Development of a Benchtop Baking Method for Chemically Leavened Crackers
II. Validation of the Method

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ABSTRACT

A benchtop baking method has been developed to predict the contribution of gluten functionality to overall flour performance for chemically leavened crackers. Using a diagnostic formula and procedure, dough rheology was analyzed to evaluate the extent of gluten development during mixing and machining. The effects of enzymes on cracker-baking performance were explored to assess the impact of damaged starch and pentosans (arabinoxylans). Validation of the method for predicting gluten functionality and performance was conducted using various flours. Cracker dough rheology, measured in the direction of sheeting, showed a positive correlation with the ratio of cracker height to dough weight, but a negative correlation with the ratio of cracker width to length. Use of α-amylase and xylanase demonstrated the improving effects of enzymes on cracker-baking performance of flour resulting from decreased dough crumbliness and increased cracker height. Flour gluten performance ratio of lactic acid solvent retention capacity (LA SRC)/(sodium carbonate (SC) SRC + sucrose (Suc) SRC) (SRC LA/(SC+Suc)) was a better predictor of cracker geometry than was flour gluten functionality value of LA SRC alone. Flours with a gluten performance ratio of <0.52 produced unacceptable, excessive blistering during cracker baking.

Soya solvent retention capacity (SRC) is increasingly used for analyzing soft wheat flour functionality. The relationship between flour SRC and cookie quality has been widely reported (Slade and Levine 1994; Gaines 2004; Guttieri et al 2004; Ram and Singh 2004; Roccia et al 2006; Zhang et al 2007; Nishio et al 2009; Kweon et al 2010), based on the widespread use of well-established benchtop cookie-baking methods. In contrast, reports relating flour SRC to cracker quality have been scarce because there have not been any previously established, easy-to-use, benchtop cracker-baking methods. Thus, to satisfy a long-standing demand from academia and industry for a benchtop baking method to predict the contribution of gluten functionality and performance to overall flour performance for cracker baking, Kweon et al (2011) have recently identified and reported a diagnostic formula and procedure for a benchtop method for producing chemically leavened crackers.

The biscuit-baking industry in the United States generally prefers soft wheat flours with high gluten strength but low water-holding capacity for use in commercial cracker production. Damaged starch generated during flour milling and arabinoxylans from the aleurone and bran layers of the wheat kernel significantly increase the water-holding capacity of flour, which is an undesirable characteristic for good quality cracker flours (Slade and Levine 1994). For flours with high water-holding capacity, cracker dough development during mixing requires the addition of excessive water, which may necessitate concomitant increases in baking time and temperature, resulting in increased energy costs to bake out the extra water to attain simultaneous finished product targets for moisture content and color. The increase in water-holding capacity of flour contributed by damaged starch and arabinoxylans can be reduced by α-amylase and xylanase enzyme treatments, respectively (Slade and Levine 1994). Such enzymes, as well as proteases, are commonly used in commercial cracker production (Slade et al 1993). Use of proteases can result in reduced dough-mixing time, increased extensibility of doughs, and improved dough handling and machinability. Measurement of biscuit dough rheology is a common practice in the U.S. baking industry for predicting dough-handling and machinability properties that relate to product quality. Numerous reports are published on the dough rheology of cracker and other biscuit products (Wu and Hoseney 1989; Amemiyia and Menjivar 1992; Oliver and Brock 1997; Pedersen et al 2004, 2005).

In the present study, cracker dough rheology was analyzed to evaluate the extent of gluten development during dough mixing and machining. The effects of enzymes on cracker-baking performance were explored to assess the impact of damaged starch and arabinoxylans. Various flours were evaluated using a diagnostic cracker formula and procedure to validate a previously developed benchtop method for chemically leavened crackers (Kweon et al 2011).

