Gamma Radiation of Wheat. I. Effects on Dough and Baking Properties[1]

L. A. MacARTHUR and B. L. D'APPOLONIA,[2] Department of Cereal Chemistry and Technology, North Dakota State University, Fargo 58105.

ABSTRACT

Cereal Chem. 60(6):456-460

The effect of cobalt 60 gamma-radiation treatments (50, 100, 200, and 300 Krad) on the rheological properties and baking characteristics of three hard red spring (HRS) wheat cultivars was investigated. Amylograph peak viscosity and falling number values of the flour decreased significantly as radiation levels increased for all three cultivars, whereas Grain Amylase Analyzer values remained essentially constant, indicating no change in α-amylase enzyme. As radiation dosage increased for all samples, farinograph absorption increased, and dough development time and stability decreased. Baking quality decreased as radiation increased but appeared to be influenced by variety. Baking quality of the irradiated flour improved slightly after the flour was stored for six months. No apparent differences were noted in wet gluten and protein solubility values.

Gamma rays are highly penetrating electromagnetic radiations of short wavelength arising from the radioactive disintegration of certain elements. The effects of gamma radiation on cereal grains and cereal grain products have been of interest to scientists for decades. Some have suggested that gamma radiation of wheat results in molecular degradation of protein (Doguchi et al 1959, Doguchi and Okada 1962, Milner 1961, and Srinivas et al 1972), of starch (Deschreider 1960, Lai et al 1959, Ananthaswamy et al 1970), and possibly of other chemical components, because gamma and X-rays are capable of breaking any kind of chemical bond in organic matter. Researchers generally agree that irradiation of wheat flour changes the physical properties of dough, but they disagree as to the extent of the change.

Contradictory results can be attributed to: variety and type of wheat; protein quantity and quality of the wheat or flour; and the dosage and the source of radiation used. This study was intended to examine three hard red spring (HRS) wheat varieties having different dough-handling and mixing characteristics to ascertain whether increasing amounts of low-level Cobalt 60 gamma-radiation significantly influenced dough and baking properties.

MATERIALS AND METHODS

Samples

The three HRS wheat cultivars used were chosen according to their mixing characteristics. Waldron, a conventional hard red spring wheat, has been the most popular variety grown in North Dakota for many years. This variety has good quality and medium mixing strength. The two extremes—Olaf, grown in Minot, ND, and an experimental variety grown in Minnesota—exhibited strong and weak mixing characteristics, respectively. All three cultivars were grown during the 1979 crop year.

Radiation Treatment

Samples of each variety were cleaned and tempered to 14.0% moisture. The wheat was then bagged in polyethylene bags and hermetically sealed. Gamma rays were emitted from a Cobalt 60 source at a rate of 9,981 rads per minute. The time of exposure was calculated to equal the radiation treatment levels of 50, 100, 200, and 300 Krads.

Analytical Measurements

Moisture, ash, and protein (14.0% mb) were determined on the milled flour according to AACC standard methods 08-01, 46-10, and 44-15A (1961).

Amylograph Data

Maximum viscosity of the various irradiated flours was determined with the Brabender ViscoAmylograph according to standard AACC procedure 22-10 (1961).

Falling Number

The falling number was determined on 7.0 g (14.0% mb) of milled flour according to AACC procedure 56-81B (1961).

Wet Gluten and Protein Denaturation

A Glutomatic 2200 (Doty Labs, Inc., Kansas City, MO) was used to determine wet gluten. Determinations were made in duplicate, using 10.0 g of flour, and were expressed on a 14.0% moisture basis. Denaturation of protein was measured by the decrease in solubility of the protein in 0.1 *N* acetic acid according to the method reported by Pence et al (1953) and modified by Kim (1981). For the determination, 5.0 g of flour (as-is basis) wetted with 10 ml of isopropanol was extracted with 100 ml 0.1 *N* acetic acid in a 50-ml plastic centrifuge tube with mechanical shaking (Wrist-Action, Burrel Corp., Pittsburgh, PA) for 1 hr. After centrifugation at 5,000 × *g* for 30 min at 5° C, 20 ml of the supernatant was analyzed for nitrogen by the macroKjeldahl method (AACC method 46-11), using 1 ml of antifoam agent (Antifoam A Emulsion, Sigma Chemical Co., diluted 1:4 with diethyl ether) to prevent foaming during digestion. Digestion was done first at a low heat setting to boil off the water, and then at full heat for 40 min. Results are expressed as percentage of total sample protein.

