Saltine Crackers: Changes in Cracker Sponge Rheology and Modification of a Cracker-Baking Procedure[1]

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ABSTRACT

A liquid starter (inoculum) was developed for use in cracker sponges. 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 of 4.1. To produce the most desirable inoculum, a mixture of flour, water, yeast, and sucrose (100:200:0.62:3) was fermented 18 hr, then fed with 20% flour, and fermented another 18 hr. The sponges produced with a 5% inoculum of this mixture reached a pH in the 4.1 range in 18 hr. The 18-hr cracker sponge fermentation is a critical step in the production of good quality crackers. Changes in the rheological properties of doughs 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 later part of fermentation, when pH was low, a proteolytic enzyme native to the flour appeared to be active. The cracker test-baking procedure was modified to accommodate weaker flours and/or flours that were modified during sponge fermentation.

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Cracker doughs are prepared by the sponge and dough process, which covers a 22–26 hr period (Heppner 1959). The lengthy fermentation is necessary to modify the gluten and to develop the unique flavor and texture of this product (Howard 1956).

Soda cracker fermentation is similar to sour dough bread production in that 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).

Bacterial fermentation has been thought to play a vital role in the 18-hr sponges used in soda crackers (Sugihara 1978 a,b). 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 1955).

When cracker sponges are fermented, significant changes in rheology occur. Strength of the cracker sponge decreases as fermentation time increases and pH decreases. In recent studies this effect was attributed to a proteolytic enzyme native to the flour (Pizzinatto and Hoseney 1980a) with optimum activity in the pH 3.8–4.2 range.

When crackers are produced in a laboratory, no starter sponge is kept, and equipment is sterile. Fermentation is greatly retarded, and the resulting dough has a high pH and a cracker with undesirable flavor (Micka 1955).

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. Pizzinatto and Hoseney (1980b) have described a laboratory-scale saltine cracker procedure. Some of the problems in producing a starter sponge for saltines were studied by Fields et al (1982).

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

The purpose of this study was to develop a starter to use as an inoculum for cracker sponges. This starter was then used to study changes in rheology during sponge fermentation and to modify a laboratory-scale test-baking procedure for crackers.

MATERIALS AND METHODS

Ingredients

Two hard wheat flours were used to prepare slurries: Kansas State University flour (12.1% protein, 0.46% ash) and a commercial flour (11.6% protein, 0.46% ash), both at 14% moisture basis. A commercial cracker flour was used for the baking experiments (9.6% protein, 0.51% ash), and a second stronger flour (10.3% protein, 0.56% ash) was used in certain rheological tests.

Compressed yeast (Anheuser-Busch, St. Louis, MO) was aged three weeks at 4° C before use. Hydrogenated vegetable shortening (Crisco, Procter & Gamble Co., Cincinnati, OH) was used in sponges prepared for rheological tests. Lard (Armour Food Co., Phoenix, AZ) was used in cracker doughs prepared for baking tests. 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 used for most experiments. Yeast was 0.62% of the flour weight. Sucrose was added to the slurries at 0, 1, 2, or 3% of the flour weight.

All slurries were fermented uncovered for 18 hr at 30° C with 90% relative humidity (rh) in a proof cabinet. A small amount of flour, sucrose, or a mixture of the two, was then added, and the slurries were given a second 18-hr fermentation.

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

Effectiveness of the slurries to lower the sponge pH was studied by adding slurries 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.

Extensigrams

A Brabender extensigraph was used to measure the rheological characteristics of sponges (Pizzinatto and Hoseney 1980a). Sponges were prepared using the formula given in Table I and mixed in a National pin mixer (454-g bowl size) for 2 min, then scraped and mixed an additional 1 min. The mixer speed was adjusted to 32 rpm by changing the pulley size. In some trials sponges were not fermented between sponge and dough stage mixing. In other trials, sponges were covered and fermented for 3, 6, 9, 12, 15, or 18 hr at 30° C and 90% rh.

