Effects of Loaf Volume, Moisture Content, and Protein Quality on the Softness and Staling Rate of Bread [1]

M. MALEKI,[2] R. C. HOSENEY, and P. J. MATTERN [3]

Cereal Chem. 57(2):138-140

ABSTRACT

Breads of different moisture contents were obtained by baking for different times. Different loaf volumes were obtained by changing the protein content of the flour and loaves of different sizes from bread pans of different sizes. Compressibility of bread was used as an indicator of staling rate. Higher moisture content and larger loaf size produced softer bread. Increasing the protein content of flour increased the loaf volume and resulted in softer bread. To determine the effect of flour fractions, four varieties of wheat were milled and two of the flours were fractionated into gluten, starch, and water solubles. Breads were baked from the original flours and from reconstituted flours with or without interchanging the fractions. Compressibility of breads was used as an indication of staling after various storage times. Breads from different flours staled at different rates. Fractionation of flour did not change the staling rate unless the fractionation procedure damaged a flour component. Gluten was the major fraction responsible for differences in staling rate. Starch and water solubles did not significantly affect staling rates.

Studies of bread staling have been numerous, and several reviews (Bechtel 1955, Hertz 1965, Knightly 1977, Zobel 1973) summarize the results. The factors affecting staling rate were detailed by Maga (1975). Platt and Powers (1940) reported that differences in the staling rate of breads baked for different times resulted from different moisture contents. Bechtel and Meisner (1954) concluded that bread with higher moisture content was significantly fresher than bread with lower moisture. Maleki and Seibel (1972b), studying the effect of adding different levels of water (from −6 to +9% of the Farinograph water absorption level) to dough, found that the effect on staling rate was significant only up to the second day of storage. Axford et al (1968) studied the effect of loaf volume on the rate of staling and found that lower specific volume increased the staling rate and higher specific volume lowered it.

Several papers (Kim and D'Appolonia 1977, Maleki and Seibel 1972c, Ponte et al 1962, Prentice et al 1954) have described the relation of flour quality to the staling rate of bread. Working with synthetic dough systems, Prentice et al (1954) and Kim and D'Appolonia (1977) reported improved keeping quality for breads made with high protein flours. Ponte et al (1962) and Maleki and Seibel (1972c), however, working with commercial flours and flours from pure wheat varieties, found no significant correlation between bread staling rate and several flour indices such as bread volume, protein, ash, sedimentation number, total or soluble pentosans, or amylograph value.

This work was designed to determine the effects of volume, moisture, and various flour fractions on the softness and staling rate of bread.

MATERIALS AND METHODS

The flour was a composite of many varieties grown at many locations in the southern Great Plains. It had a protein content of 12.2% and an ash content of 0.40%. To study the effect of loaf size, bread was made from the same flour and baking procedure but baked in different sized pans. The effect of different oxidants on bread staling was studied by replacing the 20 ppm of bromate with 50 ppm of ascorbic acid in one series. Protein level was also varied to determine its effect.

Breads were baked according to the procedure described by Baig and Hoseney (1977). The procedure is based on 100 g of flour and is a straight dough method with optimum mixing time, water absorption, and oxidation.

Staling rate was measured by compressibility with a penetrometer (Precision Scientific) as described by Maleki and Seibel (1972a), who established a correlation coefficient of 0.88 between organoleptic and penetrometer values. Breads were stored in sealed polyethylene bags at room temperature. A 5-cm thick sample was cut from the bread after discarding the first 2.5 cm at the end of the loaf. Each sample was compressed in five spots by a weight of 203 g for 5 sec. The compression spots were marked by holes on the four corners and center of a 6 × 6-cm cardboard template placed on the cut surface of each sample. Data for five points from each loaf were averaged to give the compressibility, measured in penetrometer units (PU). Each sample was measured after one hour of cooling time and after one and three days of storage.

In addition, four varieties of wheat samples grown in Hutchinson, KS (NE69774, Eagle, Omaha, and Aurora) were milled on an experimental Buhler mill and analyzed for protein, ash, and moisture contents according to AACC methods.

