NOTE

Changes in Bread Firmness and Moisture During Long-Term Storage[1]

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ABSTRACT

In contrast to most studies on bread staling that deal with storage for one week, this study investigated changes in firmness and moisture of bread during one year of storage at 25°C. Two packaging methods to prevent bread from molding were tested. Bread packaged in a sterilized bag while still hot (3 min after baking) or packaged after being sprayed with 0.2% calcium propionate 10 min after baking did not develop any mold over the storage period. Both crumb firmness and crumb moisture reached equilibria after 30 days of storage. A sharp increase in firmness and a decrease in moisture were found during the first 15 days. To study the effect of moisture on crumb firmness, high-moisture bread was obtained by reducing baking time from 24 to 8 min. Higher moisture of crumb resulted in a slower firming rate and lower equilibrium firmness. Separation of crumb from crust of fully baked bread 1 hr after baking maintained the crumb moisture during storage but did not prevent firming of crumb; however, the equilibrium firmness was much lower. Therefore, moisture plays an important role in crumb firming, but other factors cause crumb firming even without a change in moisture.

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Bread staling is a complex and not completely understood phenomenon. It refers to the changes that take place after baking other than spoilage by microorganisms (Bechtel et al 1953). Bread staling results in decreased consumer acceptance of bakery products and in great economic losses. Therefore, it has been studied extensively, as indicated by several published reviews (Wilhoft 1973, Maga 1975, Knightly 1977, Kulp and Ponte 1981).

Many studies show that bread firmness increases linearly with time (Ghiasi et al 1984). However, most of those studies were conducted with one week of storage. Therefore, many questions still persist concerning bread firming with storage for longer periods. For example, how does the firming rate change after one week of storage, and does bread reach a maximum firmness with time? The answers to these questions could provide the information necessary for understanding the mechanism of bread firming.

The objectives of this study were to investigate the changes in bread firmness and moisture that occur during long-term storage and to study the effect of moisture on bread firming.

MATERIALS AND METHODS

Flour

A commercial bread flour containing 11.5% protein and 0.48% ash was used to make bread.

Baking

AACC method 10-10B (1983) was used to bake bread. Nonfat dry milk (4.0%), 0.75% instant dry yeast, and 10 ppm of $KBrO_3$, based on the weight of flour, were added to the formula. Fermentation time was 180 min.

Packaging Bread

Three packaging methods to keep bread from molding during long-term storage were tested in this study (Fig. 1). After bread was taken from the oven, it was allowed to cool for 10 min in one series and 50 min in the second. Then, before packaging, 0.2% calcium propionate solution was sprayed on the surface of bread. In the third method, the bread was allowed to cool for 3 min and was packaged in a sterilized bag without applying any preservative. To minimize loss of water during storage, each loaf was wrapped with two polyethylene bags and stored in a sealed container at 25°C for up to one year.

Bread Baked for 8 min

To obtain a higher moisture content of crumb, pup loaves were baked for only 8 min rather than 24 min. After bread was taken from an oven and cooled for 3 min, it was packaged in a sterilized bag and then stored at 25°C for three months.

Removal of Bread Crust

To minimize the water migration in bread crumb, the bread crust was removed. After bread was cooled for 1 hr, the crust was removed aseptically, and then the crumb was packaged in a sterilized bag and stored at 25°C for three months (Fig. 2).

Measurement of Bread Firmness

Bread firmness was measured with the Instron universal testing machine. AACC method 74-09 (1983) was used to measure the firmness of bread crumb.

Moisture Measurement

After firmness measurements were taken, the moisture of the crumb was immediately determined by the AACC two-stage moisture procedure 44-18 (1983).

RESULTS AND DISCUSSION

Methods of Packaging Bread

The three packaging methods (Fig. 1) showed different effectiveness in preventing bread from molding during one year of storage. When treated with propionate and cooled for 50 min, two out of 20 loaves were moldy, but with 10 min of cooling, none of the loaves were moldy. When bread was only cooled for 3 min without applying any preservative, none of the loaves were moldy. Presumably this was because the bread was sterile as it came from the oven, and the packaged bread was hot enough to inactivate microorganisms if there were any contamination. Therefore, packaging hot bread was the easiest and most reliable method to keep bread from molding. After this study was completed, a patent was issued for a similar packaging process for bread goods (Farrar et al 1988).