MATERIALS AND METHODS

Two sets of wheat samples were obtained (10 cultivars in the first set and 18 cultivars in the second set) grown at five locations (OH, VA, IN, MI, MO) in the eastern United States in 2006 and 2007. The first set of wheats (11.8–15.0% moisture) and the second set of wheats (8.1–13.7% moisture) were tempered to 15 and 14% moisture, respectively, before milling to produce straight-grade flour on a Milli-Mat II mill. The resulting 28 flours (12.5–14.7% moisture, 7.1–10.5% protein) were used for SRC analysis and cracker baking. Xylanase (endo-arabinoxylanase, 10250 XYL/mL) and α-amylase (bacterial, 261, 375BAA/g) were obtained from Kerry/Quest Ingredients. Leavening agents, sodium bicarbonate (soda; USP 1 grade) and monocalcium phosphate (HT MCP; monohydrate, fines), were obtained from Church & Dwight (Old Port, OH) and ICL Performance Products (St. Louis, MO), respectively. Ammonium bicarbonate (ABC) was obtained from Fisher Scientific (Pittsburgh, PA). Other chemicals were reagent-grade.

SRC

All flour samples were analyzed by SRC testing. SRC tests with four solvents were done according to Approved Method 56-11.01 (AACC International 2010). Flour samples (5 g) were suspended in 25 g of deionized water, 5% (w/w) lactic acid (LA), 5% (w/w) sodium carbonate (SC), and 50% (w/w) sucrose (Suc), and hydrated for 20 min with shaking at 5-min intervals. The hydrated flour slurries were centrifuged at 1,000 × g for 15 min and the supernatants were drained. Each wet pellet was weighed and the SRC value (%) for each sample was calculated according to AACC Approved Method 56-11.01 (Haynes et al 2009). The ratio of LA SRC to the sum of SC SRC and Suc SRC was also calculated for each flour sample (Kweon et al 2009a,b). To determine effects of enzymes on water SRC values, the first representative

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doi:10.1094/CCHEM-10-10-0152
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Vol. 88, No. 1, 2011 25
set of flour samples was tested with the addition of xylanase, or α-amylase, or a combination of xylanase and α-amylase. Xylanase (1.25 mg/5 g of flour), or α-amylase (1.15 mg/5 g of flour), or a combination of xylanase (0.625 mg) and α-amylase (0.575 mg/5 g of flour) was added to 25 g of water. SRC tests on those enzyme and flour samples were conducted as described above.

Cracker Dough Rheology
The first representative set of flour samples was used for dough rheology testing, which incorporated the cracker formula and procedure reported by Kweon et al (2011). Mixed dough, dough in the direction to sheeting, and dough in the direction perpendicular to sheeting were prepared. Predissolved sugar solution (9.0 g of fine granulated [FG] sucrose + 29.0 g of water = 38.0 g of total solvent [TS]) was added to a 100-g pin mixer bowl, and 1.25 g of ABC was added and mixed to dissolve. Shortening (12 g) was added and mixed for 1 min. Dry ingredients, including flour (100 g), salt (0.75 g), soda (1.25 g), and MCP (1.25 g) were added and mixed for 10 min. Before sheeting, ≥20 g of mixed dough was placed onto the grooved base of a teflon dough form, the upper block of the dough form was positioned on top of the dough sample and pushed down firmly until the two blocks came together, and the dough form was clamped in a form press for 20 min. Thus prepared, 12 dough strips were used for tensile testing. The remaining dough was sheeted with a dough sheeter (model SFB 528, Univex, Salem, NH) in five passes without folding or rotation of the sheet between passes. The roll gap settings were 5, 3, 2, 1, and the second smallest gap on the sheeter-spacing numbers, respectively. After sheeting, the dough was rested for 1 min and the doughs were cut in the direction of sheeting and perpendicular to the direction of sheeting. Due to the thinness of the final sheeted dough, a stack of three layers of dough sheeted in each direction was used for pressing in the form to prepare dough strips for tensile testing. The tensile test used a Kieffer dough and gluten extensibility rig in a TA.XT2i instrument (Texture Technologies, Scarsdale, NY). The tensile test conditions were test mode (measure force in tension); test option (return to start); pretest speed (2.0 mm/sec); test speed (3.3 mm/sec); post-test speed (10.0 mm/sec); probe (hook with PTFE sleeve); and distance (75.0 mm). Dough resistance to extension (maximum force) and extensibility (distance at maximum force) were measured as the average on 12 strips, and the ratio of distance to force was calculated. Regression analysis was analyzed on pair-wise comparisons between distance/force in the Kieffer Rig, cracker height/dough weight, and cracker width/length.