Two of the flours, one strong (Eagle) and the other weak (NE69774), were fractionated into gluten, starch, and water-soluble fractions. The volume of water used was twice the flour weight. All the flour and one half of the water were mixed first for 30 sec at speed 1 of a Hobart mixer (model H-50) and then at speed 2 until the gluten was developed. Then half of the remaining water was mixed in gradually at speed 1. The remainder of the water was used to wash starch from the gluten. The dough slurry was centrifuged at about 1,000 × g and each fraction was collected separately. The gluten fraction was washed free of starch with several additional small portions of water. The wash water was added to the starch fraction. After centrifuging to remove the starch, the combined water solubles were frozen and freeze-dried. The starch and gluten fractions were also frozen and freeze-dried, and the dried fractions were ground in a Wiley mill. Protein content of the gluten fraction was determined and the flour reconstituted to its original protein content. Freeze-dried reconstituted flour samples were rehydrated to about the original moisture content in a fermentation cabinet, 90% rh.

Water absorption and optimum mixing time of each flour sample were determined using a mixograph (National Mfg., Lincoln, NE) as described by Finney and Shogren (1972). Breads were baked abd tested for staling rate as described. During baking, an additional 0.75% water was added for each 1% of nonfat dried milk in the formula. Mixing time was adjusted at the time of full formula mixing. All baking results and penetrometer values are averages of at least three determinations.

RESULTS AND DISCUSSION

Identical doughs baked different times had similar bread characteristics including loaf volumes (Table I). As expected,

[1] Contribution 78-281-j, Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Manhattan 66506.

[2] Present address: Department of Food Technology and Nutrition, College of Agriculture, Shiraz, Iran.

[3] Respectively: visiting professor and professor, Department of Grain Science and Industry, Kansas State University, Manhattan 66506, and professor, Department of Agronomy, University of Nebraska, Lincoln, 68583.

0009-0352/80/02013803/$3.00/0

decreased baking times produced breads with higher moisture contents. The effect of different bread moisture contents on the staling of bread is reported in Table II. Breads with higher moisture contents were initally softer (had higher PU readings) and remained softer during storage than did breads containing lower moisture. However, after three days of storage the difference was not significant and differences in staling rate (percent of original PU value) were not significant.

No significant difference was evident in the staling rates (Table III) of breads baked with two different oxidants (potassium bromate vs ascorbic acid). Bread baked in larger loaves (325 g of flour) were initially softer and remained softer during storage than did loaves from 100 g of flour; however, the staling rates were essentially the same.

As expected, samples with different protein levels produced significantly different loaf volumes (Table I). Breads with higher loaf volumes obtained from flour with higher protein content were initially softer and remained softer during storage than did breads with lower volumes (Table II). Bread baked from lower protein flours seemed to stale faster than breads baked from higher protein flours. (However, the results were barely significant at one day and not significant at three days.)

Table IV summarizes the data from the analysis of the four flours from one location. Of the four, Eagle and NE69774 had similar protein contents but varied widely in quality. Eagle, although lower in protein content than Omaha, produced the largest loaf volume (Table V). Its volume and its long mixing time show that it is the strongest flour of the four. NE69774, with a protein content close to that of Eagle, had a short mixing time and low loaf volume, indicating that it was a weak flour. Eagle and NE69774 were therefore chosen to study the effect of different flour fractions on the staling rate of bread. They were fractionated and reconstituted

TABLE I
Baking Data[a] for the Composite Flour

Treatment	Water Absorption (%)	Mixing Time (min)	Volume (cc)	Bread Moisture (%)
Variation of baking time				
24 min	63	3:40	922	34.5
21 min (control)	63	3:40	945	35.3
18 min	63	3:40	931	37.2
Variation of dough				
Control[b]	63	3:40	937	...
Replacements				
50 ppm ascorbic acid	63	4:00	912	...
10.4% protein flour	59	3:40	844	...
13.1% protein flour	66	3:40	967	...
325 g of flour	63	3:40	2639	...

[a]All results are the average of at least three values.
[b]Control contains 100 g of 12.2% protein flour and 20 ppm bromate.

TABLE II
Effect of Baking Time on Staling of Bread

Baking Time	Moisture After Baking (%)	Bread Sampled After: 1 Hr PU[a]	1 Hr % PU	1 Day PU	1 Day % PU[b]	3 Days PU	3 Days % PU
24 min	34.5	151	100	111	74	66	44
21 min	35.3	168	100	125	75	79	40
18 min	37.2	183	100	125	68	77	42

[a]Penetrometer units.
[b]Percent of original PU indicates staling rate.