At the dough mixing stage, vegetable shortening (11.0% Crisco) was placed in a bowl followed by sufficient soda to give a pH of 7.0, salt (1.8%), and sponge. The last 35% of the flour (dough flour) in the formula was not added because complete doughs were too strong to measure on the extensigraph. Sponges were given 4 min mixing followed by scraping and mixing an additional 1 min. Three 150-g test pieces were scaled from each 500 g of dough. 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 in a humidified chamber (30° C, 100% rh), dough pieces were tested for resistance to extension and extensibility.

In other experiments, the sponges were mixed with sufficient lactic acid to give a pH of 4.1. The doughs were allowed to ferment for 6 hr, and the rheology was determined as indicated above.

Cracker Baking

Crackers were baked using a slight modification of Pizzinatto and Hoseney's (1980b) procedure. The cracker formula used is shown in Table I. Sponges were mixed in the manner described above and transferred to lightly greased 1-L beakers, covered with a plastic bag, and fermented for 18 hr at 30° C and 90% rh.

At the dough mixing stage, lard was placed in the mixing bowl, followed by the dough flour, soda, salt, and the fermented sponge. Sponges were mixed 4 min, the dough scraped from the pins and bowl and mixed an additional 1 min. The dough was fermented 6 hr, so that total fermentation time was 24 hr.

After fermentation the dough was flattened by hand to uniform thickness in a rectangular frame (8.89 × 27.9 × 2.54 cm). This dough piece was cut in half before sheeting, giving two pieces 8.89 × 14.0 × 2.54 cm each, and passed 10 times through the rolls of an Anets pie-sheeter. The dough was reduced from 25 to 5.65 mm on the first four passes through sheeter openings at 16.12, 12.30, 9.50, and 5.65 mm. Then the dough was folded lengthwise and passed through the 5.65 mm setting, folded again and passed through rolls set at 2.88 mm. After a pass at 1.25 mm the dough was folded lengthwise and turned 90° before a second pass at 1.25 mm. Dough thickness was finally reduced to 0.30 mm.

The sheeted dough was placed on cookie sheets and covered with bakery parchment paper to prevent drying. The sheeted doughs were cut and docked with a small cutter-docker with 21 cells (7 × 3, 52 × 48 mm each). The dough was placed on the inverted cutter-docker, pressed onto all of the pins with a rolling pin, and inspected to ensure complete cutting. A border of dough (approximately 2 cm) was left to prevent the cracker edges from over-browning during baking.

After docking, the cutter-docker was inverted and the dough released onto a pressed board (22.9 × 43.2 × 0.64 cm) that served as a support for the dough. The cut and docked crackers were slid from the board onto a preheated (1 min at 265.5° C) baking sheet, expanded metal (gauge 20-22), measuring 21.6 × 43.2 cm, with 7.62-cm legs. Crackers were baked for approximately 3 min 15 sec in a National Manufacturing reel-type electric oven with the reel stopped and a sheet of steel 3 mm thick spanning two shelves. The oven door was opened the last 20 sec to control browning.

Baked crackers were cooled on metal racks at room temperature for about 30 min. They were stored overnight in plastic bags and 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.

TABLE I
Cracker Formula[1]

Ingredients	Sponge (%)	Dough (%)
Flour	63.50	35.0
Water	22.00	···
Yeast	0.36	···
Slurry[b]	4.52	···
Lard	···	11.0
Salt	···	1.8
Soda	···	0.45

[a] Ingredients based on flour weight.
[b] Slurry is 5% of total sponge weight and contains 1.5 g of flour and 3 g of water.

