Effect of High Doses of Gamma Rays on Corn Grains. I. Influence on the Chemical Composition of Whole Grains and the Technological Process of Starch and By-Product Isolation

M. ROUSHDI, A. HARRAS, A. EL-MELIGI, and M. BASSIM, Food Technology Department, Faculty of Agriculture, Tanta University, Kafr El-Sheikh, Cairo, Egypt

ABSTRACT

The total soluble sugars and reducing sugars in corn grains at 10% moisture content increased as the dose level of gamma rays (in megarads) increased. The soluble nitrogen increased up to an irradiation level of 2 Mrad, then tended to fall. Except at 0.5 Mrad, the soundness number (extractable acidity) increased with increasing dose level, and pH decreased. The same trend was observed, but with greater variation, in irradiated corn grains with 33.5% moisture content; the soundness number and soluble nitrogen increased and pH decreased. Irradiation at 0.5 Mrad gave the highest starch recovery; at levels higher than 0.5 Mrad, starch recovery decreased concomitantly with increase in starch protein content. The starch color from grains irradiated at doses higher than 0.5 Mrad was slightly yellow, and color intensity increased as the dosage was raised.

Cereal Chem. 58(2):110–112

In a previous manuscript (Roushdi et al 1977), the effects of low doses of gamma rays (250, 500, 750, 1,000 Krads) on starch extraction from corn grains and on the quality of by-products were studied. Many investigators (Akulova et al 1970; Berger et al 1973, 1977; El-Saadany et al 1976; Korotchenko et al 1968, 1973; Yakovenko et al 1968) have studied the effect of different gamma ray doses on some physical and chemical properties of corn starch. Nene et al (1975) reviewed the literature about the effect of gamma irradiation on proteins. Kushelevskii and Slifkin (1972) found a cleavage of the peptide linkage after gamma irradiation.

These researchers did not include a study of the influence of irradiation on the technological process from the industrial point of view. Therefore this influence was investigated in the present work. In addition to determining the effect of higher gamma ray dosage on the chemical composition of dried whole grains, the isolation, yield, and purity of starch and by-products were also studied. Because some countries harvest corn at 30% moisture content and then dry it artificially, the influence of irradiation on moist corn grains (33.5% moisture content) was also investigated.

MATERIALS AND METHODS

Origin of the Samples

Corn grains of Shedwan variety were obtained from the Agriculture Research Center, Department of Field Crops at Giza (Egypt). Some of the corn ears were harvested at 33.5% moisture content. The air-dried and moist grains were subjected to different doses of gamma rays (0.5, 1, 2, 5, and 10 Mrad) at the Middle Eastern Regional Radioisotope Center for Arab Countries, using gamma irradiation unit (^{60}Co) Noration Narcontrol A.S. Treatments were not replicated. Only one sample of each treatment was analyzed or used for starch isolation.

Starch Isolation

The starch was isolated from both air-dried and moist grains after steeping as described by Roushdi et al (1977).

The starch yield was determined by the formula:

$$\text{Starch recovery} = \frac{\text{Weight of isolated dry starch} \times 100}{\text{Dry weight of original grains}}$$

Analytical Methods

Moisture content, reducing sugars, and total protein and fat were determined according to the methods of the AOAC (1970). Total soluble sugars content was determined after acid hydrolysis, and nonreducing sugars were calculated by substracting the amount of reducing sugars after hydrolysis (AOAC 1970). Starch content was determined polarimetrically. Soundness number (extractable acidity) was determined by dispersing 10 g of finely ground corn grains in 100 ml of distilled water with stirring. The suspension was then titrated with standard sodium hydroxide solution (0.01*N*), using phenolpthalein as indicator. Starch color was examined visually, using a value of 10 for the bright white samples and zero for the yellowish brown.

RESULTS AND DISCUSSION

Chemical Composition of Irradiated Whole Corn Grains

The reducing and nonreducing sugars, soluble nitrogen, pH, and soundness number were quantitatively determined in the whole grains. The results are given (dry basis) in Table I. Reducing sugars and total soluble sugars in air-dried grains increased with increase in radiation dosage; no relationship was observed between the nonreducing sugars and the radiation dose. The increase in reducing and total soluble sugars might be attributed to degradation of starch fractions.[1] These results are in agreement with those reported by many investigators (Berger et al 1973, El-Saadany et al 1976, Korotchenko et al 1973). The reason for the irregular nonreducing sugar value is not known. It may be caused by formation of nonreducing sugars compounds.

