

A "Softer" Approach to Improving the Quality of Refrigerated Bakery Products

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Fresh bakery products have been a staple food for humans for hundreds of years. Freshly baked products have a flavorful aroma, yeasty, sweet taste, and soft but resilient texture. However, the freshness of bakery products can be lost quickly over time. This loss of freshness is due to a series of slow chemical and physical changes that leads to progressive firming of the crumb, commonly referred to as "staling," and microbial attack or, more commonly, the appearance of molds (5). The term "staling" refers to the gradually decreasing consumer acceptance of bakery products due to the chemical and physical changes that occur in the crust and crumb during storage, excluding microbial spoilage (2). Consumers no longer consider the product to be "fresh" due to the deterioration of texture, flavor, and aroma (5). The staling process is mainly due to the firming effect caused by moisture transfer from crumb to crust, as well as to the intrinsic firming of the cell wall material, which is associated with starch recrystallization during storage (8). Food scientists and the baking industry have worked for many generations to find solutions that will maintain the freshness of bakery products and extend the shelf life of these goods.

Many methods are used to prolong the shelf life of bakery products by delaying microbiological spoilage. Preservatives, such as propionates, are common additives used to minimize microbial growth (5). Modified atmosphere packaging can extend the mold-free shelf life of products, as can various forms of irradiation (5). Controlling storage temperature is an effective way to prevent microbial spoilage for extended periods of time. Frozen and refrigerated storage are also widely used in controlling the spoilage of bakery products.

- ▶ How have new ingredient technologies risen to the challenge of bread staling?
- ▶ How can current products be improved while allowing for expansion into new market channels?
- ▶ How will newer extended shelf life enzymes affect the way bakery products are produced, distributed, marketed, and consumed?

While lowering the storage temperature will reduce microbial growth, these temperatures will also have an impact on the rate of product staling. The temperature at which bread is stored has a direct impact on its staling rate. Higher temperatures retard staling, and cooler temperatures (above freezing) increase it (9). The rate of staling has a negative temperature coefficient (6). Thus, the rate of bread staling is accelerated at refrigerated storage temperatures (7).

Product formulation also has a major impact on the characteristics of bakery products. Ingredients used in the formula will impact the product throughout mixing, processing, baking, and storage. Dough strengtheners and conditioners are often used to improve dough processing tolerance, increase product volume, increase softness, and improve grain structure. Removing these additives often results in lower-quality bread.

Sugar has many functions in bakery products. American white-bread formulations are relatively high in sweeteners (4). The average formula addition in 1920 was 2% based on flour (4). However, the sugar level increased to as high as 8% in 1958 (4). The high usage of sugar was justified by marked improvements in loaf volume, crust color, flavor, shelf life, and more (11).

Aside from the many positive attributes sugars are able to provide, some negative

impacts are also observed. Proper dough development requires a greater energy input when large quantities of sugar are present (11). Sweet dough with sugar levels of 20–25% requires as much as 50% longer mix times to maintain loaf volume and produce acceptable eating quality in the finished product (3). With high sugar levels, a perceptible inhibitory effect on yeast activity occurs that depresses the rate of gas production (4).

The baking industry is constantly challenged by increasing consumer demands for higher quality and fresher products. The shelf life of bakery products is continually being stretched for both consumer satisfaction and production and marketing efficiency. Consumers want more functionality from their products, such as convenience, nutrition, good flavor, and longer shelf life. In order to keep up with the ever-changing market, new bakery technologies must be developed to meet these challenges, especially the challenge of bread staling.