TABLE III
Effect of Protein Content, Loaf Size, and Ascorbic Acid on the Staling Rate of Bread

	Bread Sampled After: 1 Hr PU[a]	1 Hr % PU	1 Day PU	1 Day % PU[b]	3 Days PU	3 Days % PU
Control[c]	172	100	113	66	72	42
Replacements						
10.4% protein	175	100	99	57	64	37
13.1% protein	187	100	117	63	74	40
50 ppm Ascorbic acid	165	100	113	68	70	42
325 g of flour	207	100	131	63	89	43

[a]Penetrometer units.
[b]Percent of original PU indicates staling rate.
[c]Control contains 100 g of 12.2% protein flour and 20 ppm bromate.

TABLE IV
Analytical Data for Four Wheat Varieties

	Protein[a] (%)	Ash (%)	Moisture (%)	Water Absorption[b] (%)	Mixing Time[b] (min)
Eagle	13.2	0.42	13.4	65	6.0
Omaha	14.0	0.41	13.2	59	2.0
NE69774	13.1	0.43	13.5	60	2.5
Aurora	12.1	0.41	13.4	59	2.5

[a]N × 5.7. (AACC 1962).
[b]Determined from mixogram.

TABLE V
Baking Data for the Original and Reconstituted Flours

Flour	Mixing Time (min)	Proof Height (mm)	Loaf Weight (g)	Volume[a] (cc)
Original				
Eagle	5:35	7.7	148.5	1018
Omaha	2:10	7.8	147.9	975
NE69774	2:10	7.4	146.9	930
Aurora	2:30	7.4	146.2	930
Reconstituted				
Eagle	3:30	7.7	148.6	1069
NE69774	1:15	7.1	144.6	768
Eagle with NE69774 gluten	1:30	7.0	144.0	790
Eagle with NE69774 starch	3:15	7.7	149.1	1077
Eagle with NE69774 water solubles	3:30	7.7	150.1	1005
NE69774 with Eagle gluten	3:15	7.7	149.2	1047

[a]Standard deviation of loaf volumes = 12 cc.

TABLE VI
Staling Rates of Breads from Various Flour Samples

Flour	Bread Sampled After: 1 Hr PU	1 Hr % PU	1 Day PU	1 Day % PU	3 Days PU	3 Days % PU
Original						
Eagle	184	100	125	68	91	49
NE69774	169	100	97	57	61	36
Omaha	177	100	108	61	78	44
Aurora	163	100	95	58	59	36
Reconstituted						
Eagle	187	100	127	68	88	47
NE69774 with Eagle gluten	204	100	125	61	86	42
Eagle with NE69774 starch	189	100	133	70	93	49
Eagle with NE69774 water solubles	184	100	122	66	83	45
Standard deviation	7.8		7.1		7.4	

in several different ways.

Table V summarizes the baking data of the original and reconstituted flours. Low loaf volumes of bread from reconstituted NE69774 flour and from Eagle starch and water solubles reconstituted with NE69774 gluten indicate that the gluten of NE69774 was damaged during fractionation In previous work, Hoseney et al (1969) showed that weak flours are susceptible to damage during fractionation. The other reconstituted flours produced loaves with volumes close to or better than the original Eagle flour. Those results indiate that the starch and water solubles from NE69774 and the starch, water solubles, and gluten of Eagle were unaffected by the fractionation techniques.

Table VI reports staling rate measurements. Values for the four original flours show that the flour of Eagle wheat produced bread that staled most slowly and of NE69774, most quickly. When the results of four replicates of these two flours were analyzed statistically, the data showed no difference between the 1-hr samples, but differences were significant at $P = 0.10$ after one day of storage, and at $P = 0.05$ after three days of storage. Differences among replicates of each group were not significant. From this, we concluded that breads baked from those two flours vary in staling rate.

Results of reconstituted Eagle flour (Table VI) show that the fractionation procedure did not change the staling rate.