Changes in Bread Firmness and Moisture During One Year of Storage

The changes in firmness during storage are shown in Figure 3. Because firmness did not increase after 180 days of storage, only the first 180 days were plotted. Regardless of the packaging procedure, the firmness of all loaves increased rapidly during

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the first 15 days, and then the rate decreased with time. After 30 days, bread firmness approached a maximum value.

Bread crumb moisture decreased sharply with time (Fig. 4). The crumb of freshly baked bread contained about 47% moisture. However, during 2 hr of cooling the moisture dropped to 41%. With additional storage time, the moisture continued to decrease, but at a slower rate. Presumably this was because the difference in moisture between the crust and the crumb decreased with time and, therefore, water migration within the bread slowed. After bread was stored for 30 days, the moisture of the bread crumb was essentially constant, about 31.5%. That moisture content appeared low. Therefore, the moisture of freshly baked bread was calculated and compared with the measured value.

The calculation was done as follows. Dry materials weight = 86 g of flour + 3 g of shortening + 1.5 g of salt + 3 g of sugar + 4 g of nonfat dry milk = 97.5 g. Fresh bread weight = 142.5 g. Moisture (%) = (1 − 97.5 g/142.5 g) × 100.

The calculated and the measured moisture values were similar—31.5 and 31.43. The measured moisture had a standard deviation of 0.23%. Therefore, 31.5% appears to be the equilibrium moisture for the pup loaf bread. Surprisingly, it took 30 days of storage for the bread to approach this value.

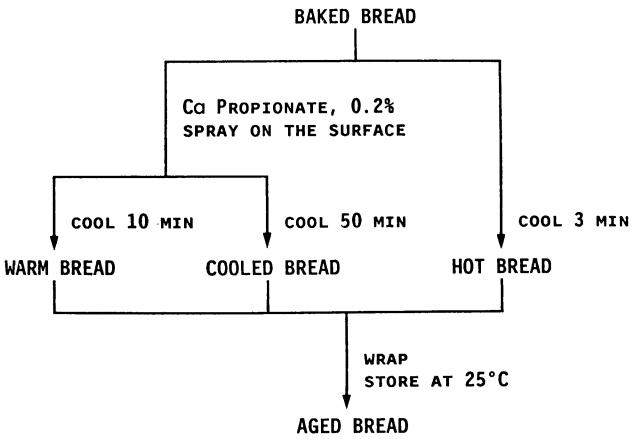

Fig. 1. Methods of packaging bread.

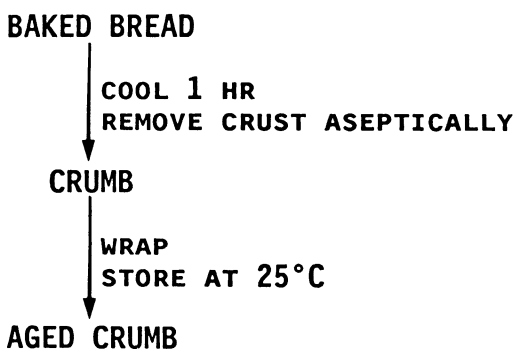

Fig. 2. Methods of packaging crumb.

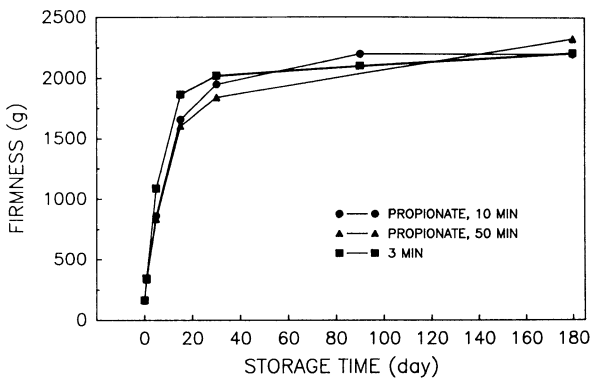

Fig. 3. Changes in firmness of bread crumb during storage. Standard deviation of measurements: day 1 = 3.95, day 5 = 103.9, day 15 = 162.7, day 30 = 146.8, and day 90 = 163.5.

