# Effect of Baking Time and Temperature on Bread Quality, Starch Gelatinization, and Staling of Egyptian Balady Bread[1]

H. A. FARIDI[2] and G. L. RUBENTHALER[3]

Cereal Chem. 61(2):151-154

## ABSTRACT

Four levels of oven baking time and temperature (540°C, 1 min; 415°C, 2 min; 370°C, 3–4 min; 260°C, 6–7 min) were used to bake balady doughs. Lower oven temperature and longer baking time produced breads that were drier and of lower quality. Breads baked at medium temperatures showed the greatest extent of starch gelatinization. Staling rate, as measured by loss of crumb soluble starch and its amylose content, pasting properties, and alkaline water-retention capacity was faster for breads baked at 260°C for 6–7 min than those baked at higher temperature and shorter time. Staling rate was faster during the first 8 hr of storage.

In Egypt, wheat in the form of bread is the daily staple. The most popular wheat bread is a flat, circular loaf composed of two layers. Flour extraction rate is high (82%), and soft white wheat is preferred. The formula consists of flour, water, yeast (or starter), and salt. Water absorption is very high and significantly affects physical characteristics and flavor of the bread (Dalby 1963, Mousa et al 1979). The oven temperature is very high and baking time is only a few minutes. In the oven, a crust forms in less than 1 min, and the internal temperature reaches a point high enough to develop steam that "puffs" the bread with almost explosive rapidity. Thus, leavening effect is due largely to steam (Tabekhia and Toma 1979, Arafah et al 1980).

Balady bread is usually baked at high temperatures (450–500°C), but can be baked at a substantially lower temperature (320°C) as well. Baking time and temperature have a significant impact on the nutritive value of bread. El-Samahy and Tsen (1981) reported a significant deterioration of balady bread's protein quality as a result of higher baking temperature or prolonged baking time.

Balady bread also has a higher dough water absorption (70–75%) than does Western white pan bread (60–65%). Pan bread in the United States has only a small portion of the starch completely gelatinized, the rest being partially swollen during baking. One reason for this is that there is too little water in the dough to allow starch to gelatinize during baking (Dalby 1966). Varriano-Marston et al (1980) reported that the degree of starch gelatinization and swelling in baked foods paralleled moisture content; ie, the higher the moisture content, the greater the starch swelling. Baking time and temperature are important in the extent of starch gelatinization during oven baking. The kinetics of starch gelatinization reactions are dependent on temperature and on heating time at a particular temperature. Gelatinization of starch generally improves carbohydrate digestibility because it allows for more rapid attack of the starch granules by digestive enzymes.

Although reports on bread staling are numerous (Kulp and Ponte 1981, Knightly 1977), none of them discusses the staling of balady bread. Bechtel and Meisner (1954) reported that bread with higher moisture content was significantly fresher than bread with lower moisture. Platt and Powers (1940) reported that differences in the staling rate of breads baked for different times resulted from different moisture contents. Maleki et al (1980) reported that breads with higher moisture content were initially softer and remained softer up to three days of storage than did breads with lower moisture.

[1]Scientific Paper No. 6486, College of Agriculture Res. Ctr., Washington State University, Pullman 99164. Presented at the 67th Annual Meeting of American Association of Cereal Chemists, San Antonio, TX, Oct. 24-28, 1982.

[2]Visiting food scientist, USDA, ARS, Western Wheat Quality Laboratory and Dept. of Food Science and Technology, WSU, Pullman, WA 99164. Present address: Nabisco Brands Inc., Fair Lawn, NJ 07410.

[3]Research food technologist-in-charge, USDA, ARS, Western Wheat Quality Laboratory, Pullman, WA 99164.



The purpose of this study was to investigate effects of various oven baking times and temperatures on balady bread quality, degree of starch gelatinization, bread freshness, and shelf life.