Materials and Methods

Bread Production

Most of the bake tests in this study were performed using a typical sponge-and-dough, white pan-bread formula. For the sponge, the formula included bread flour (65%); compressed yeast (4.5%); sodium stearoyl lactylate (SSL) (0.5%); water (42%). For the dough, the formula included bread flour (35%); water (variable); high-heat nonfat dry milk (1%); salt (2%); sugar (8%); calcium propionate (0.5%); GMS-90 (25% aqueous hydrated monoglyceride, Caravan Ingredients) (2%); dough conditioner (Dependox AXC, Caravan Ingredients) (0.06%); soy oil (2%); and compressed yeast (1%). Hobart mixers (20 qt) fitted with McDuffee bowls were used for mixing. The sponge was fermented at $30 \pm 1^\circ\text{C}$ ($86 \pm 2^\circ\text{F}$) at 85% RH for 3 hr. The sponge was added to the remaining ingredients and mixed to full development. The loaves were proofed in 1-lb pans at $36 \pm 1^\circ\text{C}$ ($96 \pm 2^\circ\text{F}$) at 92% RH for 1 hr. Bread was baked in a revolving tray oven at

216°C (420°F) for 20 min. The bread was removed from pans immediately after exiting the oven and allowed to cool on a wire rack for 50 min before being placed in airtight bags. All bread was stored at 20°C (68°F) unless otherwise stated.

Texture Analysis

A texture analyzer (TA.XT plus, Texture Technologies Corp., Scarsdale, NY) was used for the texture analysis. Firmness values were calculated using AACC Intl. Approved Method 74-09 (1). Adhesiveness and resilience values were determined using a two-part texture profile analysis (TPA, Texture Technologies Corp.) that emulates mastication.

Sensory Analysis

Bread was prepared using the sponge-and-dough procedure described previously. A total of 26 untrained panelists participated in the consumer study of white pan bread. Testing was administered on days 1, 14, and 28, with seven to eight samples per session. Bread samples were cut into 2.5-in. round disks that were 1-in. thick. These disks were then sealed in odor-free, airtight, snack-sized plastic

bags and labeled with random three-digit codes. All samples were presented at one time, and the sampling order was predetermined by the order listed on the evaluation sheets. By controlling the sampling order in a random manner, bias was eliminated. Unsalted crackers and distilled water were provided for cleansing between samples. Panelists were instructed to use the crackers and water to cleanse their palate before tasting the samples at anytime during the test if needed.

A randomized complete-block design was used for setting up the consumer panel; each panelist tested each product in random order. Consumer perceived attribute and acceptance tests were performed with a 9-point hedonic scale. All sensory attributes were analyzed using JMP (Cary, NC) statistical software. Analysis of variance (ANOVA) and least significant difference were used to determine statistical differences between samples.

Par-Baked Rolls

Par-baked rolls were produced using a sponge-and-dough formula. For the sponge, the par-baked roll formula included bread flour (70%); compressed yeast (3%); SSL

(0.25%); GMS-90 (25% aqueous hydrated monoglyceride, Caravan Ingredients) (0.5%); and water (42%). For the dough, the formula included bread flour (30%); water (variable); salt (2%); sugar (12%); calcium propionate (0.2%); soy oil (4%); and dough conditioner (Dependox AXC, Caravan Ingredients) (0.03%). Hobart mixers (20 qt) fitted with McDuffee bowls were used for mixing. The sponge was fermented at $30 \pm 1^\circ\text{C}$ ($86 \pm 2^\circ\text{F}$) at 85% RH for 3 hr. The sponge was added to the remaining ingredients and mixed to full development. The rolls were scaled at 2.25 oz and proofed at $36 \pm 1^\circ\text{C}$ ($96 \pm 2^\circ\text{F}$) at 92% RH for 1 hr. Rolls were baked in a revolving-tray oven at 149°C (300°F) for 25 min. Rolls were allowed to cool on a wire rack for 50 min before being placed in airtight bags. All bread was stored at 20°C (68°F) unless otherwise stated.

A second bake was done 4 days later for the par-baked rolls. Rolls were baked in the revolving-tray oven at 238°C (460°F) for 10 min. The rolls were allowed to cool for 1 hr before the first set of texture analyses was performed. After 5 hr at ambient temperature, the second set of texture analyses was completed.

