Effect of Gamma Irradiation on the Nutritional Quality of Grains and Legumes. II. Changes in Amino Acid Profiles and Available Lysine[1]

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ABSTRACT

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Wheat, maize, chickpea, and mung bean seeds were irradiated at 0.5, 1.0, 2.5, and 5.0 kGy in a cobalt-60 gamma cell. Nonirradiated seeds served as controls. Comparison of amino acid profiles showed that sulfur-containing amino acids were radiation labile, particularly in the legumes. Significant losses in all cultivars also were noted for lysine, tyrosine, and isoleucine. However, the percent available lysine was higher in the irradiated seeds.

Accumulating evidence indicates that there is some loss of nutritive value when gamma irradiation is used as a means of food preservation (Badshah and Klopfenstein 1988), just as there are losses with the much more widely used freezing, canning, or drying methods of spoilage prevention. However, losses from conventional preservation methods are well-documented (IFT 1986), whereas nutritional loss caused by irradiation has been much less studied. Our goal in the experiment described here was to determine the effects of gamma irradiation at levels known to effectively destroy insect infestations on the protein nutritional quality (amino acid profiles and available lysine) of wheat, maize, mung bean, and chickpea.

The principal changes that have been shown to occur in protein-component amino acids are deamination, decarboxylation, and oxidation of sulfhydryl and aromatic groups (Urbain 1986, Delincee 1983). However, at the radiation doses commonly employed for food irradiation (up to 10 kGy), reported changes in protein nutritive value and amino acid profiles have been small (Delincee 1983).

MATERIALS AND METHODS

Two cereals, wheat (*Triticum aestivum* L., cultivar Pak-81) and maize (*Zea mays* L., cultivar Sarhad white), and two legumes, mung bean (*Phaseolus aureus* L., cultivar M-13-1) and chickpea (*Cicer arietinum* L., cultivar CM-72) were obtained from the Plant Breeding Division, Nuclear Institute for Food and Agriculture, Tarnab, Peshawar, Pakistan. All cereals and legumes in this study were grown at the same location in same year under standard agronomic practices. Seed from each cultivar was irradiated at the Nuclear Institute in a cobalt-60 gamma cell at a dose rate of 0.5, 1.0, 2.5, or 5.0 kGy. The dose rates were chosen because they have previously been shown to be effective in insect control in stored grain, with 0.5 kGy producing sterility and death of most common insects in a few weeks, and 3–5 kGy causing immediate lethality (Urbain 1986). Nonirradiated seed served as the control.

Amino Acid Analysis

Duplicate samples for each treatment were hydrolyzed with *p*-toluenesulfonic acid at 100°C for 31 hr (Liu and Chang 1971). Amino acid analyses were carried out chromatographically using a D-300 Dionex amino acid analyzer with a single column accelerated system (Lorenz et al 1980, Jones 1981). Available lysine was determined in triplicate by a fluorodinitrobenzene-reactive lysine method (Carpenter 1960).

The data were statistically evaluated by analysis of variance with *t* tests (LSD) using the Statistical Analysis System 5.16 (SAS Institute 1985) at Kansas State University, Manhattan.

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RESULTS AND DISCUSSION

The effects of gamma irradiation on essential amino acid profiles in the grains and legumes tested are shown in Table I. Extensive

TABLE I
Effect of Gamma Irradiation on Amino Acid Composition of Wheat Seed, Maize, Mungbean, and Chickpea (g/100 g protein, 10% moisture content)

