Effects of Varying Baking Temperature and Time on the Quality and Nutritive Value of Balady Bread[1]

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ABSTRACT

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Effects of baking temperature and time on the quality and nutritive value of balady breads were evaluated. Baking at increasing temperature from 288 to 343° C for 4 min reduced the loaf weight and significantly darkened the top and bottom crusts of balady bread. Chemical characteristics and amino acid contents varied only slightly among breads baked at different high temperatures (248-343° C) and short times (3.5-7.0 min). Bread protein quality, however, deteriorated significantly as a result of raised baking temperature or prolonged baking time, as indicated by the increase in feed conversion ratio and the reduction in protein efficiency ratio shown by rat-feeding tests. The deterioration emphasizes the importance of controlling temperature and time when baking balady bread or related products such as pizza crust.

Of the various breads produced in Egypt and other countries in the Middle East, balady bread, a widely consumed flat bread, is the most popular. It commonly contains highly extracted flour (87% extraction) with a protein content of 10-12% and is prepared by a straight dough method with a starter instead of yeast. The starter consists of previously fermented dough containing heterogenous microorganisms (Hamed et al 1973, Mousa et al 1979).

Nutritionally, balady bread is vitally important to millions of low-income people because it provides much of the energy and protein in their diets (FAO 1977, Mousa et al 1979). Many attempts have been made to fortify balady bread with amino acids such as lysine, threonine, and methionine (Hussein et al 1973, Maleki and Djazayeri 1968) and with such protein-rich additives as chickpea, cottonseed, soybean, and faba bean flours (Dalby 1969, Finney et al 1980, Hallab et al 1974, Shehata and Fryer 1970) to improve its nutritive value.

Balady bread is baked at 300-350° C for 3-4 min according to the reports of Finney et al (1980) and Mousa et al (1979). It can also be baked at a substantially higher temperature (400-600° C) for a very short time (40-60 sec) (Dalby 1969, Hallab et al 1974). Most other breads, on the other hand, are normally baked at 218-232° C for 20-25 min. The nutritive value of bread protein in regular white bread, as expressed by the protein efficiency ratio (PER) determined by rat-feeding tests, is significantly reduced by conventional baking or toasting (Palamidis and Markakis 1980, Tsen and Reddy 1977, Tsen et al 1977). The protein quality of balady bread could be improved not only by fortifying it with amino acids or proteins but also by minimizing the deleterious effects of baking, particularly at high temperature. A study was therefore conducted to evaluate the effects of high-temperature, short-time baking on the volume and color of balady bread and on the nutritive value of its protein. Such effects, based on our laboratory baking and rat-feeding tests, are reported here.

MATERIALS AND METHODS

Wheat Flour

We used wheat flour with 85% extraction, milled in the pilot mill

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of the Department of Grain Science and Industry, Kansas State University. Its characteristics, in percentages, were: moisture, 12.8; protein, 11.1; ash, 0.81; crude fat, 1.3; and crude fiber, 1.2.

Preparation of Balady Bread

The following ingredients were used: 700 g of flour, 525 ml of water at 30° C, 10.5 g of compressed yeast, and 10.5 g of salt. These were mixed in a Hobart mixer for 15 min at the first speed, then transferred from the mixing bowl to a pan and fermented for 1.0 hr at 30° C and 85% rh in a fermentation cabinet. The fermented dough was divided into 125-g pieces, which were placed on a tray previously sprinkled with a layer of fine bran, proofed for 45 min in a proofing cabinet at 32° C and 90% rh, flattened by a molder, and placed in the proofing cabinet for 15 min at 30° C and 95% rh. The loaves were baked in the presence of about 2 psi of steam at various temperatures for different periods.

Evaluation of Bread Qualities

Loaves were weighed directly after baking and then placed in another oven at 148.9° C for 10 min to firm them for volume measurements by seed displacement. We evaluated the color of top and bottom crusts at 585 nm (yellow) on an Agtron multichromatic abridged reflectance spectrophotometer model M-300 A, standardized with standard disks M-56 and 00 to read 100 and 0, respectively.

Analyses and Nutritional Study

For feeding experiments, balady loaves were cut into pieces, dried in a fan dryer at 37° C for 24 hr, ground to uniform particle size (to pass 20 mesh), and used for diets.

The ground breads and wheat flour were analyzed for moisture, protein, and ash as described in AACC methods (1962), except that fat was determined by AOCS method Aa 4-38 (1971) with petroleum ether as extracting solvent.

Amino acids were determined by the procedures of Waggle et al (1966). The ground samples were hydrolyzed in excess 6*N* HCl for 22 hr, and 15 amino acids and ammonia were measured in a Beckman 120B amino acid analyzer. Methionine and cysteine were calculated as outlined by Moore (1963), with a 24-hr oxidation period, and hydrolyzed for 18 hr. No corrections were made for possible destruction of labile amino acid.

Vitamin and mineral premixes were prepared according to National Research Council formulas (NAS/NRC 1972) to support optimum rat growth, and 2% vegetable oil was added to each diet to improve texture and decrease dustiness. Experimental diets were formulated as in Table I.