## MATERIALS AND METHODS

A western white composite of four soft white wheats (20% each of Nugaines, Daws, Stephens, and Sprague) and two club wheats (10% each of Jacmar and Moro) was prepared and used throughout the study. Each variety was prepared by compositing different crop years grown at several locations in the Pacific Northwest. To attain the desired 82% extraction flour for balady bread production, shorts and bran streams were reground as needed and sieved through a 94-mesh stainless steel screen. The flour was stored in airtight containers until used. Protein and ash content, 9.7 and 0.58%, respectively, were typical of soft white wheat at 82% extraction.

### Bread-baking Technique

Balady bread was prepared by mixing to optimum 65 g of flour and other ingredients (Table I). After fermenting for 60 min at 85°F and 95% rh, doughs were degassed and transferred to a special molder (Rubenthaler and Faridi 1982) and flattened to a thickness of 6 mm and a diameter of 15 cm. Molded doughs were then transferred onto a canvas that had been dusted with a thin layer of flour and then were placed in the fermentation cabinet for a 30-min proof at 85°F and 95% rh. The proofed dough was transferred by sliding onto a lightly floured stainless steel sheet that was used to slide the dough onto a baking stone in a specially designed oven to bake at four oven time-temperature levels (540°C, 1 min; 415°C, 2 min; 370°C, 3–4 min;l 260°C, 6–7 min). Breads were allowed to cool on racks for 15 min and then were evaluated or sampled for analysis.

### Bread Evaluation Technique

Visual scoring of the breads was done on a numerical basis of 1 to 10, where 10 is excellent. The average score for each factor of five replicated bakes was converted to descriptive categories of excellent, satisfactory, questionable, and unsatisfactory for scores of 9–10, 7–8, 5–6, and lower than 5, respectively.

Factors scored for the breads depended upon the following

TABLE I
Egyptian Balady Bread Formula

| Ingredients[a] | Percent |
|---|---|
| Flour | 100 |
| Yeast[b] | 1 |
| Salt | 1.5 |
| Water[c] | 76 |

[a]On flour basis.
[b]Fresh bakers yeast supplied by Nabisco Brands Inc., Sumner, WA.
[c]Water was adjusted to 200 Brabender units level on Farinograph.

traditional desired characteristics: complete separation of upper and lower crusts that are equal in thickness; a soft, white, moist crumb; and a light shiny crust with brown spots (Faridi and Rubenthaler 1983).

### Determination of Gelatinization Degree

Starch was washed from different sections (upper crust, lower crust, side crumb, and middle crumb) of freshly baked balady bread, using the method of Varriano-Marston et al (1980). Chiang and Johnson's (1977) enzymatic attack method was used to determine the degree of gelatinization in starch washed from the balady bread sections.

### Determination of Staling Rate

After baking, loaves were cooled at room temperature for 15 min and then stored at 24°C in sealed polyethylene bags to prevent moisture loss. At 0.15, 1, 3, 5, 8, 24, and 48 hr of storage, bread crumbs were carefully removed with a sharp surgical blade to prevent contamination by crust, then freeze-dried and ground on a Stein mill to pass through a 60-mesh stainless steel sieve.

Soluble starch was isolated from bread crumb according to Schoch and French's procedure (1947) as modified by Morad and D'Appolonia (1980a).

Amylose content of soluble starch was determined by the method of Williams et al (1970). A standard curve for amylose was prepared using potato amylose Type III (Sigma Chem. no. A-0512). The amylopectin content in the soluble starch was obtained by subtracting the amylose content from the total amount of soluble starch.

Pasting properties of bread crumbs were determined by Brabender viscoamylograph as described by Morad and D'Appolonia (1980b).

Alkaline water-retention capacity (AWRC) of bread crumbs was measured by the method of Yamazaki (1953) as modified by Kitterman and Rubenthaler (1971).

Statistical analysis was performed as described by Steel and Torrie (1980).