TABLE II
Changes in pH During 18-hr Fermentation of Slurries

Slurry (Flour:H_2O)	pH	
	Initial	Final
1:4	6:10	4.35
1:3	6.10	4.55
1:2	6.05	4.35
Yeast		
1:4	6.05	3.93
1:3	6.09	4.00
1:2	6.05	4.25

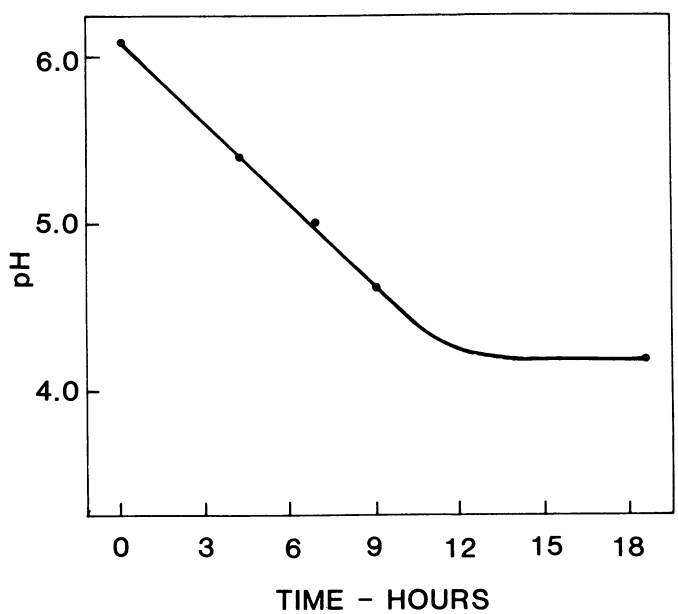

Fig. 1. Change in slurry pH during fermentation.

TABLE III
Effect of Inoculum on Sponge pH During 18-hr Fermentation

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

RESULTS AND DISCUSSION

Slurry

Over an 18-hr fermentation period, pH dropped a similar amount for slurries with flour to water ratios of 1:4, 1:3, and 1:2 (Table II). All slurries prepared without yeast developed an intense off-odor. Slurries with the same flour to water ratios but containing 0.62% yeast did not develop off-odors and gave lower pH values.

In all cases, the most rapid drop in pH occurred during the first 9 hr of fermentation (Fig. 1). According to Micka (1955), the growth of acid-producing bacteria proceeds rapidly during the first 10 hr of fermentation and then slows as the nutrient supply is exhausted. Our data support that theory.

Sponges were inoculated at different levels (sponge weight basis), and change in pH during fermentation was determined (Table III). Although sponge pH dropped significantly, the final pH of 4.2–4.38 was somewhat above the acceptable range of 3.8–4.15 for a cracker sponge.

On the assumption that the nutrient supply was exhausted, we added fermentable carbohydrates and gave the slurry a second 18-hr fermentation. This resulted in lower pH values (Table IV). Sponges produced from those slurries reached a pH in the desired range (Table V).

TABLE IV
Effect of Nutrient Source on pH and Total Acidity After 18-hr Fermentation

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

TABLE V
Effects of Sucrose Added to Flour on Slurry and Sponge After Fermentation

Slurry		pH After		
Sucrose (%)	Flour (%)	1st 18 hr	2nd 18 hr	Sponge pH
0	20	3.98	3.92	4.13
0.5	20	3.98	3.85	3.93
1	20	3.90	3.75	3.92
2	20	3.85	3.70	3.90