Except for low-moisture grain treated at 0.5 Mrad, the soundness number increased as the dosage level was increased. At 0.5 Mrad, the native free organic acids may have been partially destroyed; at higher doses partial radiolysis may occur in the glyceride ester (Dubravcic and Nawar 1968) or in peptide linkages (Kushelvskii and Slifkin 1972), which might lead to the liberation of some free fatty acids and amino acids.[1] Additionally some sugars might be changed into sugar acids or subjected to oxidative degradation, forming organic acids (Berger et al 1977, El-Saadany et al 1976, Korotchenko et al 1968).

The increase in soluble nitrogen up to a dosage of 2 Mrad could be attributed to the partial cleavage of peptide linkage. At higher than 2 Mrad, the soluble nitrogen percentage tended to fall, which might be the result of partial elimination of some amino groups from free amino acids (Simic 1968).

As indicated in Table I, irradiation of moist grains gave the same trend of increasing soundness number and soluble nitrogen and decreasing pH, but the variation was more pronounced. The pH dropped to 4.95 and the soundness number and soluble nitrogen increased to 4.68 and 56, respectively, at 2 Mrad, in comparison with values of 6.4, 64.6, and 26.46, respectively, in the corresponding irradiated air-dried grains. These variations in the irradiated moist grains could be attributed to radiolysis of peptide linkages that was faster than that occurring in the air-dried grains, therefore stopping further decomposition of liberated amino or fatty acids. This leads to an increase in soluble nitrogen and soundness number. The large decline in pH values seems to support the above explanation.

On the other hand, the presence of water in the irradiated moist grains probably retarded the breakdown of glycosidic linkage. The insignificant change in reducing sugars of moist grains in comparison with the changes induced in those of the irradiated dried grains supports this hypothesis.

Technological Process of Starch and By-Product Isolation

According to our knowledge, except for that of Yakovenko et al (1968), no information is available concerning the effect of irradiation on the industrial extraction of starch, starch quality, and loss of starch to by-products. Hence, in the present study, we investigated the isolation and separation of starch from other grain components.

Irradiation with gamma rays facilitated the ease of hand separation of the germ from the whole grain as the dose level increased. Irradiation up to 1 Mrad also facilitated the separation of hull and fibers. However, higher doses showed minimal effect. Corn grains subjected to 0.5 Mrad gave a percentage of starch recovery slightly higher than that of the nonirradiated grains (Table II). This slight increase (from 68 to 68.8%) was not significant. The protein in starch was significantly lower than that of the control (Table II). At higher than 0.5 Mrad, the starch recovery decreased concomitantly with an increase in protein content in starch (Table II). The effect of higher radiation dosages might be to cause protein denaturation and the formation of a rigid starch-protein matrix. This would result in a higher starch content in hull and fibers, as Table II shows. The high protein content in extracted starch at higher doses also confirms the validity of this assumption. At higher doses (2 Mrad or greater), some reactions could occur, ie, radiolysis as reported by Phillips (1972).

The starch recovery from irradiated moist grains (Table II) was lower than that from irradiated dried grains. The presence of water

[1] Roushdi et al, unpublished data.

TABLE I
Chemical Analysis of Irradiated Corn Grains

Moisture Content and Dosage (Mrad) Levels of Samples	pH	Soundness Number	Soluble Nitrogen (mg/100 g)[a]	Sugars (%)[a] Reducing	Nonreducing	Total Soluble
Control	6.5	11.4	20.2	0.20	2.10	2.3
Air-dried (10%)						
0.5	6.6	10.9	23.9	0.80	2.20	3.0
1	6.5	56.4	26.5	2.80	0.80	3.6
2	6.4	64.6	26.5	2.7	1.1	3.9
5	6.3	78.3	13.9	3.20	2.0	5.2
10	6.2	122.8	11.3	3.8	4.7	8.5
Moist (33.5%)						
0.5	6.1	309.6	21	0.7	2.6	3.3
1	5.3	348.1	28	0.8	1.8	2.6
2	5	468	56	0.8	1.9	2.6

[a] Data estimated on dry basis.