		Dose (kGy)			
Amino Acid	**Control**	**0.5**	**1.0**	**2.5**	**5.0**
Wheat					
Lysine	3.13 a[a]	2.93 b	2.88 bc	2.85bc	2.78 c
Methionine	2.25 a	2.05 ab	1.86 bc	1.92 bc	1.80 c
Cysteine	2.61 a	2.35 b	2.29 b	2.28 b	2.30 b
Phenylalanine	4.96 a	4.60 a	4.75 a	5.03 a	4.42 a
Tyrosine	4.27 a	4.00 bc	3.93 bc	4.10 ab	3.83 c
Isoleucine	2.89 a	2.65 b	2.64 b	2.71 b	2.58 b
Leucine	6.38 a	6.49 a	6.49 a	6.53 a	6.47 a
Threonine	3.18 a	3.11 a	3.03 a	2.90 a	2.90 a
Valine	4.11 a	4.13 a	4.00 b	4.14 a	4.07 ab
Arginine	4.59 a	4.90 a	4.89 a	4.83 a	4.57 a
Histidine	4.25 a	3.99 a	4.12 a	4.07 a	3.95 a
Maize					
Lysine	3.02 a	2.78 b	2.75 b	2.73 b	2.66 c
Methionine	3.22 a	2.84 b	2.74 b	2.66 b	2.62 b
Cysteine	2.42 a	2.07 b	2.05 b	1.98 b	1.93 b
Phenylalanine	5.67 a	5.06 b	5.00 b	4.94 b	5.04 b
Tyrosine	4.95 a	4.45 b	4.48 b	4.37 b	4.32 b
Isoleucine	3.07 a	2.52 b	2.52 b	2.47 b	2.41 b
Leucine	10.91 b	11.48 a	11.35 a	11.69 a	11.48 a
Threonine	3.82 a	3.80 a	3.75 a	3.73 a	3.57 a
Valine	4.17 a	4.22 a	4.15 a	3.98 a	3.90 a
Arginine	4.56 a	4.08 b	4.34 ab	4.51 ab	4.63 a
Histidine	4.32 a	4.04 a	4.07 a	4.07 a	4.49 a
Mungbean					
Lysine	6.75 a	6.56 ab	6.47 ab	6.33 ab	6.12 b
Methionine	2.54 a	2.09 b	2.06 b	1.64 c	2.05 b
Cysteine	1.44 a	1.04 ab	1.10 ab	0.98 ab	0.89 b
Phenylalanine	6.06 a	5.98 a	5.79 a	5.98 a	5.95 a
Tyrosine	4.19 a	3.67 d	3.54 e	3.98 c	3.92 b
Isoleucine	3.49 a	3.19 d	2.93 e	3.36 b	3.23 c
Leucine	7.09 a	7.20 a	7.30 a	7.15 a	7.38 a
Threonine	3.75 a	3.71 a	3.73 a	3.62 a	3.62 a
Valine	4.49 a	4.17 a	4.15 a	4.25 a	3.76 a
Arginine	7.33 a	7.32 a	7.33 a	6.73 a	7.51 a
Histidine	4.93 a	4.95 a	5.27 a	5.35 a	4.93 a
Chickpea					
Lysine	6.06 a	5.96 a	5.88 a	5.93 a	5.94 a
Methionine	2.89 a	2.88 a	2.28 b	2.34 b	2.32 b
Cysteine	1.82 a	1.68 b	1.58 c	1.49 d	1.47 d
Phenylalanine	5.63 a	5.45 a	5.45 a	5.22 a	5.51 a
Tyrosine	3.91 a	3.49 b	3.52 ab	3.29 b	3.52 b
Isoleucine	3.12 a	2.78 b	2.75 b	2.65 b	2.76 b
Leucine	6.67 d	6.74 cd	6.97 a	6.86 b	6.76 bc
Threonine	3.71 a	3.63 a	3.65 a	3.59 a	3.64 a
Valine	3.30 a	3.08 a	3.21 a	2.99 a	3.28 a
Arginine	10.03 b	10.03 b	10.81 a	10.66 ab	10.25 ab
Histidine	5.09 a	4.79 a	4.81 a	5.05 a	4.89 a

[a] Means in the same row with the same letter are not significantly different ($P < 0.05$).

TABLE II
Effect of Gamma Irradiation on Essential Amino Acids in Wheat, Maize, Mungbean, and Chickpea Seeds[a]

Amino Acid	Percent Change Resulting from 5.0-kGy Irradiation			
	Wheat	Maize	Mungbean	Chickpea
Lysine	−11.1	−11.9	−9.3	−2.0 ns
Methionine	−20.0	−18.6	−35.0	−19.7
Cysteine	−11.9	−18.2	−38.2	−19.2
Phenylalanine	−10.9 ns	−11.1	−2.0	−2.1 ns
Tyrosine	−10.3	−12.7	−6.4	−10.0
Isoleucine	−10.7	−21.5	−7.4	−11.5
Leucine	+1.4 ns	+5.2	+4.0 ns	+1.3
Threonine	−8.8 ns	−6.5 ns	−3.4 ns	−2.0 ns
Valine	−1.0 ns	−6.5 ns	−16.3 ns	−1.0 ns
Arginine	−0.4 ns	+1.5 ns	+2.4 ns	+2.2 ns
Histidine	−7.0 ns	−3.9 ns	0.0 ns	+3.9 ns

[a]The percent change was significant at $P < 0.05$ unless followed by the letters ns (not significant).