Model 191 Grain Amylase Analyzer Determination

The procedure used for determining amylase with the model 191 Grain Amylase Analyzer (GAA), was described by Campbell and Ranum (1980). Results were based on an average of three determinations and reported as GAA units per 4 g of flour.

Physical Dough Testing

The farinograph and extensigraph were used to determine the physical dough properties of the irradiated flours. For the farinograph studies, the 50-g bowl and the standard AACC constant flour weight procedure, 08-01 (1961), was used.

Extensigrams were obtained according to AACC procedure 46-10 (1961) with the following modifications. One-hundred-gram samples on a constant moisture basis were mixed in a standard National dough mixer (National Mfg. Co., Lincoln, NE) with variable mixing times in accordance with data obtained from the farinogram. Measurements were made at 90 and 180 min.

Baking Studies

The irradiated flours were baked in duplicate using a conventional straight-dough procedure. Baking absorption was estimated from the farinograph absorption, whereas optimum mixing time was obtained by visual examination of the dough.

[1] Presented in part at the AACC 66th Annual Meeting, Denver, CO, October 1981. Published with the approval of the director of the Agricultural Experiment Station, North Dakota State University, Fargo, as Journal series no. 1253.
[2] Instructor and professor, respectively.

Mixing was performed in a National 100–200-g mixer. The baking formula used, with ingredients expressed on a flour basis, was: flour, 100% (14% mb); salt, 2%; sugar, 5%; shortening, 3%; compressed yeast, 3%; potassium bromate, 10 ppm (used in one set of loaves); and water, variable.

After a 2-hr fermentation period with two punches, the doughs were sheeted, hand-molded, proofed for 55 min, and baked for 25 min at 230°C. The bread was allowed to cool for 1 hr and the volume measured by rapeseed displacement. The bread was stored overnight and judged for grain and texture and crumb color the following day on a scoring system of 1 to 10, with 10 being the best score.

RESULTS AND DISCUSSION

Analytical Measurements

No apparent change was observed in ash and protein content (Table I) of the various irradiated samples. Because no heat is generated with gamma radiation, the moisture content remained the same as before radiation treatment.

Amylograph, Falling Number, and GAA Data

Falling number values and amylograph peak viscosity of the irradiated flour samples (Table II) showed a steady decrease in viscosity as radiation level was increased. The high falling number and amylograph values of the control samples indicate that the three wheat samples were sound.

The GAA values (Table II), which are a measure of α-amylase activity, showed very little change within a particular variety as the level of radiation was increased. These results therefore indicate that the falling number and amylograph values decreased because of an alteration in the starch component. In separate studies, Samec (1958) and Deschreider (1960) reported that reduced viscosity in irradiated starches was attributable to degradation and uncoiling of the starch chain as well as to the rupture of hydrogen bonds within the molecule.

Wet Gluten and Protein Denaturation

Table III shows percent wet gluten and soluble protein values for the various irradiated samples. Solubility of the protein is considered an index of denaturation, with lower solubility indicating a higher degree of denaturation. At the levels of radiation exposure used in this study, neither the wet gluten nor the soluble gluten protein values changed as radiation treatments increased.

Physical Dough Testing

Table IV shows the farinograph data obtained for the three flour samples before and after irradiation at various levels. Farinograph absorption increased slightly with increasing radiation exposure

TABLE I
Ash and Protein Content of Flour Samples[a]

Variety	Radiation (Krad)	Ash (%)	Protein (%)
Waldron	0 (control)	.410	13.2
	50	.410	13.2
	100	.410	13.2
	200	.410	13.2
	300	.407	13.2
Olaf	0 (control)	.318	13.4
	50	.327	13.4
	100	.326	13.4
	200	.328	13.5
	300	.338	13.3
Experimental	0 (control)	.371	11.7
	50	.379	11.8
	100	.379	11.7
	200	.378	11.6
	300	.378	11.7

[a] Results expressed on a 14.0% moisture basis.