TABLE II
**Effect of Four Oven Baking Conditions on Physical Characteristics of Egyptian Balady Bread**

| Baking Conditions | Moisture Content[a,b] (%) | Upper to Lower Crust Ratio | Pocket Formation | Crumb Texture | Crust Color |
|---|---|---|---|---|---|
| 540°C, 1 min | 36.8 | E[c] | E | E | E |
| 415°C, 2 min | 36.2 | E | E | E–S | E–S |
| 370°C, 3–4 min | 34.3 | E | E | S | S |
| 260°C, 6–7 min | 28.0 | E–S | E | Q | Q |

[a] Breads were cooled for 15 min. After baking, the moisture was measured according to AACC Methods (1983).
[b] Averages of at least two replicates. Standard error and least significant difference were 0.53 and 1.62, respectively.
[c] E = excellent, S = satisfactory, Q = questionable, U = unsatisfactory.

TABLE III
**Effect of Four Oven Baking Conditions on Degree of Starch Gelatinization of Different Sections of Egyptian Balady Bread[a,b,c,d]**

| Baking Conditions | Upper Crust (%) | Lower Crust (%) | Middle Crumb (%) | Side Crumb (%) |
|---|---|---|---|---|
| 540°C, 1 min | 85.4 | 87.4 | 90.2 | 91.0 |
| 415°C, 2 min | 83.8 | 85.0 | 89.0 | 92.8 |
| 370°C, 3–4 min | 89.6 | 86.2 | 93.6 | 96.2 |
| 260°C, 6–7 min | 80.2 | 78.6 | 91.0 | 89.8 |

[a] Degree of starch gelatinization of control flour was 12.4%.
[b] On dry basis.
[c] Determinations were done on starch washed from the samples.
[d] Averages of at least two replicates. Standard error and least significant difference were 1.53 and 5.28, respectively.

## RESULTS AND DISCUSSION

### Effect of Various Oven Time and Temperature on Physical Characteristics of Bread

The effects of four levels of oven baking time and temperature on the physical properties of bread are shown in Table II. Breads baked at higher temperature and shorter time were generally of better quality than those baked at lower temperature and longer time, although separation of upper and lower crusts was complete at all treatments. This indicates that pocket formation is more a function of dough moisture content than of oven temperature. Longer oven baking time and lower temperature resulted in drier breads. Crumb was also rough and dry. Lower temperature and longer baking also failed to yield breads with desirable bread crusts. Although dough moisture is higher in balady bread than in Western white pan bread dough, the proportion of moisture loss during and after oven baking is higher for balady bread, as shown in Table II.

### Effect of Various Baking Conditions on Starch Gelatinization

Effect of four oven baking times and temperatures on degree of starch gelatinization of different sections of freshly baked Egyptian balady bread is shown in Table III. The extent of starch gelatinization of balady bread was generally higher than that of Western pan bread (Varriano-Marston et al 1980) at all four baking conditions tested. This was probably due to higher dough moisture during oven baking, so more water is available to starch to gelatinize during baking. However, moisture content of balady bread is not higher than white pan bread, because of excessive moisture loss during and immediately after oven baking. Higher degree of starch gelatinization also binds more water in balady bread than in white pan bread. Because millions of low-income Egyptians depend on the nutrient intake they receive from balady bread, the impact of higher starch gelatinization and more

TABLE IV
**Effect of Staling on the Quantity and Composition of Soluble Starch Extracted from Egyptian Balady Bread Crumb Baked Under Four Baking Conditions[a,b]**