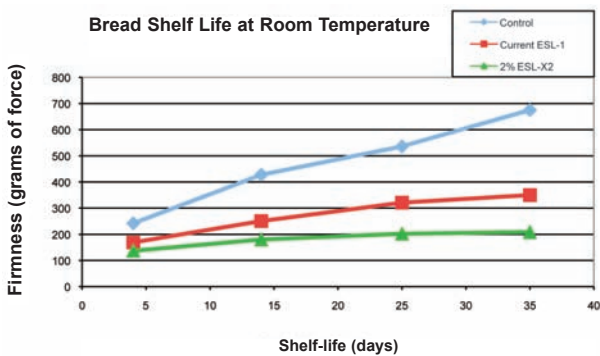


Fig. 1. Bread containing ESL-X2 had a lower firmness value after 5 weeks than the control after only 4 days. This 5-week-old sample was comparable in firmness to current ESL-1 products on day 8.

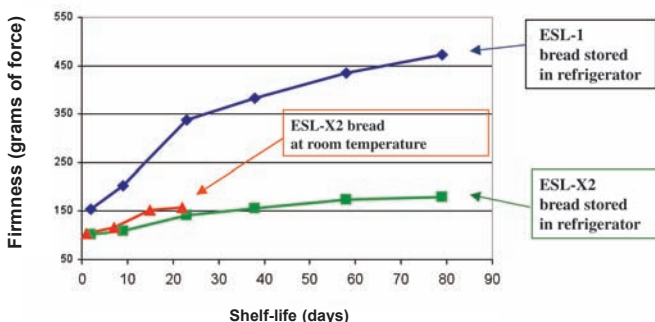


Fig. 2. The ESL-X2 product stored in the refrigerator for 79 days remained lower in firmness than the current ESL product after only 1 week in the refrigerator.

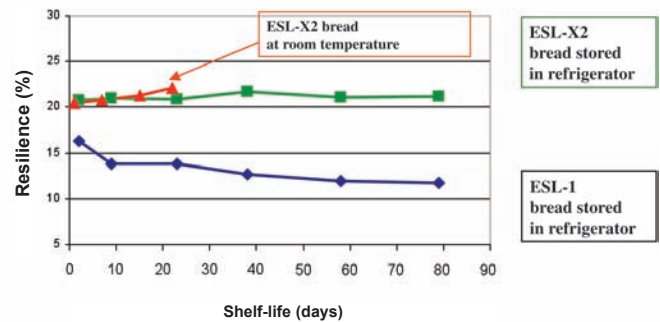


Fig. 3. High resilience allows for easy handling and stacking of breads.

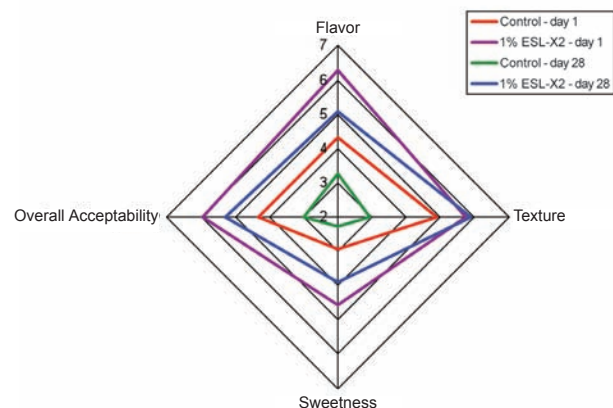


Fig. 4. ESL-X2 improves the flavor of bread over extended periods of time. The texture of bread is also consistent over 4 weeks. Overall, consumers preferred the bread made with ESL-X2.

Results and Discussion

Extending Shelf Life

The addition of an enzyme shelf life extender (ESL-X2, Fridge Soft™, Caravan Ingredients, Lenexa, KS) to bakery items greatly extended the acceptable product shelf life, with decreased firmness, increased resiliency, low adhesiveness, and improved flavor. Figure 1 shows how bread with 2% added ESL-X2 remained softer than a control product without enzymes added or a product with a commercial enzyme shelf life extender added (ESL-1: commercial extended shelf life enzyme system). As a reference, many consumers characterize bread with a firmness of 250–275 grams of force as being stale. Bread made with ESL-X2 produced a very slow staling curve in the initial days of testing. It is believed that this slight increase in firmness was due to moisture migration from the moist center of the bread to the dry outer crust. Once moisture equilibrium was reached, staling was extremely slow if not completely eliminated.