Cracker Baking with Addition of Enzymes
For evaluating the effects of enzymes on cracker baking, xylanase and α-amylase were used to assess the impact of damaged starch and pentosans in flour. Xylanase alone, α-amylase alone, and a combination of xylanase and α-amylase were tested. A calculated amount of xylanase (25 mg/100 g of flour), or α-amylase (23 mg/100 g of flour), or a combination of xylanase and α-amylase (12.5 mg + 11.5 mg/100 g of flour, respectively) was added to 38 g of predissolved sugar solution (9 g of FG sucrose + 29 g of water), which was used according to the cracker-making procedure reported previously (Kweon et al 2011). After preparing the cracker dough as described in Kweon et al (2011), the mixed dough was sheeted with a dough sheeter. After sheeting, the dough was rested for 1 min and then cut with a custom-made hand-cutter (2.25 × 1.65 in perpendicular diameters, 7 docker pins, Weidenmiller, Itasca, IL) to produce eight oval-shaped cracker pieces. Before the start of dough sheeting, a cord-weave baking mesh (13 in. long × 10 in. wide, Hi-Carbon Steel, spec. C-100-3F, Audubon, Feasterville, PA) on top of a cookie-baking sheet was placed in an oven at 500°F for 5 min to preheat. Eight cut-dough pieces were placed on another cookie-baking sheet to measure dough weight. The eight dough pieces were transferred to the preheated baking mesh and baked at 500°F for 5–6 min (depending on dough weight). Immediately after baking, the crackers were transferred from the baking mesh to a cookie-baking sheet and weighed to calculate cracker weight loss during baking. After the baked crackers cooled to room temperature, the stack height of eight crackers was measured with a height gauge; the width and length (perpendicular diameters) of eight crackers were also measured. The average cracker height, width, and length were calculated. For evaluating the cracker-baking performance of a flour, the ratio of cracker height to dough weight (CH/DW) was calculated because dough weight affects both weight loss during baking and cracker height, and thus should be accounted for in the context of cracker geometry. Also, the ratio of cracker width to length (W/L) was calculated to characterize the extent of dough snap-back during baking. All bakes were done in duplicate. In addition, cracker dough rheology was measured for separately prepared doughs with added enzymes.

Cracker Baking with Various Flours
For validating the developed cracker-baking method, 28 flour samples (first set of 10 and second set of 18) were tested for cracker-baking performance using the procedures reported previously (Kweon et al 2011). All bakes were done in duplicate. Regression analysis was made on pair-wise comparisons between sample, SRC LA/(SC+Suc), and LA SRC.

RESULTS AND DISCUSSION
SRC Profiles of Flour Samples
The SRC results shown in Table I for 28 flour samples exhibited wide ranges for the SRC values in the four standard solvents: water SRC, 45.6–56.5%; LA SRC, 72.9–110.7%; SC SRC, 62.5–79.8%; Suc SRC, 81.8–110.7%; and ratio of SRC LA/(SC+Suc),
0.434–0.702. These SRC values and ratios covered ranges for both good and poor quality soft wheat flours for cracker-making, thus confirming our selection of an appropriate series of flour samples for use in validating the cracker-baking method. Flours with lower water SRC (related to lower overall water absorption), lower SC SRC (related to lower absorption due to damaged starch), and lower Suc SRC (related to lower contribution to absorption by solvent-accessible arabinoxylans) are generally desirable for commercial production of good quality cookies and crackers. But in addition, crackers, in contrast to cookies, require flours with greater gluten strength for ovenspring. Thus, flours with higher LA SRC (related to higher contribution to absorption by functional gluten protein) are beneficial to cracker quality (Slade and Levine 1994).

The effects of added enzymes on the water SRC values for the first set of flour samples in Table I are shown in Fig. 1. The SRC values for flours with added xylanase showed a consistently significant decrease, but those with added α-amylase showed a negligible effect. Because all these samples were soft wheat cultivars, the damaged starch contents of the flours were relatively low, resulting in low amounts of substrate for α-amylase enzyme reaction. Also, the SRC measurement was performed at room temperature. Consequently, there was no significant impact of added α-amylase on the water SRC values. But the combination of added xylanase and α-amylase showed a noticeable decrease in the SRC values, which is the result expected primarily from the reaction of xylanase on the flour pentosans (Slade et al 1993).