TABLE II
Amylograph Peak Viscosity, Falling Number, and Grain Amylase Analyzer Values of Irradiated Flour Samples

Variety	Radiation (Krads)	Falling Number[a] (sec)	Amylograph Peak Height[a] (BU)[b]	GAA Model 191 (units)
Waldron	0 (control)	510	3,130	26
	50	448	2,920	15
	100	399	2,580	26
	200	349	2,160	14
	300	300	1,765	18
Olaf	0 (control)	507	3,530	48
	50	445	3,345	85
	100	378	2,995	77
	200	338	2,340	74
	300	264	785	69
Experimental	0 (control)	338	1,340	37
	50	328	1,280	31
	100	321	1,185	34
	200	287	920	37
	300	258	720	40

[a] Results expressed on a 14.0% mb.
[b] Brabender units.

TABLE III
Wet Gluten and Soluble Protein of Flour Samples Irradiated at Various Levels

Variety	Radiation (Krads)	Wet Gluten (%)	Soluble Protein[a] (%)
Waldron	0 (control)	41.6	65.2
	50	37.6	64.4
	100	41.2	65.2
	200	38.3	64.4
	300	38.6	65.9
Olaf	0 (control)	36.1	63.4
	50	39.8	64.2
	100	36.3	65.7
	200	40.2	65.2
	300	38.1	66.2
Experimental	0 (control)	38.3	70.1
	50	39.5	72.0
	100	39.7	70.9
	200	40.6	71.6
	300	38.6	72.0

[a] Percent of sample protein.

TABLE IV
Farinograph Data of Irradiated Flour Samples

Variety	Radiation (Krads)	Absorption[a] (%)	Development Time (min)		Stability (min)
Waldron	0 (control)	62.2	6.75		12.0
	50	62.7	6.00		13.5
	100	63.9	5.00		11.5
	200	64.5	5.00		9.5
	300	64.8	4.75		9.0
			Peak 1	Peak 2	
Olaf	0 (control)	66.6	9.0	27.0	...[b]
	50	66.7	10.0	23.0	...[b]
	100	66.7	10.5	28.5	...[b]
	200	67.0	8.0	28.0	...[b]
	300	67.0	7.0	25.5	...[b]
Experimental	0 (control)	64.0	4.50		3.5
	50	65.2	4.00		3.5
	100	65.9	4.00		3.5
	200	66.0	3.75		3.5
	300	66.9	4.00		3.0

[a] Results expressed on a 14.0% moisture basis.
[b] Sample too strong to measure.