Storing bread in the refrigerator is not a common practice because it causes an increase in the rate of staling. With ESL-X2, bread can be stored in the refrigerator and still maintain a low rate of staling. Figure 2 shows that the bread containing ESL-X2 stored in the refrigerator had a slower staling rate than bread containing ESL-1 held at ambient temperature. Bakery products containing ESL-X2 can be held for 80 or more days in the refrigerator without mold growth and remain softer than bakery products containing ESL-1.

Crumb resilience is another important bread quality attribute. Resilience is measured by how effectively the bread can bounce back after being pressed. Bread can lose resilience in various ways. As bread stales, the crumb becomes drier and more brittle, causing the crumb structure to collapse when pressed and lose its ability to bounce back. Some crumb softening

additives can make the crumb too soft and gummy with high adhesiveness, resulting in low resiliency. Results show ESL-X2 not only increased the resiliency of bread at the beginning of its shelf life, but also maintained high resiliency over a long shelf-life period. Bakery products containing ESL-1 products may lose resiliency as the product firms and the crumb begins to fracture and crumble (Fig. 3).

One way to measure the gumminess of the bread is to measure its adhesiveness. Often, when enzymes are used to make bread softer, the eating quality is reduced, and the product becomes gummy. Test results indicate that while ESL-X2 can make bread very soft, with high resiliency and low adhesiveness, it will not become gummy.

Current extended shelf life technology will allow bread to have a shelf life of two weeks under ambient temperatures. Throughout this time, the bread not only progressively becomes firmer, but it also loses its attractive fresh flavor. The sweet, yeasty notes are replaced by stale flavors. A consumer study conducted internally at Caravan Ingredients indicated that the addition of ESL-X2 to bread improved flavor characteristics from day 1 of testing and throughout a 4-week period. The panel also noted the increased sweetness, improved texture, and overall acceptability of the product (see Fig. 4).

A Solution for High-Demand Periods

Adding extended shelf life enzymes to bread and bun products can be helpful during high-demand periods. Bakeries are often not capable of producing fresh products fast enough to fill large holiday orders. Instead of producing products in advance and having to store the goods frozen, products can be produced with ESL-X2 and stored at ambient temperatures. Figure 5 displays data from a test comparing the firmness data for products containing

ESL-X2 and ESL-1. The sample containing 2% ESL-X2 and held at room temperature for 3 weeks had comparable firmness data to the sample containing ESL-1 and stored for 2 weeks in the freezer and then held at ambient temperature for 1 week. The staling rate of the sample containing ESL-X2 was lower than for the ESL-1 samples, showing that with extended time the product containing ESL-X2 would remain lower in firmness than the product containing ESL-1.

Extreme Staling Conditions

Situations arise when the staling rate of baked products is pushed to its limits. These extreme conditions may include par-baking or microwaving products. In the case of par-baked products, staling occurs very quickly, and the products become unsuitable for consumption in a short period of time. When microwaving baked goods, products firm excessively due to moisture loss.

Par-baked rolls were tested 1 hr and 5 hr after the final bake. The increase of only 10 grams of force at 1 hr was small. This difference could be felt with the touch of a hand, but both products were considered fresh and acceptable for consumption. After 5 hr, the ESL-1 sample had staled considerably and increased in firmness by 33 grams of force, roughly equivalent to 2 days of staling. The sample containing ESL-X2 increased in force by 12 grams of force, making it similar in value to the sample containing ESL-1 after only 1 hr. The product containing ESL-X2 remained acceptable for consumption, while the product containing ESL-1 did not.

Similar results were obtained with microwavable products. The addition of ESL-X2 allowed the baked good to remain soft for extended periods of time. These microwavable items would have superior eating quality, with a tender bite that is not tough or rubbery. Microwaving causes excessive

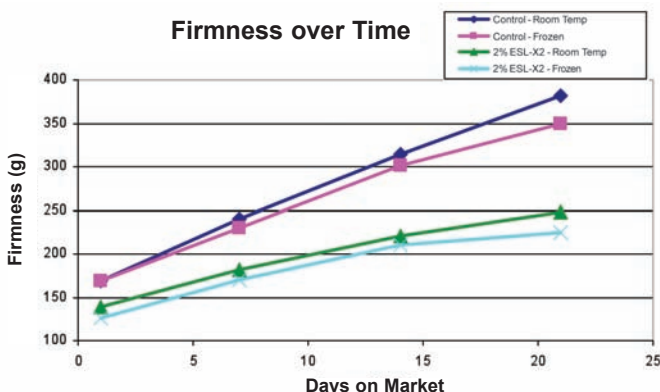


Fig. 5. There is no longer a need to freeze products in order to fulfill high-volume orders around the holidays.