TABLE II
Starch Recovery and Analysis of Extracted Parts[a]

Moisture Content and Dosage Level (Mrad) of Samples	Starch Recovery (%)	Content in Starch (%)		Starch (%)	
		Protein	Fat	In Hull	In Fibers
Control	68.0	0.84	0.22	16.0	28.3
Air-dried (10%)					
0.5	68.8	0.53	0.16	15.8	29.9
1	67.3	1.22	0.12	18.1	30.9
2	66.6	1.36	0.10	19.9	31.2
5	62.3	1.76	0.09	20.4	32.8
10	65.6	2.90	0.05	21.6	26.6
Moist (33.5%)					
0.5	63.7	3.50	...[a]	18.0	41.0
1	64.6	2.95	...	17.2	39.7
2	64.4	3.94	...	18.7	34.3

[a]Data calculated on dry basis.

TABLE III
Color of Isolated Starch

Dosage Level (Mrad)	Color	
	Description	Scores[a]
Untreated (control)	Bright white	10
0.5	White	9
1.0	Slightly yellowish white	8
2	Yellowish	7
5	Yellow	4
10	Yellowish brown	0

[a]By visual examination, showing range between lightest (10) and darkest (0) samples.

in irradiated moist grains may have accelerated protein denaturation and starch gelatinization, forming a rigid starch-protein matrix, which may have caused the adherance of starch to hulls and fibers. The increase of starch content in hulls and fibers supports this hypothesis.

Table III showed that the starch color from grains irradiated at 1 Mrad and higher was yellow. Color intensity increased as the dose level was raised. During centrifugation for starch isolation, no interface line occurred between protein layer and starch sediment at the high doses. The above observation may be explained on the basis that high irradiation doses cause a high release of energy, which promotes the breakdown of glycosidic and peptidic linkages and the interaction between liberated carbonyl and amino compounds, forming colored compounds (as in Maillard reaction).

Irradiation of dry corn grains at less than 0.5 Mrad to extend the storage life of grains appears to have no effect on starch recovery or starch quality.

LITERATURE CITED

AKULOVA, I. S., PUTILOVA, I. N., and TREGULOV, N. N. C. 1970. Effect on the molecular weight and oxial ratios of some gamma radiolysis products of starch. Food Sci. Technol. Abstr. 3:204.

ASSOCIATION OF ANALYTICAL CHEMISTS. 1970. Official Methods of Analysis, 11th ed. Washington, DC.

BERGER, G., AGENEL, J. P., and SAINT-LEBE, L. 1973. Identification and determination of sugars formed during irradiation of corn starch. Staerke 25:203.

BERGER, G., DAUPHIN, J. F., MICHEL, J. P., ENRICO, G., AGENEL, J. P., SEGUIN, F., and SAINT-LEBE, L. 1977. Studies on the mechanism of formation of some radiolysis products identified after γ-radiation of maize starch. Staerke 29:80.

DUBRAVCIC, M. F., and NAWAR, W. W. 1968. Radiolysis of lipids. Mode of cleavage in simple triglycerides. J. Am. Oil Chem. Soc. 45:656.

EL-SAADANY, R. M. A., EL-SAADANY, F. M., and FODA, Y. H. 1976. Degradation of corn starch under the influence of gamma irradiation. Staerke 28:208.

KOROTCHENKO, K. A., DOROZHKINA, T. I., and SOCHNEVA, E. N. 1973. Properties of corn starch irradiated with high doses of gamma rays. Chem. Abstr. 78:2857.

KOROTCHENKO, K. A., STANIMIROVICH, S. G., and STANIMIROVICH, D. L. 1968. Identification of organic acid in cobalt 60 γ-irradiated starch. Chem. Abstr. 70:59110.

KUSHELEVSKII, A. P., and SLIFKIN, H. A. 1972. Study of the γ-radiolysis of amino acids and dipeptides by ultra violet reflectance spectrophotometry. Radiat. Res. 50(1):56.

NENE, S. P., VAKIL, U. K., and SREENIVASAN, A. 1975. Effect of gamma irradiation on red gram (Cajanus caja) proteins. J. Food Sci. 40:815.

PHILLIPS, G. O. 1972. Effect of ionizing radiation on carbohydrate systems. J. Rad. Res. Rev. 3:355.

ROUSHDI, M., FAHMY, A. A., and ABDEL MALEK, G. S. 1977. Effect of gamma rays on corn grains. Part I. Influence on starch extraction and quality of by-products. Staerke 8:260.

SIMIC, M. G. 1968. Radiation chemistry of amino acids and peptides in aqueous solutions. J. Agric. Food Chem. 26(1):6.

YAKOVENKO, V. A., ROMENSKII, N. V., and MASENKO, L. V. C. 1968. Alternation of corn starch effected by irradiation and temperature. Chem. Abstr. 69:83933.

[Received March 24, 1980. Accepted August 14, 1980]