TABLE III
Effect of Gamma Irradiation on Percent Available Lysine Content of Wheat, Maize, Mungbean, and Chickpea Seeds

Dose (kGy)	Wheat		Maize		Mungbean		Chickpea	
	%	(g)[a]	%	(g)	%	(g)	%	(g)
Control	85.5 b[b]	(2.54)	80.0 b	(2.42)	84.0 b	(5.67)	82.0 b	(5.00)
0.5	85.0 a	(2.49)	85.5 a	(2.38)	85.0 ab	(5.50)	83.5 b	(4.98)
1.0	85.0 a	(2.45)	85.5 a	(2.35)	85.0 ab	(5.50)	85.5 a	(5.03)
2.5	85.0 a	(2.42)	85.5 a	(2.33)	86.0 ab	(5.44)	86.0 a	(5.10)
5.0	86.0 a	(2.39)	86.0 a	(2.28)	87.0 a	(5.32)	86.0 a	(5.11)

[a]Numbers in parentheses represent actual grams of available lysine per 100 g of protein.
[b]Means in the same column with the same letter are not significantly different ($P < 0.05$).

losses of essential amino acids were caused by irradiation, and those losses were often significant even at the lowest radiation dose (0.5 kGy). Table II shows the percent change at the 5.0 kGy dose level of each essential amino acid, which in most cases represents the maximum change. Wheat and maize showed an 11% loss of lysine. Lysine was more stable in the legumes than in the grains, but the decrease was significant for mung bean at the 5.0-kGy dose level.

Compensating for the lysine loss to some extent was the increase in percent available lysine after irradiation in all cultivars (Table III). When that factor is taken into consideration, actual maximum (5.0 kGy) lysine losses for wheat, maize, and mung bean were about 6%, whereas lysine content for chickpea was about the same before and after radiation (Table III, values in parentheses).

Large losses of methionine and cysteine were noted for all cultivars, with over 30% decreases in both amino acids in mung bean (Table II). Since the sulfur-containing amino acids are limiting in most legumes, this decrease from irradiation could significantly impair their nutritional quality. Conflicting results have been reported about the nutritional quality of irradiated legume protein. Coelho et al (1978) found protein efficiency ratios to be much lower for rats fed irradiated macacar beans (*Vigna unguiculata* (L.) Walp.) than for those fed untreated beans. In contrast, Reddy et al (1979) found that dry field beans irradiated with 210 kGy improved chick growth and nitrogen retention. Partial resolution of these conflicting data might come from our results, which show quite different essential amino acid losses from different cultivars. Different responses in rats and chickens might also be attributed in part to rats' higher requirement for sulfur-containing amino acids.

There were no significant changes in threonine, valine, arginine, or histidine, and the percent decrease in phenylalanine was significant only for maize. Tyrosine appeared to be more susceptible to radiation than phenylalanine, showing significant decreases in all cultivars at 0.5 kGy. Although statistical analysis of the means of duplicate samples indicates significance at the 0.05 level, it is unlikely that the small apparent percent increase in leucine in maize and chickpea is real. The precision error of the Dionex analyzer is 5%.

CONCLUSIONS

At the maximum dose level (5.0 kGy), losses of lysine, methionine, cysteine, phenylalanine, tyrosine, and isoleucine ranged from 10 to 20% in wheat and maize. Essential amino acid decrease was generally somewhat lower in the legumes than in the grains, except in the case of methionine and cysteine in mung bean, where those two amino acids appeared to be particularly vulnerable to radiation destruction. Lysine loss was partly compensated for by the significant increase in percent available lysine after irradiation in all cultivars.

In general, irradiation of these grains and legumes resulted in some loss of essential amino acids, particularly those containing sulfur. Therefore, additional sulfur-containing amino acids might need to be added to diets consisting largely of irradiated seeds. However, when one considers the enormous yearly losses caused by insects both directly, and through increased susceptibility to microbial infestations in stored seeds, the nutritional changes found in this study could easily be judged as affordable.

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