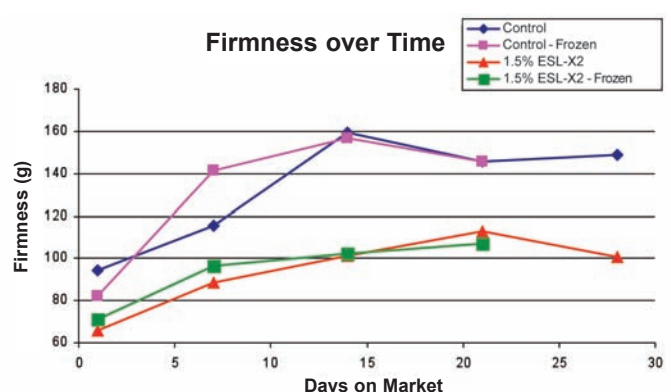


Fig. 6. The samples labeled “frozen” were held in the freezer two weeks prior to being tested.

moisture loss, but ESL-X2 can mitigate the firmness caused by dehydration and allow a product to remain soft and tender.

Enzyme Activity

One of the effects of ESL-X2 is the production of sugar from starch digestion. Bread was baked according to the white pan-bread, sponge-and-dough formula described earlier. An ESL-1 sample was evaluated along with a test sample containing 1% ESL-X2. Both samples of bread were analyzed for sugar content using high-performance liquid chromatography. Adding ESL-X2 had the following effect on baked-bread sugar content: maltose (5.37%); fructose (1.99%); sucrose (0%); glucose (0%); lactose (0%); total sugars (7.36%); and fructose basis (4.67%). In comparison, ESL-1 had the following effect on baked-bread sugar content: maltose (0.48%); fructose (2.04%); sucrose (0%); glucose (0%); lactose (0%); total sugars (2.52%); and fructose basis (2.28%). (Percentages are based on wet weight.)

The starting formulas for both the ESL-1 and the ESL-X2 had 8% added sugar. The final analysis showed that after baking the product containing ESL-X2 has three times as much total sugar as the product containing ESL-1 and was judged to be significantly sweeter in flavor. The increase in final total sugar allowed for a sweeter tasting product or reformulation.

Giving Strength to the Dough

The addition of ESL-X2 can strengthen dough, allowing for reformulation as well as increased volume. A test bake was conducted using the basic white pan-bread, sponge-and dough formula described earlier. Table I describes the changes made in this test. The bread was evaluated for final baked volume, shape, and crumb grain.

Table II indicates that test 9 was the only variable with a significantly different volume. The test showed sugar can be reduced

from 8 to 4%, SSL can potentially be eliminated, yeast may be reduced from 4.5 to 3.5%, and water may be increased from 59 to 63%. Test 9 showed that when all of these variables are changed to the greatest degree in one single test, there may be a slight reduction in volume. Bread shape and crumb grain were judged to be similar for all breads, with the exception of test 4, which resulted in some misshapen loaves. This difference in test 4 was considered to be due to the combination of an excessively low yeast level and reduced sugar.

A field trial was conducted to determine if ESL-X2 could replace various dough conditioners. The control formula was a commercial bun formula containing ethoxylated monoglycerides (Do Crest 60, Caravan Ingredients), hydrated monoglycerides, (GMS 90 Double Strength, Caravan Ingredients), two commercial enzyme strengtheners, azodicarbonamide, and a commercial enzyme shelf life extender.