Cracker Dough Rheology Properties

Results for cracker dough rheology as linked to cracker-baking performance (expressed in terms of cracker height/dough weight [CH/DW] and cracker width/cracker length [W/L]) are shown in Fig. 2. In Fig. 2A, CH/DW is positively correlated with distance/force in the Kieffer Rig for all doughs (i.e., mixed dough, dough in the direction of sheeting, and dough in the direction perpendicular to sheeting). The correlation coefficients (r²) for CH/DW with distance/force for mixed dough, dough in the direction of sheeting, and dough in the direction perpendicular to sheeting were 0.99, 0.78, and 0.10, respectively. CH/DW increased with increasing distance/force for the mixed dough, dough in the direction of sheeting, and dough in the direction perpendicular to sheeting. That is to say, doughs that were too firm to easily expand during baking were also heavy in dough weight and thus did not show good ovenspring during baking. In contrast, doughs that were too soft were also light in dough weight and very easy to expand during baking but showed uneven ovenspring and increased blistering, which contributed to overestimated CH/DW. In Fig. 2B, cracker W/L was negatively correlated with distance/force for all doughs. The correlation coefficients (r²) for cracker W/L with distance/force for mixed dough, dough in the direction of sheeting, and dough in the direction perpendicular to sheeting were 0.59, 0.81, and 0.36, respectively. Cracker W/L indicates the extent of dough snap-back generated during sheeting and baking. W/L values for all samples decreased with increasing distance/force for all doughs. The firmer the dough, the greater was the snap-back. For all the doughs, rheology measured in the direction of sheeting showed a significantly positive correlation with CH/DW, but a negative correlation with W/L. These results suggested that gluten development during dough machining was highly correlated with superior cracker-baking performance.

Effects of Enzyme Addition on Cracker Baking

Cracker-baking results for flours (first set in Table I) with or without added enzymes are shown in Fig. 3. Use of α-amylase and xylanase demonstrated the improving effects of those enzymes on cracker-baking performance, resulting directly from decreased dough crumbliness and manifested as increased cracker height. Both xylanase and a combination of xylanase and α-amylase significantly affected CH/DW. Addition of α-amylase to the cracker formula also resulted in improved cracker-baking performance, even though the water SRC values for the flours with the added enzyme did not show a major change. We speculate that the reaction of α-amylase with damaged starch granules in the flour would be enhanced at higher temperatures early in baking, resulting in accelerated starch gelatinization and pasting to form three-dimensional starch networks. The specific cultivars (Jensen, MPV 57, and USG 3209) that showed a blistering problem generated more blisters during baking because their doughs were softened...
by added enzymes, especially xylanase. To decrease blistering, the amount of water added in the cracker dough formula should be decreased (Slade et al 1993), as suggested by the decreased water SRC value for flour with added xylanase.

The earlier results on cracker dough rheology showed that the properties of dough in the direction of sheeting were highly corre-

![Fig. 3. Effects of added xylanase, α-amylase, or a combination of xylanase and α-amylase on cracker-baking performance for the first set of flour samples in Table I.](image)

lated with cracker-baking performance. For doughs with or without added enzymes, force, distance, and distance/force for dough in the direction of sheeting are shown in Fig. 4. The effect of added xylanase on dough rheology was dramatic. With addition of xylanase, doughs became significantly softer (decrease in force) and much more extensible (increase in distance) (Fig. 4A and B). The calculated distance/force ratio for the doughs increased with the addition of xylanase (Fig. 4C). Effects of enzymes on dough rheology were dependent on the particular wheat cultivar. Pedersen et al (2005) reported that the addition of sodium metabisulfite and a commercial protease in semisweet biscuit dough changed dough rheological properties, and the effects varied among cultivars and between the sodium metabisulfite and protease. Wu and Hoseney (1989) showed that sponges made with different flours, after the same time for fermentation to the same pH, varied in extent of decrease in resistance to extension.