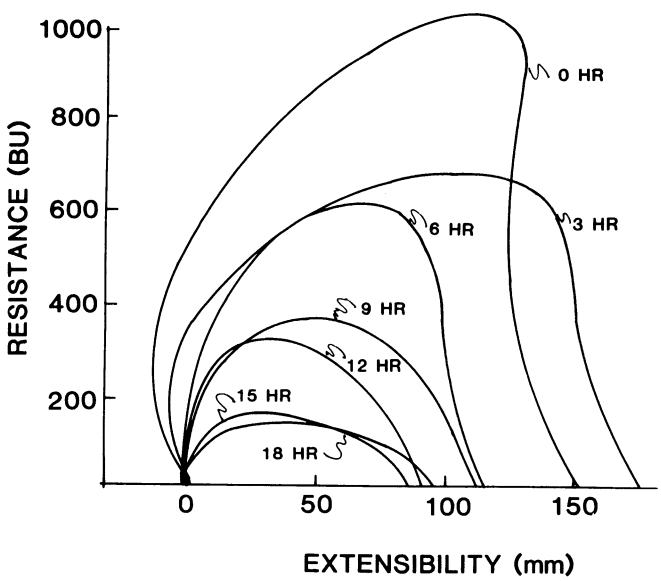

Fig. 2. Effect of fermentation time on the extensigram properties of cracker sponges. Each sponge was adjusted to pH 7.0 with soda. BU = Brabender units.

When slurries reach a pH in the 3.75–3.9 range, sponges reach a pH between 3.8 and 4.15. Thus, a slurry seems to be effective in producing cracker sponges with sterile equipment or without a starter sponge.

Rheology

Results of extensigraph studies on cracker flours showed that resistance to extension and extensibility of sponges decreased with fermentation (Fig. 2) and that the change was progressive throughout the fermentation period. When compared with the pH change during fermentation, it is clear that much of the rheological change occurred at relatively high pH (above pH 5.2). Clearly, this is not the result of the proteolytic enzyme active at pH 4.1 as suggested by Pizzinatto and Hoseney (1980a).

Extensigraph studies showed that changes in resistance to extension were similar for sponges made with or without yeast or slurry. Initial strength differed, but all came to the same point after 15 hr of fermentation (Fig. 3). The extensibility of all sponges increased during the first 3 hr, then decreased in yeasted systems. The flour-water system became very extensible, increasing up to the ninth hour of fermentation (Fig. 4). The flour-water dough remained extensible through the last 9 hr of fermentation. Pizzinatto and Hoseney (1980a) attributed changes in the rheological character of the dough to the action of a proteolytic enzyme with optiumum activity at pH 4.1. If the proteolytic enzyme were solely responsible for the rheological changes, then no changes should be found until the pH dropped to near pH 4.1 (9th–12th hr). Clearly other factors are at work.

If a proteolytic enzyme native to the flour is responsible for changes that occur late in the fermentation period, then its action should be evident when the pH is dropped to the optimum level for its activity. Samples "fermented" 6 hr at pH 4.1 showed decreased resistance to extension. Both strong and weak flours had less resistance to extension after fermentation for 6 hr at pH 4.1 than after 6 hr of normal sponge fermentation. The weak flour showed a more rapid drop in resistance to extension than did the strong flour (Fig. 5). Both strong and weak flours showed increased extensibility when fermented at low pH (Fig. 6). These results are

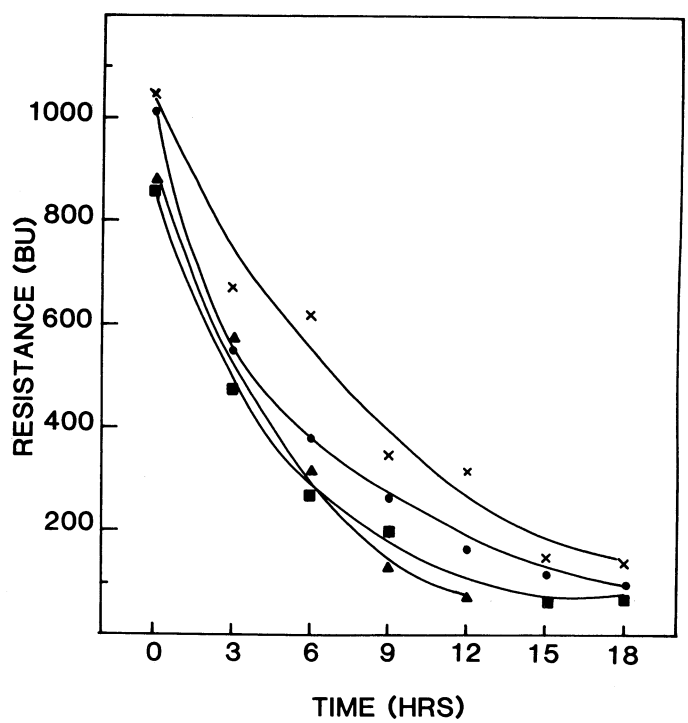

Fig. 3. Effects of ingredients on the resistance to extension of fermenting sponges. Sponges from a weak flour were produced containing flour and water (•); flour, water, and yeast (▲); and flour, water, yeast, and slurry (■). A sponge from a strong flour was produced containing flour, water, yeast, and slurry (X).

