sufficiently for the proteolytic enzymes inherent in the flour to become active, as shown by Wu (1987).

To test the relationship between gas production during sponge fermentation and cracker quality, the gasograph was used. Sponges made with flour, water, yeast, and slurry (control, Fig. 2) had a rapid initial rate of gas production that leveled off after approximately 6 hr of fermentation. A plot of sponge pH during the 18-hr fermentation (Fig. 3) indicates that at 6 hr the pH was probably near pH 5.5, the optimum for yeast gas production (Pylar 1973, Holmes and Hoseney 1987).

Depletion of fermentable carbohydrates appears to be the most likely reason for the reduction in gas production at 6 hr. To test that assumption, sucrose (3%) was added to a sponge after 6 hr of fermentation. The rate of gas produced during the next 6 hr was 0.945 gassing units/hr, whereas that for the control (unfed) sample was 0.569 gassing units/hr during the second 6-hr period.

Gas production of the sponges set with flour, water, and yeast was equal to that of the control (Fig. 2). The sponges made with only flour, water, and slurry produced relatively little gas during the 18-hr period. These data supported the hypothesis that adequate gas production was necessary for good quality crackers.

The bacteria in the slurry lower the sponge pH. If lowering the pH is the only important function of the starter, then one should be able to mimic that change by using acid. To produce a "mock" starter system, a constant 3-hr yeast fermentation was arbitrarily selected, followed by a lactic acid reaction time that varied from 8 to 14 hr (Table III). This reaction time was to allow the flour proteolytic enzymes time to work. With an 8-hr reaction time, the dough was stiff and strong and did not sheet uniformly. As the acid reaction time was increased, the doughs became more extensible and softer to the touch.

The crackers produced with either 8 or 10 hr of acid reaction time gave nonuniform puffing. This indicated an excessively strong sponge. In general, over the time range studied, increasing acid treatment times resulted in decreased stack heights and slightly decreased stack weights. The 12- and 14-hr treatment crackers had uniform puffing. Because additional time did not appear to be of

TABLE III
Effect of Varying Acid Reaction Time,
Following 3 hr of Yeast Fermentation, on Baking Performance^a

Acid Time (hr)	Sponge pH	Stack Ht ^b (mm)	Stack Wt ^{b,c} (g)	Ht/Wt Ratio
8	3.95	73.97	33.67	2.20
10	3.87	73.09	33.70	2.17
12	3.82	71.39	32.66	2.19
14	3.85	70.31	32.11	2.19

^a Baked using flour 1; average of three replicates. Mean standard deviation for stack height = 0.79, for stack weight = 1.09.

^b Stack of 10 crackers.

^c Dry basis.

any benefit, a 12-hr lactic acid treatment was selected as optimum.

With lactic acid rest time held constant at 12 hr, the length of the initial yeast fermentation was varied (Table IV). In general, stack height increased as the time of yeast fermentation increased from 1 to 5 hr. No trend was apparent in the stack weight. The height/weight ratio, an indication of lift, appeared to plateau at 2 or 3 hr of fermentation. The quality of the cracker cell structure for all yeast fermentation times longer than 1 hr was equal to that of the control crackers, as was the texture of the crackers. Therefore, an adequate mock cracker system had been developed, using a 2-3-hr yeast fermentation followed by a 12-hr reaction time at pH 4.

Effect of Sponge Fermentation Time

As might be expected, the sponge pH decreased, and total titratable acidity (expressed as milliequivalents of acid per gram of sponge) increased as the fermentation time increased (Table V). Doughs with 0- and 6-hr sponge fermentation times were too crumbly to hold together during sheeting. An additional 2% water was added, but even then the doughs appeared dry in areas and were too crumbly to sheet satisfactorily. The crackers produced from both the 0- and 6-hr sponge fermentation samples shattered easily and puffed unevenly.

As fermentation time was increased, both the stack height and stack weight of the crackers decreased, indicating a continual protein modification and/or increased gas production. This was in agreement with work by Pizzinatto and Hosoney (1980a,b). Increasing fermentation time resulted in doughs that were more pliable and easier to machine.