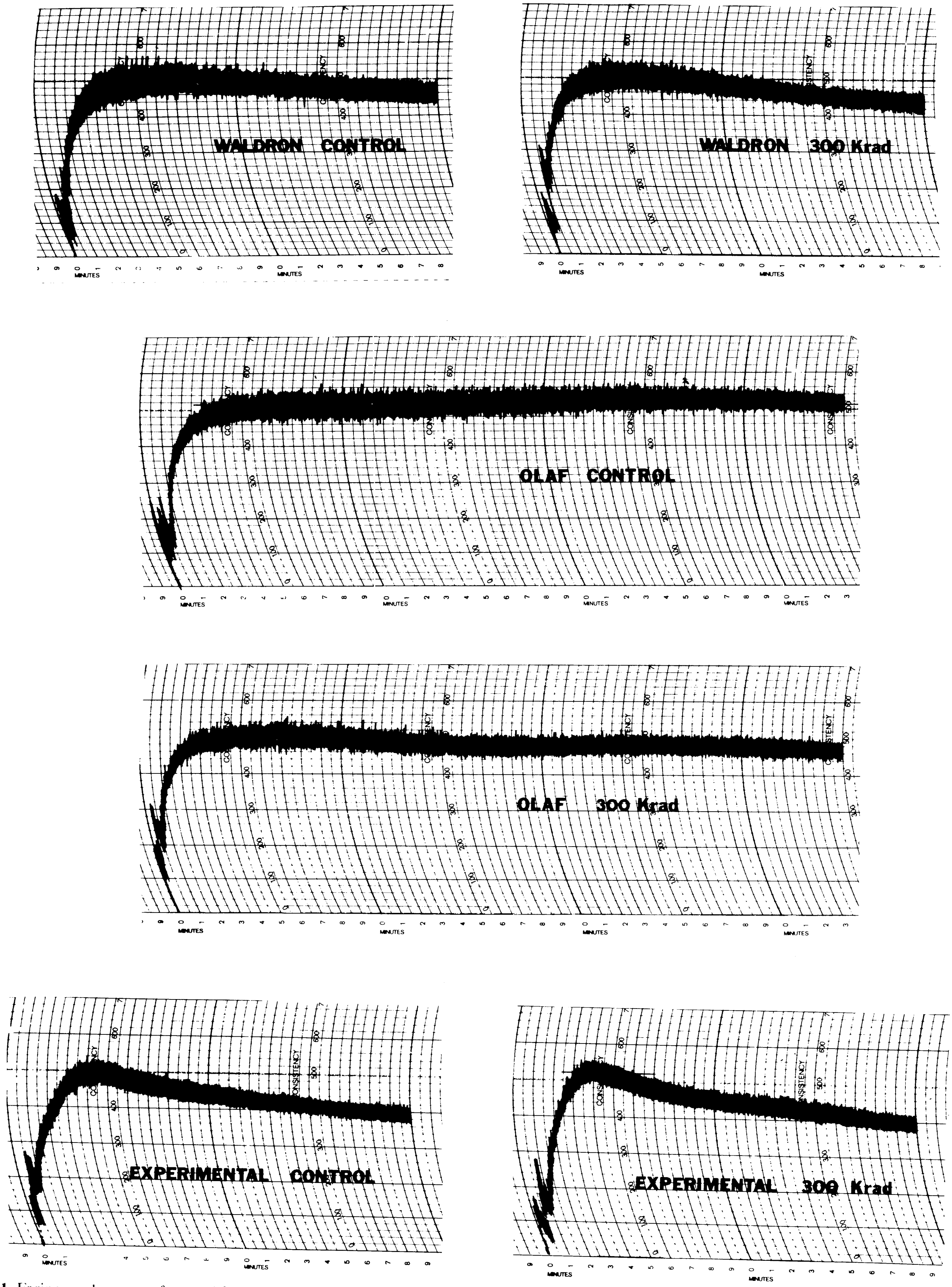

Fig. 1. Farinograph curves of control flours and flour irradiated at 300 Krad.

for each variety investigated, with the strong flour, Olaf, showing the smallest increase. In general, development time and stability of the dough decreased as radiation levels increased. The decrease appeared to depend somewhat on the variety. This suggests either that irradiation may have a more pronounced effect on certain varieties, or that certain characteristics of a variety may influence the effect of radiation to a greater extent. The two dough development peaks recorded for Olaf are characteristic of this particular variety. The two varieties with extremes in mixing properties (weak and strong) were not affected to the same extent as the variety Waldron with normal mixing properties. Figure 1 shows the farinograph curves for the control flours and the flours derived from wheat subjected to 300 Krads of gamma radiation. The slight changes for each variety in dough development time and stability are evident. Table V gives extensigraph data obtained for the control flours and for those derived from wheat irradiated at 300 Krads. All three varieties decreased in extensibility, resistance to extension, and area, with the varieties Waldron and Olaf showing the greatest effects (Fig. 2).

Baking Studies

Baking quality data for the control flours and those flours derived from wheats irradiated at 100 and 300 Krads are shown in Table VI. Results are from bread produced from flour stored at