consistent with a proteolytic enzyme acting at an optimum of pH 4.1. Although the results of these studies do provide some evidence that a proteolytic enzyme acts in the system, other factors must be at work.

Cracker Baking

A commercial cracker flour, identified by the flour supplier as one that made good saltines, was used to evaluate the effectiveness of the starter in the cracker-baking procedure of Pizzinatto and Hoseney (1980b). The same flour was used at both sponge and dough stages. Incorporation of the starter in the sponges resulted in crackers with very low weights and poor oven spring. It appeared their sheeting procedure was too rigorous for a properly modified dough.

Cracker doughs do not become fully developed during mixing. The development occurs during the sheeting process. It follows that stronger flours or those not properly modified during fermentation 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.

Visual examination showed that the physical character of the dough changed when it was sheeted at 1.25 mm. Passes made at that setting or at smaller gaps appeared to affect the strength of the dough. When the sheeting procedure was modified to produce crackers with the correct weight, however, the stack height or oven spring was low. To test whether the rate of heating was too slow

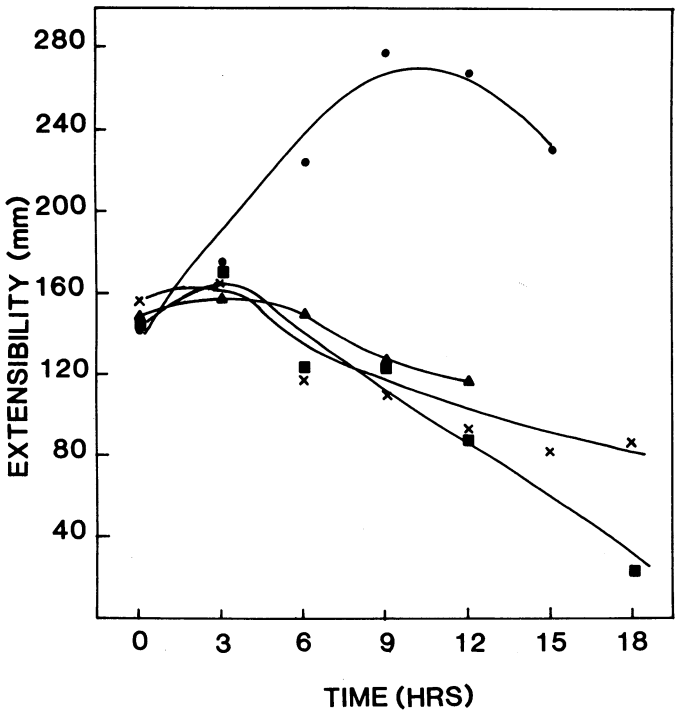

Fig. 4. Effect of ingredients on the extensibility of fermenting sponges. Sponges from a weak flour were produced containing flour and water (•); flour, water, and yeast (▲); and flour, water, yeast, and slurry (■). A sponge from a strong flour was produced containing flour, water, yeast, and slurry (X).