| Baking Conditions | Time (hr) | Soluble Starch (%) | Amylose (%) | Amylopectin (%)[c] |
|---|---|---|---|---|
| 540°C, 1 min | 0.15 | 2.38 | 0.95 | 1.43 |
| | 1 | 2.12 | 0.77 | 1.35 |
| | 3 | 1.98 | 0.68 | 1.30 |
| | 5 | 1.48 | 0.45 | 1.03 |
| | 8 | 0.98 | 0.26 | 0.72 |
| | 24 | 0.70 | 0.17 | 0.53 |
| | 48 | 0.68 | 0.11 | 0.57 |
| 415°C, 2 min | 0.15 | 2.42 | 0.80 | 1.62 |
| | 1 | 2.24 | 0.65 | 1.59 |
| | 3 | 2.24 | 0.64 | 1.60 |
| | 5 | 2.16 | 0.58 | 1.58 |
| | 8 | 1.82 | 0.43 | 1.39 |
| | 24 | 1.36 | 0.23 | 1.13 |
| | 48 | 1.18 | 0.16 | 1.02 |
| 370°C, 3–4 min | 0.15 | 2.62 | 1.07 | 1.55 |
| | 1 | 2.56 | 0.93 | 1.63 |
| | 3 | 2.54 | 0.77 | 1.77 |
| | 5 | 2.50 | 0.66 | 1.84 |
| | 8 | 1.98 | 0.42 | 1.56 |
| | 24 | 1.50 | 0.30 | 1.20 |
| | 48 | 1.20 | 0.22 | 0.98 |
| 260°C, 6–7 min | 0.15 | 2.82 | 0.96 | 1.86 |
| | 1 | 2.36 | 0.80 | 1.56 |
| | 3 | 1.96 | 0.54 | 1.42 |
| | 5 | 1.78 | 0.47 | 1.31 |
| | 8 | 1.54 | 0.37 | 1.17 |
| | 24 | 1.14 | 0.17 | 0.97 |
| | 48 | 0.98 | 0.11 | 0.87 |

[a] On dry basis.
[b] Averages of at least two replicates. Standard error and least significant difference of soluble starch were 0.040 and 0.12 and for amylose were 0.032 and 0.09.
[c] By difference.

digestibility must be evaluated.

Among breads baked under four different conditions, those baked at 370°C for 3–4 min had a higher degree of starch gelatinization. In these breads, 370°C temperature and 3–4 min duration of baking provide the most favorable condition of moisture and temperature for starch to gelatinize.

Among different sections of breads, crumb starch gelatinized more than crust starch, mainly because it had more access to water and was not subject to intense heat as crusts were. Starch from the side crumb was more gelatinized than starch from the middle crumb because middle crumbs of upper and lower crusts separate very quickly in the oven and lose moisture faster than does the side crumb. Varriano-Marston et al (1980) have also observed more starch swelling in the centermost portions of bakery products than in the exterior portions.

### Effect of Various Baking Conditions on Crumb Soluble Starch and Amylose

The effect of storage on the quantity and composition of soluble starch extracts from bread crumbs produced from breads baked under different conditions is given in Table IV. The recovery of soluble starch from fresh bread crumb was related to the oven baking time and temperature. The soluble starch content from fresh bread decreased as oven baking temperature increased. The staling rate as indicated by the soluble starch content was faster for breads baked at the highest (540°C, 1 min) and at the lowest (270°C, 6–7 min) than those baked at the medium baking temperatures (370°C, 3–4 min and 415°C, 2 min).

The composition of soluble starch indicates that the soluble starch leached from the crumb of fresh balady bread was predominantly amylopectin, confirming the observations of Kim and D'Appolonia (1977) and of Schoch and French (1947) on white pan bread. Although the amylose content in the soluble starch leached from the fresh bread crumb (Table IV) was small, it also progressively decreased during bread storage for all four levels of oven baking times and temperatures. However, amylose content decreased more rapidly upon storage for breads baked at 540°C for 1 min and at 260°C for 6–7 min than those baked under other conditions. The largest decrease in soluble starch and its amylose content occurred during the first 8 hr of storage; thereafter the changes were small. In practice, balady bread is purchased and consumed on a daily basis because it loses its freshness in a few hours.

Amylopectin content leached from the fresh bread crumb progressively decreased during storage for all baking conditions except for breads baked at 370°C for 3–4 min. In these breads, amylopectin somewhat increased during the first 5 hr of storage.

### Effect of Various Baking Conditions on Pasting Properties

Initial viscosity of freeze-dried crumb samples decreased sharply during the first 8 hr of bread storage as shown in Table V and continued to decrease at a slower rate up to 48 hr of storage at all levels of oven time and temperature. Maximum viscosity at 95°C, viscosity at 95°C after 15 min, and viscosity at 50°C all decreased during the first 8 hr of storage time at all four levels of oven time and temperature. However, the decrease was smaller for breads baked at 540°C for 1 min. No clear trend was observed with the pasting properties of bread crumbs stored beyond 8 hr.