For the field trial variables, the following percentages for the control and test were used based on 100 lb of flour: Do Crest 60 (Control 0.3%; Test 0%); GMS 90 (Control 1%; Test 1%); commercial enzyme strengthener 1 (Control 0.06%; Test 0%); commercial enzyme strengthener 2 (Control 1.5%; Test 1.5%); azodicarbonamide (20 ppm/tab) (Control 1.5 tab; Test 0 tabs); and a commercial enzyme shelf life extender (Control 1 tab; Test 0 tabs).

Even when the ethoxylated monoglycerides, enzyme strengthener 1, azodicarbonamide, and an enzyme shelf life extender were removed, the test dough received the same dough mixing time and handling conditions as the control. The test dough handled well and had similar properties to the control throughout processing. The final baked product also had an equivalent volume, crumb cell structure, and overall outward appearance as the control. However, the ESL-X2 product was considerably softer than the control product (Fig.

6) when stored under ambient or frozen conditions. The products containing ESL-X2 were also significantly more resilient than the control products (Fig. 7).

The ability to reformulate bread products containing ESL-X2 can be beneficial in various ways. The removal of dough conditioners can help clean up the label. Ingredient costs might also be reduced if fewer dough improvers are needed and if water uptake can be increased.

Manufacturing and Distribution Advantages

Manufacturing costs can be responsible for 25% of the wholesale cost of a loaf of bread. With the addition of ESL-X2, new opportunities arise to alter the way baked goods are manufactured. With the reformulation changes mentioned above, the manufacturing rate of baked products may be increased. Because yeast cells have greater functionality with lower additions of sugar, this difference can allow for faster proof times in a bakery. Sugar also promotes rapid crust color through caramelization and the Maillard reaction between reducing sugars and the proteins in flour (10). If sugar is reduced, bake temperature may be increased, and bake time decreased. The enzyme activity of ESL-X2 will also produce additional sugars in the internal crumb of the bread and enhance overall flavor. The exterior of the loaf will heat quickly and deactivate the enzymes on the crust, thus preventing excessive external sugars from forming. This reduction in external sugar allows for increased oven temperatures to achieve the desired crust color. With these higher temperatures, bake times can be reduced, and the final product will maintain higher levels of moisture and freshness.

Figure 8 shows how reducing sugar from 8 to 4% increased the *L* value, which represents the lightness of the crust color. Products with high *L* values are lighter in color.

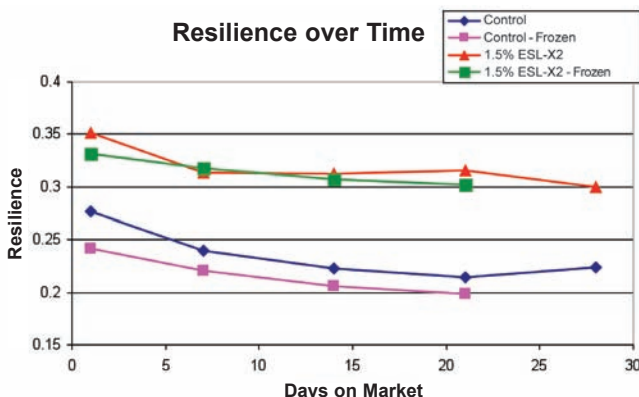


Fig. 7. The samples labeled "frozen" were held in the freezer two weeks prior to being tested.

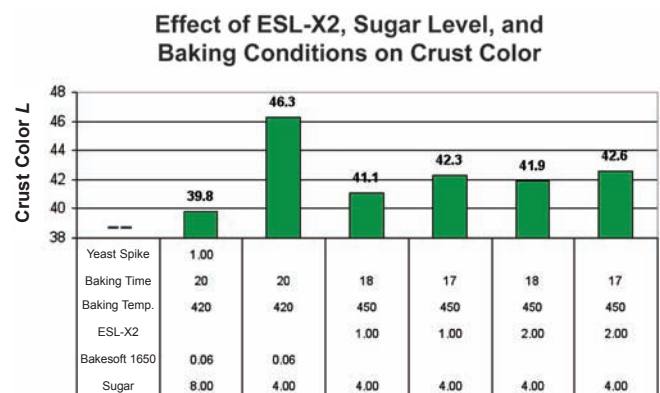


Fig. 8. ESL-X2 makes it possible to reduce bake time and production costs.

