Effects of Gamma Irradiation on the Nutritional Quality of Grain and Legumes. I. Stability of Niacin, Thiamin, and Riboflavin[1]

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ABSTRACT

Seed from wheat, maize, mungbean, and chickpea was irradiated in a cobalt-60 gamma cell at a dose rate of 0.5, 1.0, 2.5, or 5.0 kGy. The irradiated seed was then analyzed for thiamin, riboflavin, and niacin and compared to the nonirradiated controls. Losses in thiamin content were significant, whereas riboflavin was unaffected. Niacin decreased slightly, but significantly, at higher doses of irradiation (2.5–5.0 kGy) in wheat, mungbean, and chickpea, whereas it was unaffected in maize.

Cereals and legumes are important dietary components, providing many nutrients including vitamins, minerals, protein, and complex carbohydrates. These products are stored as dry seeds and form an enormous reserve of food. However, vast quantities of stored grains and legumes are lost annually as a result of insect attack. It is estimated that for large areas of the world, as much as 30% of the harvested foods are destroyed by insects (Hall 1970). Losses of stored grain caused by insect infestation often equal cereal grain losses that occur in the field (Harein 1982). The use of gamma irradiation as a method of disinfesting stored foods, including cereal grains and legumes, has opened a new field for irradiation application in which considerable work has been done (Urbain 1986). Development of this technique involves the basic consideration that gamma radiation might reduce the nutritive value of stored seeds. The absolute relationship of radiation dose and possible effects must be known in order to comprehensively assess the acceptability of radiation-treated food or feed grains.

The stability of separate food components such as vitamins, protein, carbohydrates, and fats during gamma radiation has been extensively studied, but foods, which are complex systems, may not react as predicted from results with individual components.

Some vitamins have been shown to be quite susceptible to destruction by ionizing radiation. Thiamin has been reported to be the most radiolabile of the B vitamins, and its loss in irradiated food has been well documented (Basson 1983, Tobback 1977). The same authors also reported that niacin and riboflavin have generally been found to be more resistant to ionizing radiation than thiamin.

The present work is part of a series of investigations concerning some nutrition-related chemical changes induced in cereals and legumes upon gamma irradiation, with special attention to changes in niacin, thiamin, and riboflavin content.

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 the cultivars 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 death (Urbain 1986). Nonirradiated seed served as the control. Before analysis, seeds of each cultivar were ground to pass through a 20-mesh hammer mill screen and stored in a refrigerator.

Determination of Moisture Content and Vitamins

Moisture, thiamin, riboflavin, and niacin were determined by the use of manual methods as outlined by the American Association of Cereal Chemists (AACC 1983). Moisture contents of wheat, maize, mung bean, and chickpea were 11.7, 13.3, 8.8, and 10.1%, respectively. Values reported for vitamin contents in Tables I, II, and III represent the means of at least three separate determinations per treatment for each cultivar.

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.

TABLE I
Effect of Gamma Irradiation on Thiamin Content (mg/100 g) of Wheat, Maize, Mungbean, and Chickpea Seeds

Dose (kGy)	Wheat	Maize	Mungbean	Chickpea
Control	0.560 a[a]	0.470 a	0.347 a	0.293 a
0.5	0.547 a	0.443 b	0.330 ab	0.267 b
1.0	0.543 a	0.437 b	0.313 bc	0.253 b
2.5	0.523 b	0.427 bc	0.297 c	0.250 b
5.0	0.510 b	0.423 c	0.297 c	0.243 b

[a]Means in the same column followed by the same letter are not significantly different ($P < 0.05$).

TABLE II
Effect of Gamma Irradiation on Riboflavin Content (mg/100 g) of Wheat, Maize, Mungbean, and Chickpea Seeds

Dose (kGy)	Wheat	Maize	Mungbean	Chickpea
Control	0.0117 a[a]	0.143 a	0.317 a	0.263 a
0.5	0.0117 a	0.143 a	0.300 a	0.257 a
1.0	0.0117 a	0.143 a	0.300 a	0.257 a
2.5	0.0117 a	0.142 a	0.300 a	0.250 a
5.0	0.0116 a	0.140 a	0.293 a	0.250 a

[a]Means in the same column followed by the same letter are not significantly different ($P < 0.05$).