Four-week-old male weanling rats (Charles River CD) were fed experimental diets that contained 10% protein supplied by experimental breads or casein for 28 days. The rats, whose initial weights varied from 56 to 70 g, were randomly divided into groups of six per treatment. Each rat was housed in a screen-bottomed cage in an environmentally controlled laboratory and given diet and water ad libitum. Fresh water was supplied every second day; feed cups were checked daily and filled as needed. Weights and feed consumed were recorded weekly for each rat, and feed conversion ratios and PERs were calculated.

RESULTS AND DISCUSSION

Effects of Baking Temperatures on Bread Quality

Data presented in Table II show the average of 18 readings of six replicates for balady bread baked at indicated temperatures for 4.5 min.

Analysis of variance showed that increasing baking temperature significantly decreased loaf weight and darkened both top and bottom crusts, but that it had no significant effect on loaf volume or specific volume.

We found that baking at 343° C for 3.5 min was optimum for processing balady bread in our laboratory (data not shown). The finished bread was regarded as a high-quality product with an average loaf weight of 104.23 g, specific loaf volume of 5.78, top-crust color of 51.79 Agtron units, and bottom-crust color of 48.50.

TABLE I
Composition of Experimental Diets[a]

Protein Source	Protein (%)	Casein or Ground Bread[b]	Starch (%)
Casein[c]	82.0	12.2	77.00
Bread baked at			
248° C, 6.4 min	13.23	75.59	10.77
288° C, 7.0 min	13.17	75.93	10.52
327° C, 3.6 min	13.63	73.37	12.44
327° C, 5.0 min	13.32	75.08	11.15
327° C, 6.4 min	13.41	74.57	11.54
343° C, 3.5 min	13.44	74.41	11.66
343° C, 5.0 min	13.52	73.96	11.99

[a] All diets contained 2.0% fat (oil), 2.8% sugar, 2.0% vitamin mixture, and 3.0% mineral mixture (vitamin and mineral mixtures were adjusted for vitamin and mineral contents of flour, with starch as a filler).
[b] Amount added to make diet with 10.0% protein.
[c] Casein diet contained 1% nonnutritive fiber.

TABLE II
Effects of Baking Temperatures on the Quality of Balady Bread[a,b]

Temperature (° C)	Loaf Volume (cc)	Loaf Weight (g)	Specific Loaf Volume (cc/g)	Crust Color	
				Top (Agtron units)	Bottom (Agtron units)
343	626.7	95.8 a	6.5	18.44 d	33.44 d
329	646.6	96.9 a	6.7	34.22 c	43.17 c
316	571.1	104.2 b	5.5	49.28 b	54.50 b
302	577.8	106.2 b	5.4	65.89 a	58.63 ab
288	586.7	107.9 b	5.4	66.83 a	62.22 a
LSD[c]	···	5.8	···	12.45	5.37

[a] Average of six replicates, each read three times. Baking time, 4.5 min.
[b] Duncan's multiple range test (1955). Means without a letter in common differ significantly ($P < 0.05$).
[c] Least significant difference.

TABLE III
Chemical Composition of Bread Used for Diets Fed to Rats for 28 Days

Bread Baked at					
Temperature (° C)	Time (min)	Moisture (%)	Protein (%)	Ash (%)	Fat (%)
248	6.4	12.3	11.6	2.1	0.39
288	7.0	9.9	12.0	2.2	0.31
327	3.6	9.8	12.3	2.3	0.45
	5.0	9.2	12.1	2.3	0.43
	6.4	8.3	12.3	2.3	0.43
343	3.5	9.9	12.1	2.3	0.48
	5.0	9.8	12.2	2.2	0.42

TABLE IV
Amino Acids (g/100 g of protein) of Balady Bread Baked at Different Temperatures and Times

	Bread Baked at						
	248° C	288° C	327° C			343° C	
Amino Acid	6.4 min	7.0 min	3.6 min	5.0 min	6.4 min	3.5 min	5.0 min
Asp	4.78	4.99	4.81	4.51	4.80	5.18	4.76
Thr	2.87	3.06	2.86	2.74	2.81	3.17	2.90
Ser	5.63	5.90	5.52	5.61	5.23	6.20	5.15
Glu	33.92	30.37	35.23	36.79	34.68	28.89	34.51
Pro	11.02	12.15	10.78	10.51	11.31	12.51	11.24
Gly	3.78	4.06	3.83	3.68	3.89	4.31	3.87
Ala	3.74	3.82	3.68	3.57	3.78	3.62	3.81
Val	3.08	3.41	3.03	2.92	3.22	3.22	3.12
Met	1.56	1.62	1.55	1.51	1.53	1.66	1.55
Ileu	2.28	2.47	2.35	2.23	2.32	2.47	2.32
Leu	6.46	6.69	6.34	6.19	6.52	6.98	6.52
Tyr	2.59	2.55	2.47	2.39	2.55	2.66	2.49
Phe	4.30	4.53	4.28	4.26	4.56	4.73	4.40
His	2.10	2.05	1.95	2.05	1.83	2.11	1.99
Lys	2.57	2.55	2.52	2.50	2.09	2.53	2.35
Arg	4.06	4.22	3.84	4.13	3.78	4.23	4.08