Table I. Test Formula Variables

Ingredient (% Flour)	Control	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
Sugar	8	6	4	4	4	4	4	4	4	4
SSL	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0
Yeast	4.5	4.5	4.5	3.5	2.5	3.5	3.5	3.5	3.5	3.5
Water	59	59	59	59	59	61	63	59	61	63
ESL-X2	0	2	2	2	2	2	2	2	2	2

Table II. Means Comparisons for All Parts Using Tukey-Kramer HSD

Sample	Mean Volume (cc/g)	Grouping
Test 5	6.616	A
Test 2	6.548	A
Test 4	6.412	AB
Test 1	6.372	AB
Test 3	6.371	AB
Test 7	6.357	AB
Test 6	6.345	AB
Control	6.290	AB
Test 8	6.264	AB
Test 9	6.101	B

LSD = 0.41966, α = 0.05

When ESL-X2 was added at 1% to a formulation with only 4% sugar, the bake temperature could be increased from 420 to 450°F, and the bake time reduced from 20 to 17 min—a 15% reduction in bake time. With these processing changes in place, the internal temperature required for baking was within one degree Fahrenheit of the control's internal temperature. Also, the *L* value was lowered, and the crust color became more like the color of the product containing ESL-1. When the added ESL-X2 was increased from 1 to 2%, the crust color did not darken further under the same processing conditions, indicating that high dosages will not cause excessive browning of the crust, because the enzymes on the surface are deactivated so quickly.

With today's ingredient and processing technologies, there is no longer the need to have a bakery on "every corner" in order to reach all consumers. Bakery products have the extended shelf life needed to ship products farther from the site of production, and daily deliveries are no longer needed. With increased shelf life, bakeries can now be consolidated and centralized to form highly productive, efficient facilities with increased profits. Production runs can be lengthened with fewer changeovers. Bakers will no longer need to produce every variety of product each day to have fresh products on the grocery shelves. The way of life for employees can also be improved. Split weekends with down days on Sundays and Tuesdays will be a thing of the past. The employee turnover rate may be reduced, allowing more experienced staff to run the plants.

While the cost of manufacturing is high, distribution is even more expensive. Distri-

bution costs make up 40–60% of the price of bread. With escalating fuel prices, this number will only rise. The use of ESL-X2 offers manufacturers the ability to not only centralize production, but products can now go through current warehouse channels. In addition, fewer routes will be needed, and deliveries can be made less frequently.

New Market Channels

With the ability to keep baked products refrigerated without increasing the staling rate, current products can be improved while also allowing expansion into new market channels. Dairy cases, convenience stores, vending machines, and the refrigerated and frozen aisles of grocery stores become prime targets for such baked goods. Snack foods, breakfast foods, and ready-to-eat lunches are ideal targets for high-quality bakery items. High-end ingredients such as nutraceuticals, fruits, nuts, and cheeses can now be included in these items without the risk of losing ingredients to staling. Individual packaging and portion control also becomes an option for baked products.

Conclusion

With innovations in enzyme shelf life extenders, consumers will no longer have to accept stale sandwiches from convenience stores and vending machines. No longer will flavor and texture be compromised for speed and convenience. Current products can be improved, while new and exciting marketing avenues will become available for yeast-leavened products, while eliminating the staling problem, ESL-X2 produces products that maintain the sweet, yeasty flavor of baked goods

over an extended shelf life. Baked products will remain soft with increased resilience, improved texture, and desirable toasting qualities. Consumers can now store products in the refrigerator for extended mold-free periods, and producers can utilize this technology to expand into refrigerated and frozen markets. ESL-X2 can help reduce the use of strengtheners, and sugar, with its inhibiting effects, can be reduced or eliminated. The production process may also be sped up for a quicker bake time. Consumers will appreciate cleaner product labels. Large, mega-sized bakeries may become an option with increased efficiency and profitability. With an extended shelf life comes a versatility of products that will aid in reducing stale returns, open new distribution avenues, and ultimately create superior products.

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