As shown previously (Rogers and Hosoney 1987), for any given

TABLE IV
Effect of Varying Yeast Fermentation,
Prior to 12-hr Lactic Acid "Fermentation," on Baking Performance^a

Yeast Time (hr)	Sponge pH	Stack Ht ^{b,c} (mm)	Stack Wt ^{b,d} (g)	Ht/Wt Ratio
1	3.88	77.49 bc	37.53	1.93
2	3.95	73.05 bc	36.02	2.03
3	3.86	73.54 bc	35.51	2.07
4	3.89	71.72 c	36.70	1.95
5	3.88	75.84 a	38.12	1.99
6	3.96	74.68 ab	36.56	2.04
7	3.88	73.71 abc	35.83	2.06
8	3.92	73.77 abc	35.71	2.07

^a Baked using flour 1; average of five replicates.

^b Stack of 10 crackers.

^c Different letters denote significant differences at the 0.05 level.

^d Dry basis.

TABLE V
Effect of Varying Sponge Fermentation Time on Baking Performance^a

Fermentation Time	Sponge pH	TTA ^b (meq/g)	Stack Ht ^{c,d} (mm)	Stack Wt ^{c,d,e} (g)	Ht/Wt Ratio
Flour 1					
0 hr (+2%)	5.35	0.0150	76.72 a	38.78 a	1.99
6 hr (+2%)	4.95	0.0254	73.95 ab	35.67 b	2.07
12 hr	4.61	0.0304	74.26 ab	36.12 b	2.06
19 hr	4.10	0.0433	73.04 b	34.18 b	2.14
Flour 2					
0 hr (+2%)	5.10	0.0145	70.33 a	38.99 a	1.80
6 hr (+2%)	4.54	0.0251	68.64 b	37.46 ab	1.83
12 hr	3.92	0.0392	67.29 b	35.67 b	1.89
18 hr	3.60	0.0523	63.48 c	35.50 b	1.79
Flour 3					
0 hr (+2%)	5.57	0.0152	76.19 a	45.65 a	1.67
6 hr (+2%)	4.89	0.0299	75.18 a	44.35 ab	1.70
12 hr	4.15	0.0436	72.08 b	42.16 b	1.71
18 hr	3.82	0.0607	73.05 b	42.26 b	1.73

^a Average of four replicates.

^b Total titratable acidity.

^c Stack of 10 crackers.

^d Different letters within flours denote significant differences at the 0.05 level.

^e Dry basis.

treatment, increasing the water level caused a decrease in stack height and stack weight. Therefore, the effect of sponge fermentation time on stack height and stack weight is greater than noted in Table V and can be used to explain the slight increase in stack height and weight between the 6- and 12-hr samples for flour 1.

The doughs became more extensible as fermentation time increased. The doughs not only felt different, but, because of increased extensibility, the final sheeted dough-piece increased in dimensions as fermentation time was increased. That resulted in a change in the weight of an unbaked cracker cell. The net result was that important, time-mediated changes occurred during sponge fermentation that affected the final cracker quality. These changes may have been caused by increased flour protease activity, pH-induced conformational changes of the protein, or a combination of those phenomena.

The effect of the fermentation time on cracker texture was also studied. The UTM breaking strength increased as fermentation time increased. There was a definite continuum of the organoleptic texture from the crackers fermented 0 hr through those fermented 18 hr. Those crackers with no sponge fermentation were overly tender and easily broken on the first bite. The layers appeared to be very thin, both visually and organoleptically. However, the crackers seemed to cling to the teeth, as if the fragments remained positioned in the mouth exactly where they broke. The 18 hr fermentation crackers required more force to bite initially, yet they broke cleanly in the mouth.

UTM compression curves showed a slight building of resistance with few major failures for the samples fermented for 0 and 6 hr. The samples fermented for 12 and 18 hr were stronger and had more major failures. It would appear from these data that sponge fermentation time was necessary to transform the texture of the crackers from exceedingly tender to strong.

One explanation for such a transformation would be that in a low water system, the flour particles remain discrete entities that do not form a continuous matrix during mixing or during the sheeting process. After baking, the crackers fracture easily at the particle-particle interfaces, resulting in overly tender crackers. Small increases in the baking absorption permit a more continuous dough mass to be formed, although most of the protein remains within the particles. Further increases in the baking absorption result in a disappearance of all (or most) of the particles. The matrix is strong, yet brittle, and breaks all at once. When a mixture of particles and matrix is present, as at the medium absorption levels, failures occur first around the particles and then through the developed matrix. Increasing fermentation time permits more of the flour particles to hydrate and, thereby, form a more continuous matrix. The more extensive the matrix, the stronger the cracker.