TABLE V
Feed Intake, Weight Gain, and Feed Conversion Ratio of Rats Fed Bread Diets for 28 Days

Diet Containing Bread Baked at		Feed Intake[a,b] (g)	Weight Gain[a,b] (g)	Feed Conversion Ratio[a,b]
Temperature (°C)	Time (min)			
Casein diet		420.1 ± 16.0 a	126.2 ± 7.25 a	3.36 ± 0.11 e
248	6.4	320.2 ± 13.9 bc	53.21 ± 3.80 b	5.9 ± 0.24 d
327	6.4	253.0 ± 7.5 d	25.86 ± 1.07 f	9.83 ± 0.28 a
327	5.0	314.4 ± 8.2 bc	42.43 ± 1.87 cd	7.67 ± 0.18 b
343	5.0	263.3 ± 12.2 d	29.93 ± 2.90 ef	9.17 ± 0.73 a
327	3.6	309.1 ± 13.3 bc	47.68 ± 1.96 bc	6.61 ± 0.15 cd
343	3.5	284.7 ± 17.9 cd	36.57 ± 3.77 ed	8.08 ± 0.51 b
288	7.0	321.7 ± 16.9 b	44.00 ± 3.70 bc	7.36 ± 0.33 bc
LSD[c]		35.85	9.48	0.96

[a] Mean ± SEM.
[b] Duncan's multiple range test (1955): Means without a letter in common differ significantly ($P < 0.05$).
[c] Least significant difference.

TABLE VI
Protein Efficiency Ratios (PERs) of Bread Diets Fed Rats for 28 Days

Diets Containing Bread Baked at			
Temperature (°C)	Time (min)	PER[a,b]	Adjusted PER
Casein diet		2.99 ± 0.09 a	2.50
248	6.4	1.65 ± 0.06 b	1.38
327	6.4	1.03 ± 0.03 f	0.87
327	5.0	1.35 ± 0.04 d	1.13
343	5.0	1.13 ± 0.08 ef	0.95
327	3.6	1.52 ± 0.03 bc	1.27
343	3.5	1.26 ± 0.08 ed	1.05
288	7.0	1.38 ± 0.07 cd	1.16
LSD[c]		0.17	...

[a] Mean ± SEM.
[b] Duncan's multiple range test (1955): Means without a letter in common differ significantly ($P < 0.05$).
[c] Least significant difference.

Effects of Baking Temperature and Time

On Chemical Composition. Although no substantial changes were found in the chemical composition of balady breads baked at varied temperatures and times (Table III), the moisture content was higher for the bread baked at 248° C for 6.4 min than for those baked at higher temperatures, eg, 327° C for 6.4 min or even 3.6 min. The fat content was lower for the bread baked at 248 or 288° C than for the other breads. The reason why the breads baked at the low temperatures contain less fat is not clear.

On Amino Acid Content. Amino acids did not show marked changes in the breads baked at varied temperatures and times (Table IV). However, the histidine content appeared to decrease with increased baking temperature or prolonged baking time. The total lysine content also showed such a reducing tendency. Available lysine, not total lysine, is reduced significantly in regular bread baked conventionally (Palamidis and Markakis 1980, Tsen[3]). Available lysine contents in regular bread correlate highly with PER (Palamidis and Markakis 1980). Because the total lysine was not significantly reduced in the breads baked at varied temperatures and times, the reduced nutritive value of protein in balady breads probably results from a decrease in the availability of lysine induced by the browning reaction during baking.

Changes in the Feed Value of Balady Breads

Feed value deteriorated significantly and critically with high baking temperature and prolonged baking time (Table V), as shown by the increase in feed conversion ratio. Raising the baking temperature from 248 to 327° C increased the feed conversion ratio 0.05 per degree of temperature for breads baked 6.4 min, and 0.94 per degree between 327 and 343° C for bread baked 5.0 min. Prolonging the baking time almost doubled the deterioration. When baking time was extended from 3.6 to 5.0 and from 5.0 to 6.4 min at 327° C, the ratio increased 0.76/min and 1.54/min, respectively.

Changes in the Nutritive Value of Bread Protein

Like the feed conversion ratio, the nutritive value of balady bread was significantly affected by the high-temperature, short-time baking. Significant differences in PERs were found between breads baked for 6.4 min at 248 and 327° C or for 5.0 min at 327 and 343° C and also among breads baked at 327° C for 3.6, 5.0, or 6.4 min (Table VI).

Although improvement of the protein quality of balady bread by fortifying it with lysine, soy flour, or others is beneficial, efforts should also be made to minimize the deleterious effect of high-temperature baking on the bread's protein quality. As shown in Tables V and VI, the feed conversion ratio of balady bread is increased and the PER is significantly reduced by raising baking temperature and/or prolonging baking time. A difference in baking time of only 1.4 min can significantly change the nutritive value of bread protein when the breads are baked at 327° C. That finding shows the importance of controlling baking conditions (in high-temperature, short-time baking) while processing balady bread and such related products as pizza crust.

[3] Tsen, C. C. Unpublished data.

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