**Cracker Baking with Various Flours**

Cracker-baking results for the first and second sets of flour samples in Table I are shown in Figs. 5 and 6, respectively. For the plot in the top part of Fig. 6, CH/DW is aligned from highest to lowest value. Cracker samples with blisters are grouped separately and plotted in the right-hand portions of the graphs in the top parts of Figs. 5 and 6 because it is more valid to compare cracker ovenspring for nonblistered and blistered samples separately. Cracker samples from three cultivars (USG 3209, Jensen, and MPV 57) in the first set of flours, and four cultivars (USG 3209, Pur 03112A1-7-3, VA03W-409, and Bess) in the second set of flours showed blisters. In particular, MPV 57 showed the worst blistering, which accounted for the highest cracker thickness, and all those crackers had an objectionable appearance. For the purpose of linking flour SRC results to cracker-baking performance, LA SRC and SRC LA/(SC+Suc) ratio values for all 28 flour samples are shown in the bottom parts of Figs. 5 and 6. Even though a flour’s LA SRC value is known to be related to its gluten strength, these LA SRC results did not show a good correlation with the CH/DW. Nevertheless, the SRC ratio values showed a much better correlation, in that flours with relatively higher ratio values were generally those showing higher CH/DW. Cultivars GA96603-
By use of a diagnostic cracker formula and procedure, cracker dough rheology was analyzed to evaluate the extent of gluten development in a flour during dough mixing and machining, and the effects of added enzymes on cracker-baking performance were explored to assess the impact of damaged starch and pentosans in flour. Validation of the cracker-baking method for predicting gluten functionality and performance was conducted using various flours. Gluten development during dough machining showed a significant correlation with cracker-baking performance; dough rheological properties for dough in the direction of sheeting were positively correlated with the ratio of baked cracker height to dough weight but negatively correlated with the ratio of baked cracker width to length. Xylanase and α-amylase showed the improving effects of added enzymes on cracker-baking performance, resulting directly from decreased dough crumbliness and manifested as increased cracker height. Gluten performance ratio of SRC LA/(SC+Suc) for a flour was a better predictor of cracker baking geometry than was the flour gluten functionality value of LA SRC alone.

ACKNOWLEDGMENTS

We express our appreciation to Lonnie Andrews and Scott Beil for flour milling, and Ron Martin and Tom Donelson for SRC analysis.

LITERATURE CITED


CONCLUSIONS

Fig. 6. Cracker-baking results for the second set of flour samples in Table I.

4E06 and Envoy were the two notable exceptions to this rule; they showed low CH/DW values despite higher ratios of SRC LA/(SC+Suc) (0.660 and 0.701, respectively). However, while the SRC ratios for both cultivars were high, the full SRC profiles revealed that relatively high Suc SRC values (>90%) contributed by higher levels of arabinoxylans would have resulted in a negative effect on cracker ovenspring during baking. In contrast, flour from the Ambassador cultivar showed relatively low LA SRC (78.8%) and low SC SRC (67.4%) and also showed the lowest Suc SRC (81.8%), which evidently contributed to a positive effect on ovenspring.

Slade and Levine (1994) have explained the effects of network development by flour polymers on cookie and cracker baking. For example, the networks developed by damaged starch and arabinoxylans during dough mixing can contribute to dough resistance to expansion during baking. The results in the present work have shown clearly that LA SRC values alone cannot fully predict the cracker-baking performance of a flour and that, in SRC profiles particularly, lower Suc SRC values are preferred for high-quality cracker flours. Among the flours studied here, that from cultivar MO 11126 showed low SRC values for water, SC, and Suc, but a high SRC value for LA, and the highest SRC ratio (0.730). Thus, the full SRC profile for MO 11126 flour was the most desirable for commercial cracker production. As illustrated in Figs. 5 and 6, the correlation coefficients for LA SRC alone with cracker-baking performance for the first and second sets of flour samples were 0.16 and 0.29, respectively. But those for the ratio of SRC LA/(SC+Suc) with cracker-baking performance for the first and second sets of flour samples were 0.63 and 0.49, respectively, thus showing much higher correlations. Overall, gluten performance ratio of SRC LA/(SC+Suc) of a flour was a better predictor of cracker geometry than was the corresponding gluten functionality value of LA SRC alone. Flours with a gluten performance ratio of <0.52 produced unacceptable, excessive blistering during cracker baking.


[Received October 31, 2010. Accepted December 20, 2010.]