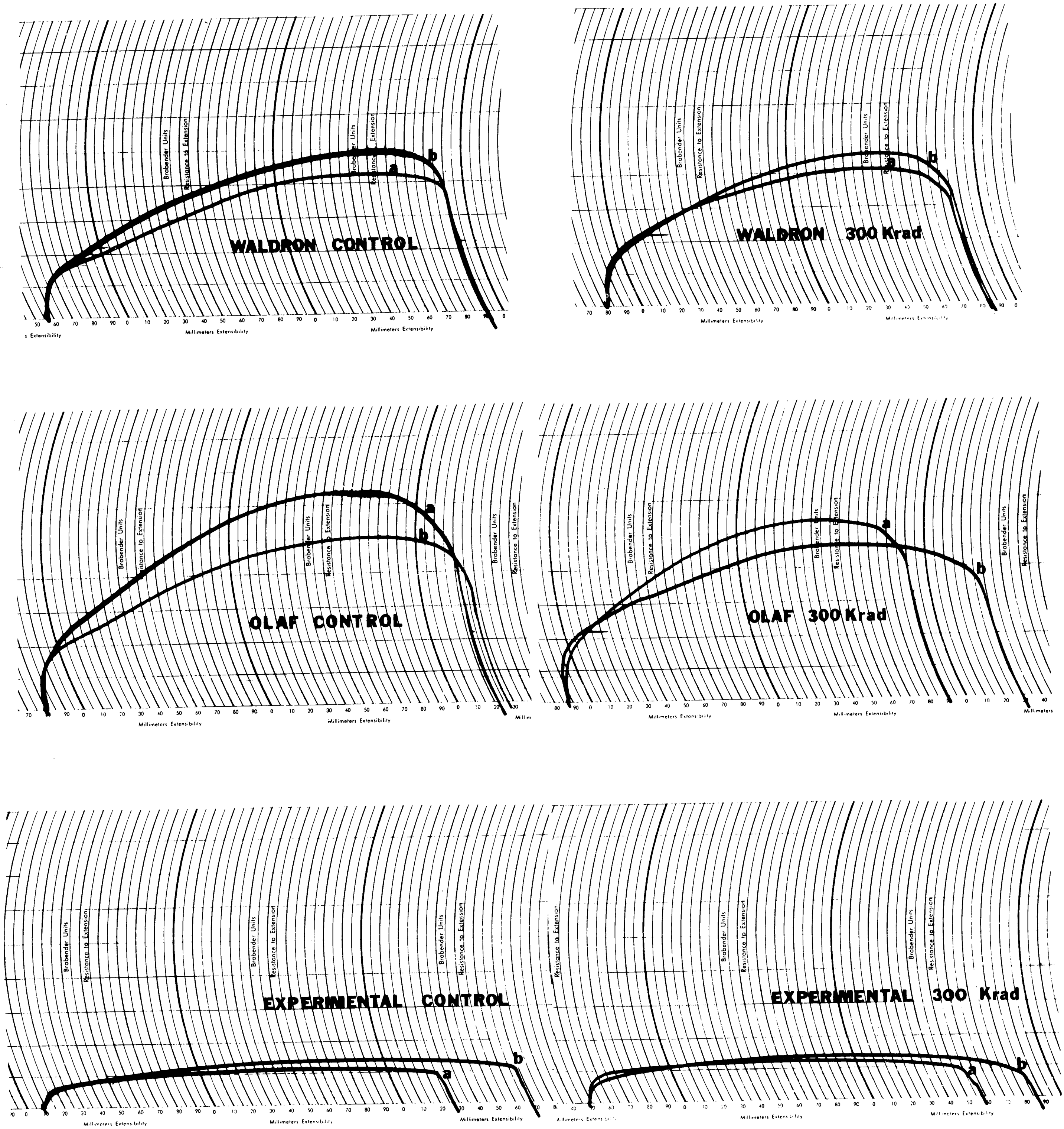

Fig. 2. Extensigraph curves of control flours and flour irradiated at 300 Krad. **a,** = 90 min; **b,** = 180 min.

TABLE V
Extensigraph Data on Control Flour and Flour Irradiated at 300 Krad Level

Variety	Radiation (Krad)	Extensibility (min) 90	Extensibility (min) 180	Resistance to Extension (min) 90	Resistance to Extension (min) 180	Area (cm)
Waldron	0 (control)	23.5	23.5	7.5	8.8	150
	300	20.3	20.4	7.2	8.1	125
Olaf	0 (control)	24.7	24.2	9.0	11.4	207
	300	24.2	20.3	8.2	9.6	146
Experimental	0 (control)	21.9	26.0	1.9	2.4	48
	300	20.9	23.8	2.0	2.3	44

room temperature for one month and six months after milling. Loaf volume of bread after the first baking for the varieties Waldron and Olaf were similar for the control and radiated samples, whereas the experimental variety decreased progressively in volume. After the flour was stored for six months and then baked, all three varieties decreased in loaf volume with irradiation. Generally, bread volume was larger after six months of storage for the control and irradiated samples than for the corresponding loaf after one month of storage. The exception to this trend is the weak variety. The increase in volume for the samples with storage is probably an effect of maturation.