TABLE III
Effect of Gamma Irradiation on Niacin Content (mg/100 g) of Wheat, Maize, Mungbean, and Chickpea Seeds

Dose (kGy)	Wheat	Maize	Mungbean	Chickpea
Control	6.557 a[a]	2.737 a	3.060 a	2.330 a
0.5	6.530 ab	2.700 a	3.030 a	2.300 ab
1.0	6.527 ab	2.650 a	2.970 b	2.243 ab
2.5	6.470 ab	2.620 a	2.970 b	2.243 ab
5.0	6.440 b	2.620 a	2.970 b	2.217 b

[a]Means in the same column not followed by the same letter are significantly different ($P < 0.05$).

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RESULTS AND DISCUSSION

Tables I, II, and III show the thiamin, riboflavin, and niacin contents, respectively, of irradiated wheat, maize, mung bean, and chickpea. In general, thiamin content in the grains and legumes in this study decreased as irradiation dose increased. Thiamin in wheat appeared to be the most stable, with significant loss occurring only at 2.5 kGy. Kennedy (1965) also found thiamin to be quite stable in wheat after irradiation at 0.2 kGy. The decrease in thiamin content was significant at 0.5 kGy in maize and chickpea, and at 1.0 kGy in mung bean. In wheat, mung bean, and chickpea, loss of thiamin was not significantly greater at a dose of 5.0 kGy than at 1.0 kGy, whereas for maize the loss of thiamin was significantly greater at the higher irradiation dose. In this study, maximum losses of thiamin were 8.7% in wheat, 10% in maize, 15% in mung bean, and 17% in chickpea. Our data support those of Hanis et al (1985), who reported a loss of about 7% of thiamin when diets containing 60% ground wheat were irradiated at a level of 25 kGy. Results of the present experiment indicate that thiamin is more susceptible to radiation destruction in legumes than in grains. However, much greater thiamin loss (47%) has been reported in codfish treated with 6.0 kGy (Kennedy and Ley 1971). It is apparent that radiation-induced thiamin loss varies widely in different foods.

Riboflavin was the most radiation-resistant of the three vitamins studied (Table II). No significant decrease in this vitamin was observed for any cultivar at any dose level applied in this experiment. These data compare favorably with those of Hanis et al (1985), who reported only a 6% riboflavin loss in cereal- and legume-based rat diets that had been irradiated at 25 or 50 kGy. Others have reported similar findings of zero riboflavin loss in wheat irradiated at 0.2–1.5 kGy (Causeret and Mocquot 1964, Kennedy 1965). Conversely, a 48% loss of riboflavin was reported in kidney beans irradiated at 0.15 kGy (Basson 1983).

Losses of niacin even at the highest irradiation level were small, although significant, except for maize (Table III). Maximum loss for wheat was 1.8%; for maize, 4.3%; for mung bean, 2.9%; and for chickpea, 4.8%. Similar to results for thiamin, radiation affected niacin differently in the samples tested. Niacin in maize was most stable and remained statistically the same for each level of irradiation dose applied. No significant decrease in niacin content occurred in wheat and chickpea to an irradiation dose of 2.5 kGy, but at 5.0 kGy, the loss was significant. In mung bean, niacin decreased significantly at a dose rate of 1.0 kGy and above.

Other studies have shown that irradiation induces textural changes in pulses, which shortened their cooking times (Sreenivasan 1974, Badshah et al 1987). Since prolonged heating is known to destroy B vitamins, a reduction in cooking time could result in better retention of vitamins in irradiated cooked cereals and legumes, thereby compensating for losses incurred during irradiation.

CONCLUSIONS

Thiamin was shown to be the most radiolabile of the B vitamins assayed. Significant loss of this vitamin was observed even at the lowest radiation dose (0.5 kGy) in maize and chickpea. Riboflavin was the most radiation-resistant vitamin, with no significant loss at any irradiation level. The effect of irradiation on niacin content was minor. A significant decrease in this vitamin occurred only at higher doses of irradiation (2.5 and 5.0 kGy).

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