Effect of Dough-Up Rest Time

The importance of the dough-up "fermentation" or rest time was also studied. It was assumed that the dough-up rest period was simply a hydration time, allowing the 35% additional flour to become equilibrated in moisture with the sponge ingredients.

Stack height increased as dough rest increased from 0 to 4 hr, then dropped (Table VI). The crackers with a 2-hr dough rest had stack weights that were much heavier than those with the other rest times. The crackers produced with 0- and 2-hr dough-up rest times

TABLE VI
Effect of Varying Dough-Up Rest Time on Baking Performance^a

Dough Rest (hr)	Stack Ht ^b (mm)	Stack Wt ^{b,c} (g)	Ht/Wt Ratio
0	66.40	37.29	1.78
2	72.40	39.42	1.84
4	74.66	37.00	2.02
6	71.84	37.72	1.90

^a Baked using flour 1; average of four replicates. Mean standard deviation for stack height = 0.79, for stack weight = 1.07.

^b Stack of 10 crackers.

^c Dry basis.

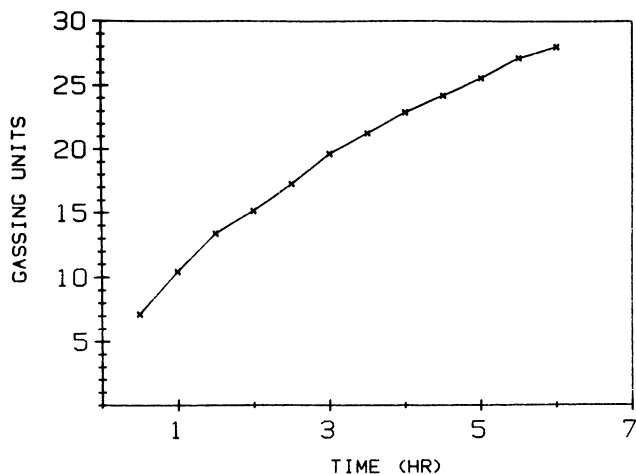


Fig. 4. Gasograph curve of cracker dough during the dough-up fermentation time.

were uneven in puffing characteristics, somewhat resembling crackers made with short sponge fermentation times. Increasing the dough-up rest times increased the evenness of puff and improved the overall lamination characteristics.

The 0-hr doughs felt soft and excessively wet to the touch, yet would not hold together well. A rest time of 2 hr caused the dough to feel drier, but it remained crumbly during sheeting. The dough with 6 hr rest time felt dry prior to sheeting but was elastic during the sheeting process.

These data indicate that a hydration time was required for the water to equilibrate throughout the dough. If the dough was given too long a rest time, the dough appeared to become slightly dry, yet the effects were similar to those resulting when excess water was added to the sponge. The 6-hr dough-up rest sample felt more developed (elastic) than did the 4-hr (control) dough, and the crackers decreased in stack height. The texture of the crackers changed continually over the dough rest time studied. The 0-hr samples were tender or fragile, whereas the 6-hr samples were strong.

Recent work (Holmes and Hosenev 1987) indicated that although the optimum pH for yeast activity is approximately 5.5, yeast is tolerant to large changes in pH, maintaining a substantial rate of gas production between pH 3.7 and 8.0. That study was carried out at conditions simulating bread production. However, it indicated that yeast may remain active in the pH range found in cracker doughs.

When cracker dough was placed in the gasograph for the dough rest period, substantial quantities of gas were produced (Fig. 4). The rate of gas production started to slow by 4 hr, but gas was produced during the entire 6-hr period studied. Therefore, the decrease in stack height for the 6-hr dough rest samples could not be attributed to reduction in gas production.

CONCLUSIONS

Two cracker texture tests were developed to simulate the initial force required to bite a cracker and the shattering of the cracker in

the mouth during chewing with the molars. Yeast was found to be necessary for gas production in the sponge. During sheeting, large bubbles are subdivided to create the fine, even laminations desired in saltine crackers. Starter is required to lower the pH sufficiently for proteolytic enzymes in the flour to become active. Lengthening the sponge fermentation time decreased sponge pH, increased total titratable acidity, increased the cohesiveness of the dough, decreased both stack height and stack weight of the crackers, increased the evenness of puffing, and increased cracker strength. Increasing the dough-up rest time increased the elasticity of the sheeted dough and the evenness of cracker puffing.

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