Reconstitution of starch and water solubles from NE69774 with the gluten from Eagle (Table VI) gave a reconstituted flour that staled at a rate equal to reconstituted Eagle. Therefore, the starch and water-soluble fractions from the two different flours did not significantly affect the staling rate. However, when the gluten of NE69774 was replaced with the gluten of Eagle, reconstituted NE69774 flour's staling rate improved and approached that of Eagle flour. That indicates that the flour component primarily responsible for differences in staling rate of those two flours was the gluten fraction. That finding is contrary to the views of Kim and D'Appolonia (1977). They reported that the primary effect of protein in reducing staling rate was its dilution of the starch.

The results described here should not be interpreted as evidence against the large volume of data showing that the starch is responsible for staling in bread. What is shown is that a number of factors can affect either the absolute softness or the staling rate. For example, the moisture content and loaf size of bread affect the absolute softness but not the staling rate. The protein content affects the softness and at low protein, the staling rate. Different flours stale at different rates, and the quality of protein appears to be responsible for the difference in rate.

ACKNOWLEDGMENTS

We thank Richard Junge for his help during the baking and Gary Paulsen for growing the wheat samples.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Approved Methods of the AACC. Methods 46-10 and 08-01, approved April 1961, and Method 44-15A, approved October 1975. The Association: St. Paul, MN.

AXFORD, D. W. E., COLWELL, K. H., CONFOR, S. J., and ELTON, G. A. H. 1968. Effect of loaf volume on the rate and extent of staling in bread. J. Sci. Food Agric. 19:95.

BAIG, M. M., and HOSENEY, R. C. 1977. Effect of mixer speed, dough temperature, and water absorption on flour-water mixograms. Cereal Chem. 54:605.

BECHTEL, W. G. 1955. A review of bread staling research. Trans. Am. Assoc. Cereal Chem. 13:108.

BECHTEL, W. G., and MEISNER, D. F. 1954. Staling studies of bread made with flour fractions. III. Effect of crumb moisture and of tailing starch. Cereal Chem. 31:176.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flours. Bakers Dig. 46(2):32.

HERTZ, K. O. 1965. Staling of bread, a review. Food Technol. 19:1828.

HOSENEY, R. C., FINNEY, K. F., SHOGREN, M. D., and POMERANZ, Y. 1969. Functional (breadmaking) and biochemical properties of wheat flour components. III. Characterization of gluten fractions obtained by ultra-centrifugation. Cereal Chem. 46:126.

KIM, S. K., and D'APPOLONIA, B. L. 1977. Bread staling studies. I. Effect of protein content on staling rate and bread crumb pasting properties. Cereal Chem. 54:207.

KNIGHTLY, W. H. 1977. The staling of bread, a review. Bakers Dig. 51(5):52.

MAGA, J. A. 1975. Bread staling. Page 443 in: FURIA, T. E. (ed.) Critical Reviews in Food Technology. Chemical Rubber Co.: Cleveland, OH.

MALEKI, M., and SEIBEL, W. 1972a. Uber das Altbackenwerden von Brot. I. Beziehungen zwischen Sensorik, Penetrometer und Panimeter beim Messen des Altbackenwerdens von Weizenbrot. Getreide Mehl Brot 26:58.

MALEKI, M., and SEIBEL, W. 1972b. Uber das Altbackenwerden von Brot. III. Der Einfluss von Fett, Emulgatoren und Schuttwassermenge. Getreide Mehl Brot 26:258.

MALEKI, M. and SEIBEL, W. 1972c. Uber das Altbackenwerden von Brot. IV. Einfluss der Weizensorte auf das Altbackenwerden. Getreide Mehl Brot 26(7):190.

PLATT, W., and POWERS, R. 1940. Compressibility of bread crumb. Cereal Chem. 17:601.

PONTE, J. G., Jr., TITCOMB, S. T., and COTTON, R. H. 1962. Flour as a factor in bread staling. Cereal Chem. 39:437.

PRENTICE, N., CUENDET, L. S., and GEDDES, W. E. 1954. Studies on bread staling. V. Effect of flour fractions and various starches on the firming of bread crumb. Cereal Chem. 31:988.

ZOBEL, H. F. 1973. A review of bread staling. Bakers Dig. 47(5):52.

[Received February 26, 1979. Accepted August 27, 1979]