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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Effect of Gamma Irradiation on the Nutritional Quality of Maize Cultivars (*Zea mays*) and Sorghum (*Sorghum bicolor*) Grains

Amro B. Hassan*[1], Gammaa A.M. Osman[1], Mohamed. A.H. Rushdi[2],
Mohamed M. Eltayeb[3] and E.E. Diab[1]
[1]National Center for Research, Environment and Natural Resource Research Institute, Khartoum, Sudan
[2]Sudanese Atomic Energy Corporation, Khartoum, Sudan
[3]Department of Food Science and Technology, Faculty of Agriculture,
University of Khartoum, Khartoum, Sudan

Abstract: To investigate the effect of gamma irradiation on the nutritional quality of maize and sorghum grains, packs were exposed to doses of 0 and 2 kGy in a 60 Co package irradiator. Irradiated and non-irradiated samples were stored at refrigeration temperatures. Proximate composition, minerals content, minerals bio-availability, tannins content, phytic acid content, protein fractions and *in vitro* protein digestibility were evaluated. The results indicated that gamma irradiation caused no effect on proximate composition, minerals content and minerals bioavailability. For protein fractions, in both maize cultivars no significant differences were observed in all fractions, except in prolamins and glutelins of Maize 75. While for sorghum significant increase in globulins, prolamins and glutelins was observed. While, gamma irradiation reduced the phytic acid and tannins contents significantly. The *in vitro* protein digestibility of maize cultivars was increased significantly, while the digestibility of sorghum was reduced.

Key words: Gamma irradiation, protein fraction, tannin, phytic acid, mineral bio-availability

Introduction

Cereals are considered to be a very important group of plant food stuff, particularly in the developing and under-developed countries of the world. They supplies substantial amount of carbohydrates and adequate amount of other nutrients (Hoseney *et al*., 1987) Cereal grains are usually stored as dry seeds and forms an enormous serve of food; however large quantities of grains are damaged annually as a result of moulds contamination and insects attacks (Kapu *et al*., 1989) Many post harvest procedures for control of insects and moulds in stored product are chemical, biological and physical control, or a combination of these techniques (Bond, 1984). Fumigation with ethylene bromide, methyl bromide, ethylene oxide, aluminum phosphide and malathion has been the method of choice for controlling most of dried seeds pest and contamination (UNEP, 2000) However, the extensive use of these chemicals has been shown to have adverse effects on both food and environment, associated with residues and ozone depletion, furthermore, the effectiveness of fumigation method, is dependent on some environmental factors such as temperature and relative humidity (Bond, 1984). Gamma irradiation technology is a physical technique in food processing that seems to have the ability to kill insects and eliminate microbes and moulds to a certain levels (Hallman, 2001). The effectiveness of gamma irradiation as an alternative method to chemical treatment of dried food has been investigated world-wide in the last decades by many researchers (Kertesz *et al*., 1984; USDA/APHIS, 1989; Hallman, 2001). For low doses of gamma irradiation, most of research studies indicated that no substantial changes were observed in different physico-chemical quality of dried food and grains (Dogbevi *et al*., 2000; Wu *et al*., 2002; Al-bashir, 2004; Sung, 2005). However, little information is available regarding the effect of such treatments on quality of some cereal grains. Therefore, in this study, it was aimed to evaluate the effect of gamma irradiation on chemical quality of maize and sorghum grains.

Materials and Methods

Two maize (*Zea mays*) cultivars Maize 75 and Maize 6616 and one local sorghum (*Sorghum bicolor*) variety Fetarita, were used in this study. Grain samples were obtained from the Field Crops Improvement Research unit, Faculty of Agriculture, University of Khartoum. Samples were cleaned and placed in polyethylene bags under ambient temperature.