Crumb color scores decreased as radiation treatment increased for both bakes. Crumb color of the bread baked from the flour receiving the highest level of radiation was slightly gray or yellow when compared to the control. Grain and texture values also decreased as radiation increased. The weak flour exhibited the lowest scores for crumb color, and grain and texture for both bakes. These results are due to the quality of the wheat itself. There was a slight improvement in both crumb color and grain and texture for all samples with flour storage, again indicating an improving effect due to maturation. No organoleptic testing was conducted on the bread produced from the irradiated wheat used in this study.

SUMMARY

The effects of gamma radiation of wheat on the physical dough and baking properties of the milled flour were reported. Current studies are investigating the biochemical components, with particular emphasis on the starch, to determine whether the difference noted in the various quality characteristics with gamma radiation can be accounted for.

ACKNOWLEDGMENTS

The authors gratefully acknowledge George Gassner, Metabolism and Radiation Research Laboratory, USDA, ARS, North Central Region, Fargo, ND, and his technical staff for conducting the radiation treatments; and Vernon Youngs, Spring and Durum Wheat Quality Laboratory, USDA, ARS, Cereal Chemistry Department, North Dakota State University, Fargo, for his assistance in this study.

TABLE VI
Baking Quality Data of Irradiated Flour Samples One Month After Milling (A) and After Six Months of Storage (B)

Variety	Radiation (Krad)	Loaf Volume, cc A	Loaf Volume, cc B	Crumb Color[a] A	Crumb Color[a] B	Grain and Texture[a] A	Grain and Texture[a] B
Waldron	0 (control)	870	1,025	8.5	9.0	8.5	9.0
	100	870	925	8.0	8.5	7.5	9.0
	300	890	900	7.0	7.5	7.5	7.5
Olaf	0 (control)	890	995	8.5	9.0	8.5	8.5
	100	890	1,000	8.0	8.5	8.5	8.5
	300	910	970	7.0	7.0	8.0	8.0
Experimental[b]	0 (control)	835	805	6.5	8.5	7.0	8.0
	100	815	790	7.0	7.5	7.0	7.5
	300	725	785	6.0	7.0	7.0	7.0

[a]Values are based on a score of 1 to 10, with 10 being the best score.
[b]10 ppm potassium bromate used in formula.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1961. Approved Methods of the AACC, 7th ed. Methods 08-01, 46-10, 54-10, and 54-21, approved April 1961; Method 44-15A, approved April 1967; Method 22-10, approved May 1960; and Method 56-81B, approved November 1972. The Association, St. Paul, MN.
ANANTHASWAMY, H. N., VAKIL, U. K., and SREENIVASAN, A. 1970. Susceptibility to amylolysis of gamma-irradiated wheat. J. Food Sci. 35:792.
CAMPBELL, J. A., and RANUM, P. M. 1980. Measurement of alpha-amylase in grains. Cereal Foods World 24(2):46.
DESCHREIDER, A. R. 1960. Changes in starch and its degradation products after treatment of wheat with gamma rays. Staerke 12:197.
DOGUCHI, M., and OKADA, I. 1962. Polargraphic studies on gamma-irradiated wheat gluten. Kogyo Kagaku Zasshi 65:1837.
DOGUCHI, M., YOKOYAMA, Y., and OKADA, I. 1959. Some effects of gamma irradiation on wheat gluten. Kogyo Kagaku Zasshi 62:1883.
KIM, S. H. 1981. Extrusion cooking of durum semolina. M.S. thesis. North Dakota State University, Fargo.
LAI, S. P., FINNEY, K. F., and MILNER, M. 1959. Treatment of wheat with ionizing radiations. Cereal Chem. 36:401.
MILNER, M. 1961. Technological effects of gamma-irradiation on wheat. Proc. Fifth Int. Congr. Biochem. August 10-16, 1961. Moscow.
PENCE, J. W., MOHAMMAD, A., and MECHAM, D. K. 1953. Heat denaturation of gluten. Cereal Chem. 30:115.
SAMEC, M. 1958. Veranderung der Kartoffel-starke unter dem Einflub ionisierender. Strahlen I. Staerke 10:76.
SRINIVAS, H., ANANTHASWAMY, H. N., VAKIL, U. K., and SREENIVASAN, A. 1972. Effect of gamma-radiation on wheat proteins. J. Food Sci. 37:715.

[Received February 17, 1983. Accepted August 11, 1983]