Relationship Between Bread Firmness and Moisture

Figures 3 and 4 together indicate that the increase in firmness is related to the decrease in moisture. Moisture content has been shown to be inversely proportional to the rate of firming (Rogers et al 1988). Bread firmness is caused mainly by the formation of cross-links between partially solubilized starch and gluten proteins (Martin et al 1989). In bread, water acts as a plasticizer. When moisture decreases, it accelerates the formation of cross-links between starch and protein and, thus, the bread firms faster.

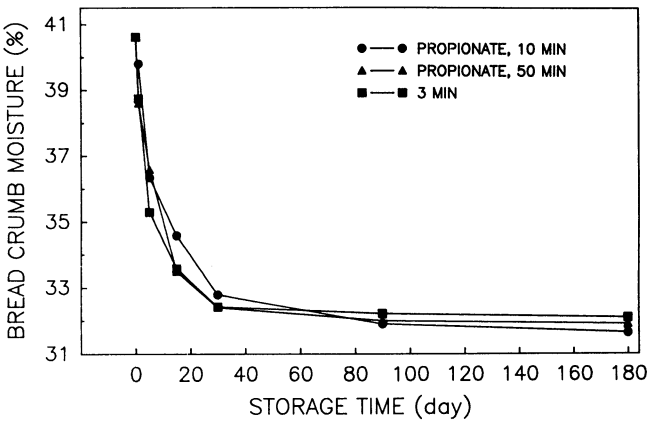

Fig. 4. Changes in bread crumb moisture during storage. Standard deviation of the measurements was less than 0.68.

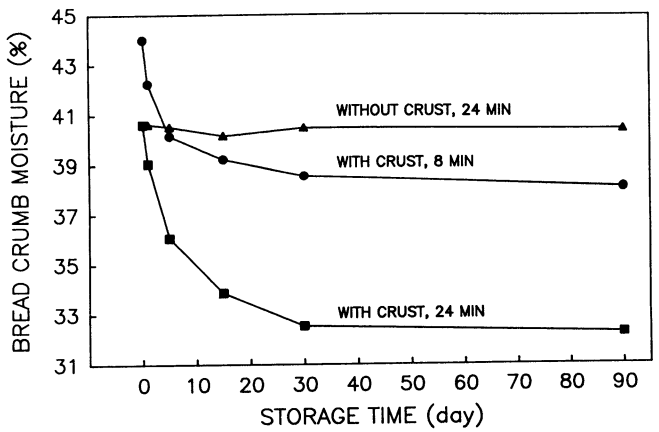

Fig. 5. Effect of baking times and packaging methods on changes in bread moisture content during storage.

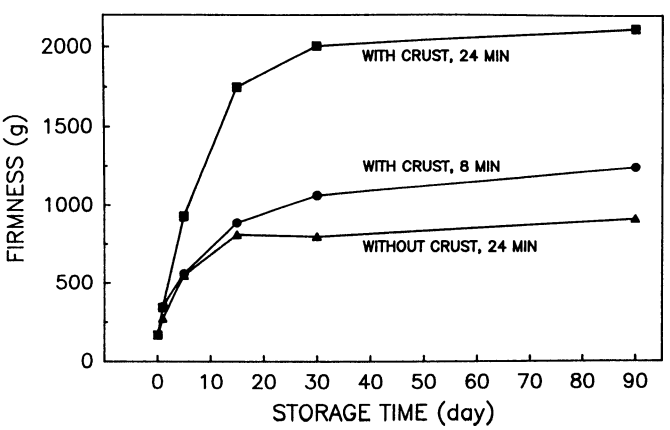

Fig. 6. Effect of baking times and packaging methods on changes in bread crumb firmness during storage.

Therefore, crumb moisture and firmness are closely related. However, over one century ago, Boussingault (1852) showed that bread firming occurred without a loss of water.

Effect of Moisture on Bread Firmness

To better understand the relationship, the effect of moisture on bread firming was studied further. Bread was baked for only 8 min to obtain bread with a higher moisture. In a second test, the crust was removed from the fresh bread to minimize water migration from the bread crumb. In the tests of long-term storage, both firmness and moisture essentially reached their final values after 30 days. Therefore, a storage time of 90 days was used for these tests.