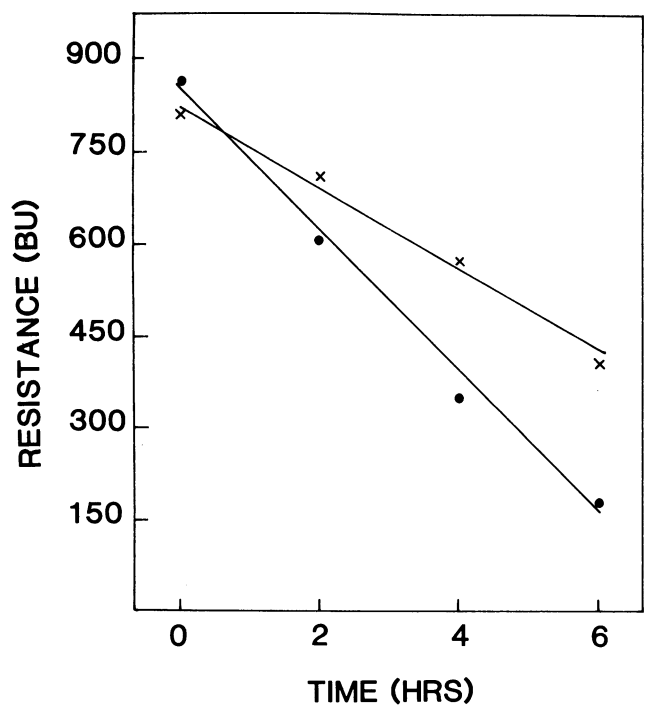

Fig. 5. Effect of fermentation at low pH on the resistance to extension of cracker sponges. Sponges produced from a strong flour (X) and a weak flour (•) had pH dropped to 4.1 with lactic acid. Sponges were neutralized with soda before testing.

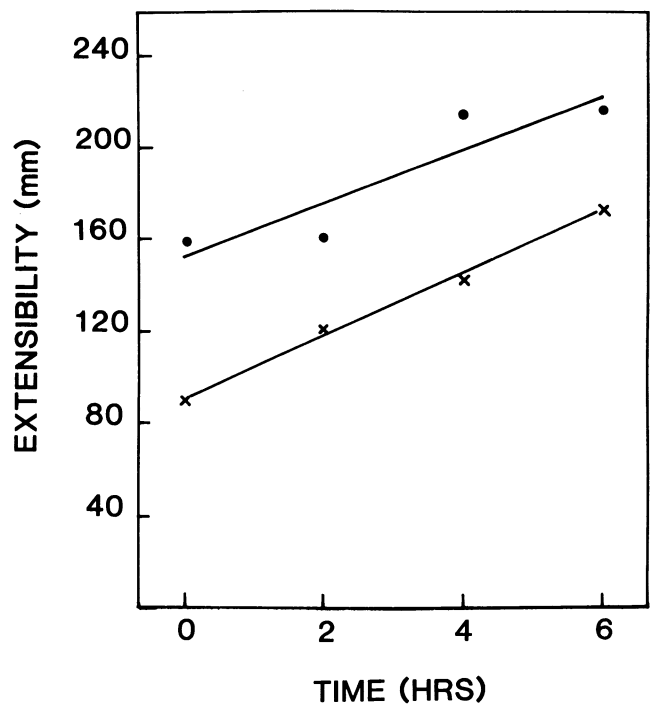

Fig. 6. Effect of fermentation at low pH on the extensibility of cracker sponges. Sponges produced from a strong flour (X) and a weak flour (•) had pH dropped to 4.1 with lactic acid. Sponges were neutralized with soda before testing.

TABLE VI
Reproducibility of Cracker Baking Procedure[a]

Trial	Height (mm)	Weight (g)	Height/ Weight
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
Standard deviation	1.72	1.78	0.12

[a] Data for stack of ten crackers.

when the crackers were first placed in the oven, 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 the crackers had improved ratios of height to weight. The reproducibility of the modified procedure was determined (Table VI). Standard deviation for the height to weight ratio was 0.12.

In conclusion, the modified baking method is quite reproducible. It seems to be well suited for the flours commonly used in the cracker industry. Flours that are strong or not properly modified during fermentation need and can tolerate more rigorous sheeting before they lose their elasticity. Use of rheological tests to predict baking quality of cracker flours has limited value, which indicates a need for more reliable predictive tests.

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