### Effect of Various Baking Conditions on AWRC

The AWRC, a test for determining the water-binding capacity of flours, was found to be significantly correlated with the composition of soluble starch (Table IV) and the amylograph pasting properties (Table V) of the bread crumb. Like the soluble starch data, AWRC data sharply decreased during the first 8 hr of storage. The decrease was minimal when breads were stored for a second day (Table VI). These and other correlation coefficients are shown in Table VII. AWRC related the closest to the initial pasting viscosity and percent amylose of the soluble starch. Since AWRC is a simple and quick test, it may be useful in following staling and

**TABLE V**
**Effect of Four Baking Conditions on Pasting Properties of Balady Bread Crumb During Storage[a,b]**

| Baking Condition | Time (hr) | Viscosity Initial (BU)[c] | Maximum Viscosity (BU)[c] | Viscosity at 95°C After 15 min (BU)[c] | Viscosity at 50°C (BU)[c] |
|---|---|---|---|---|---|
| 260°C, 6–7 min | 0.15 | 80 | 690 | 530 | 1,040 |
| | 8 | 38 | 590 | 500 | 1,010 |
| | 24 | 18 | 520 | 500 | 1,010 |
| | 48 | 12 | 455 | 470 | 990 |
| 370°C, 3–4 min | 0.15 | 80 | 725 | 610 | 1,050 |
| | 8 | 40 | 583 | 500 | 1,020 |
| | 24 | 20 | 585 | 600 | 1,090 |
| | 48 | 18 | 590 | 610 | 1,090 |
| 415°C, 2 min | 0.15 | 90 | 730 | 635 | 1,080 |
| | 8 | 22 | 600 | 555 | 1,060 |
| | 24 | 10 | 590 | 610 | 1,090 |
| | 48 | 20 | 640 | 660 | 1,110 |
| 540°C, 1 min | 0.15 | 75 | 760 | 615 | 1,100 |
| | 8 | 40 | 685 | 605 | 1,090 |
| | 24 | 15 | 620 | 630 | 1,100 |
| | 48 | 18 | 670 | 690 | 1,130 |

[a]On dry basis.
[b]Averages of at least two values. $S\bar{x}$ (standard error) and LSD (least significant difference) for initial viscosity, maximum viscosity, Vis at 95°C after 15 min, and viscosity at 50°C were 8.75, 26.4; 37.28, 112.4; 38.12, 114.9; and 77.14, 232.46, respectively.
[c]Brabender units.

**TABLE VI**
**Effect of Four Oven Baking Conditions on Alkaline Water-Retention Capacity of Balady Bread Crumb During Storage[a,b]**

| Baking Condition | Time (hr) | Alkaline Water-Retention Capacity (%) |
|---|---|---|
| 540°C, 1 min | 0 | 431 |
| | 8 | 340 |
| | 24 | 238 |
| | 48 | 215 |
| 415°C, 2 min | 0 | 390 |
| | 8 | 318 |
| | 24 | 234 |
| | 48 | 207 |
| 370°C, 3–4 min | 0 | 393 |
| | 8 | 310 |
| | 24 | 235 |
| | 48 | 208 |
| 260°C, 6–7 min | 0 | 372 |
| | 8 | 296 |
| | 24 | 231 |
| | 48 | 214 |

[a]On dry basis.
[b]Averages of at least two values. Standard error and least significant difference were 2.87 and 8.66, respectively.

**TABLE VII**
**Correlation Coefficients of Soluble Starch, Amylograph Viscosity, and Alkaline Water-Retention Capacity (AWRC)**

| | Soluble Starch (%) | Amylose (%) | Amylograph (BU)[a] Initial Viscosity | Amylograph (BU)[a] Max. Viscosity | AWRC (%)[b] |
|---|---|---|---|---|---|
| Soluble starch (%) | ··· | 0.86 | 0.69 | 0.61 | 0.68 |
| Amylose (%) | ··· | ··· | 0.91 | 0.57 | 0.82 |
| Amylograph (BU)[a] Initial viscosity | ··· | ··· | ··· | 0.58 | 0.86 |
| Amylograph (BU)[a] Max. viscosity | ··· | ··· | ··· | ··· | 0.41 |
| AWRC (%) | ··· | ··· | ··· | ··· | ··· |

[a]Brabender units.
[b]AWRC = alkaline water-retention capacity.

shelf life by predicting amylose and initial pasting viscosity of bread crumbs.