The effect of the different treatments on changes in the moisture of bread crumb is shown in Figure 5. For comparison, the crumb moisture of fully baked bread also was plotted. After 2 hr of cooling, crumb of bread baked for 8 min had higher moisture than bread baked for 24 min, as would be expected. During storage, the moisture of bread baked for 8 min decreased similarly to that of bread baked for 24 min. However, the crumb moisture of the 8-min bread changed at a slower rate. Both treatments took 30 days for bread to reach equilibrium. The 8-min bread had an equilibrium moisture about 39% higher than the 24-min bread. For the bread with crust removed, the moisture essentially stayed constant at about 40% during 90 days of storage.

The effect of moisture on firmness is shown in Figure 6. The bread with higher moisture (baked for 8 min) firmed at a slower rate than did the bread with lower moisture (baked for 24 min). Also the final firmness of the 8-min bread was lower. The slower firming rate and the lower final firmness may be attributed to its higher moisture content. However, it could also be affected by shorter baking time, which might result in less solubilized starch that could potentially decrease bread firming (Martin et al 1989). The bread with a constant moisture (without crust) firmed during the first 15 days at about the same rate as the bread baked for 8 min. After 15 days, the firmness remained essentially constant.

CONCLUSIONS

Two methods were developed to prevent bread from molding, which enabled a study of changes in bread firmness and moisture through one years' storage at room temperature. After bread was taken from an oven and cooled for 10 min, the surface was sprayed with 0.2% calcium propionate solution, and the bread was packaged in a sterilized bag. In the other method, bread was allowed to cool for 3 min and then packaged in a sterilized bag. No mold occurred with either treatment.

Bread firmness increased rapidly during the first 15 days of storage. A maximum firmness was approached after 30 days. Crumb moisture decreased sharply with time and reached the equilibrium moisture after 30 days.

Moisture content significantly affected bread firming. The higher the moisture, the slower the firming rate and the lower the final firmness. However, bread with the crust removed, to give a constant moisture, firmed during the first 15 days of storage.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1985. Approved Methods of the AACC. Method 10-10B, approved January 1983, revised September 1985; Method 44-18, approved April 1961; Method 74-09, approved October 1986, revised November 1987 and October 1988. The Association: St. Paul, MN.

BECHTEL, W. G., MEISNER, D. F., and BRADLEY, W. B. 1953. The effect of the crust on the staling of bread. Cereal Chem. 30:160.

BOUSSINGAULT, J. B. 1852. De la transformation du pain tender en pain rassis. Ann. Chem. Phys. 3 Ser. 36, p. 490. (Original not seen. Cited in Wilhoft 1973.)

FARRAR, P. A., PATTON, J. C., SULLIVAN, K. L., WISAKOWSKY, E. E., and DEWBERRY, D. L. 1988. Packaging process for baked goods. U.S. patent 4,769,245. Patented Sept. 6.

GHIASI, K., HOSENEY, R. C., ZELEZNAK, K., and ROGERS, D. E. 1984. Effect of waxy barley starch and reheating on firmness of bread crumb. Cereal Chem. 61:281.

KNIGHTLY, W. H. 1977. The staling of bread. A review. Baker's Dig. 51(5):52.

KULP, K., and PONTE, J. G. 1981. Staling of white pan bread. Fundamental causes. Crit. Rev. Food Sci. Nutr. 15:1.

MAGA, J. A. 1975. Bread staling. Crit. Rev. Food Technol. 5:443.

MARTIN, M., HOSENEY, R. C., and ZELEZNAK, K. J. 1989. A mechanism of bread firming. (Abstr.) Cereal Foods World 34:738.

ROGERS, D. E., ZELEZNAK, K. J., LAI, C. S., and HOSENEY, R. C. 1988. Effect of native lipids, shortening, and bread moisture on bread firming. Cereal Chem. 65:398.

WILHOFT, E. M. A. 1973. Mechanism and theory of staling of bread and baked goods and associated changes in textural properties. J. Texture Stud. 4:272.

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