Our data show that balady breads baked at higher temperature for shorter time were softer initially and remained softer during 48 hr storge. Maximum freshness is lost in the first 8 hr of storage, indicating that balady bread has a relatively short shelf life. Changes from 8 to 48 hr of storage were less significant.


## ACKNOWLEDGMENTS

This project was funded in part by the Washington, Oregon, and Idaho Wheat Commissions, whose support is acknowledged. Technical assistance from G. E. King and P. A. Sperry is also acknowledged.


## LITERATURE CITED


AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 44-16. The Association, St. Paul, MN.

ARAFAH, A., ABASSY, M., MORCOS, S., and HUSSEIN, L. 1980. Nutritive quality of balady bread supplemented with fish protein concentrate, green algae, or synthetic amino acids. Cereal Chem. 57:35.

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

CHIANG, B. Y., and JOHNSON, J. A. 1977. Measurement of total and gelatinized starch by glucoamylase and *o*-toluidine reagent. Cereal Chem. 54:429.

DALBY, G. 1963. The baking industry in Egypt. Bakers Dig. 37(6):74.

DALBY, G. 1966. The baking industry in Sudan and Saudi Arabia. Bakers Dig. 34(3):64.

EL-SAMAHY, S. K., and TSEN, C. C. 1981. Effects of varying baking temperature and time on the quality and nutritive value of balady bread. Cereal Chem. 58:546.

FARIDI, H. A., and RUBENTHALER, G. L. 1983. Experimental baking techniques for evaluating Pacific Northwest wheats in North African breads. Cereal Chem. 60:74.

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.

KITTERMAN, J. S., and RUBENTHALER, G. L. 1971. Assessing the quality of early generation wheat selection with the micro AWRC test. Cereal Sci. Today 16:313.

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

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

MALEKI, M., HOSENEY, R. C., and MATTERN, P. J. 1980. Effect of loaf volume, moisture content, and protein quality on the softness and staling rate of bread. Cereal Chem. 57:138.

MORAD, M. M., and D'APPOLONIA, B. L. 1980a. Effect of surfactants and baking procedure on total water-solubles and soluble starch in bread crumb. Cereal Chem. 57:141.

MORAD, M. M., and D'APPOLONIA, B. L. 1980b. Effect of baking procedure and surfactants on the pasting properties of bread crumb. Cereal Chem. 57:239.

MOUSA, E. T., IBRAHIM, R. H., SHUEY, W. C., and MANEVAL, R. H. 1979. Influence of wheat classes, flour extractions, and baking methods on Egyptian balady bread. Cereal Chem. 56:563.

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

RUBENTHALER, G. L., and FARIDI, H. A. 1982. Note on a laboratory dough molder for flat breads. Cereal Chem. 59(1):72.

SCHOCH, T. J. and FRENCH, D. 1947. Studies on bread staling. I. The role of starch. Cereal Chem. 59(1):72.

STEEL, R. G. D., and TORRIE, J. H. 1980. Principles and Procedures of Statistics. McGraw-Hill, New York.

TABEKHIA, M. M., and TOMA, R. B. 1979. Chemical composition of various types of Egyptian breads. Nutr. Rep. Int. 19:377.

VARRIANO-MARSTON, E., KE, V., HUANG, G., and PONTE, J., Jr. 1980. Comparisons of methods to determine starch gelatinization in bakery foods. Cereal Chem. 57:242.

WILLIAMS, P. C., KUZINA, F. D., and HLYNKA, I. 1970. A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem. 47:411.

YAMAZAKI, W. T. 1953. An alkaline water-retention capacity test for the evaluation of cookie baking potentialities of soft winter wheat flours. Cereal Chem. 30:242.


[Received March 18, 1983. Accepted September 2, 1983]