Gamma irradiation process: Gamma radiation process was conducted in an irradiation facility at Kaila irradiation processing unit, Sudanese Atomic Energy Corporation (SAEC) using an experimental cobalt-60 gamma source (Nordion gamma cell 220-Excell). Sorghum and maize grains (1000 g) were divided into two portions. Each portion of 1000 g was irradiated in a glass bottle with gamma rays at room temperature, with the dose of 2 KGry. Non-irradiated seeds served as control. Irradiated and non-irradiated samples of groundnut seeds were ground to pass through 0.4 mm screen and kept in glass bottles at room temperature for analysis.

Determination of proximate composition: Moisture and ash content of the samples were determined according to the methods of AOAC (1984). Oil content was assessed in soxhlet extraction method with petroleum ether (AOAC, 1984). Protein was calculated from the percentage of nitrogen which was determined by using Kjeldahl method described by Pearson (1981). Crude fiber was determined by treating an of oil-free sample by sulphuric acid (0.26 N) and potassium hydroxide (0.23 N) solution in refluxing systems, followed by oven drying and muffle furnace incineration. (AOAC, 1984). Carbohydrate was estimated by differences.

Determination of mineral content: Mineral of raw and processed samples were extracted according to Pearson's method (1981). Each sample was burnt in a muffle furnace at 550°C. Each sample was placed in a sand bath for 10 minutes after addition of 5 ml of 5 N HCl. Then the solution was carefully filtered in a 100 ml volumetric flask and finally distilled water was added to make up to mark. The extracts were stores in bottles for further analysis. Minerals Fe, Mn, Co and Zn were determined using atomic absorption spectrophotometer. Calcium content was carried out according to Chapman and Pratt (1968). Potassium and sodium contents of each extracted sample were determined according to AOAC (1984) using Flame photometer (Corning 400). Analysis of phosphorous was carried out according to the method of Chapman and Pratt (1968).

HCl-extractability of mineral (*in vitro* availability): Mineral in the samples were extracted by the method described by Chauhan and Mahjan (1988). One gramme of the sample was shaken with 10 ml of 0.03 M HCl for 3 h at 37°C and then filtered. The clear extract obtained was oven-dried at 100°C and then acid-digested. The amount of the extractable minerals was determined by the methods described above. Thereafter, the extractable mineral was determined as a percentage of the individual minerals.

Determination of tannin content: Quantitative estimation of tannin for each sample was carried out using modified vanillin-HCl in methanol method as described by Price and Butler (1978). A standard curve was prepared expressing the result as tannic acid equivalent i.e. amount of tannic acid (mg/100g) which gives a color intensity equivalent to that given by tannins after correction for blank.

Determination of phytic acid content: Phytate of raw and processed samples was determined according to the method described by Wheeler and Ferrel (1971). A standard curve was prepared to calculate the ferric ion concentration. The phytate phosphorous was calculated from the ferric ion concentration assuming 4:6 iron to phosphorous molar ratio.

***In vitro* protein digestibility (IVPD):** *In vitro* protein digestibility of raw and processed samples was measured according to the method of Saunders *et al.* (1973). A known weight of the sample containing 16 mg nitrogen was taken in triplicate and hydrolyzed with 1 mg pepsin in 15 ml of 0.1 M HCl at 37°C for 18 h. The reaction was terminated by addition of 15 ml of 10% w/v trichloroacetic acid (TCA). The mixture was filtered quantitatively through Whatman No. 1 filter paper. The TCA soluble fraction was assayed for nitrogen using the micro-Kjeldahl method. Digestibility was calculated using the following formula:

$$\text{IVPD \%} = \frac{\text{N in supernatant - enzyme N}}{\text{N in sample}} \times 100$$

Protein fractionation: Protein fractions were extracted according to their solubilities in different solvents, as described by Landry and Moureaux (1970) Defatted guar flour (3.5 g) was extracted twice with 50 ml distilled water for 30 min at room temperature. The extract was centrifuged at 3000 x g for 30 min and the supernatant was used for the determination of a water-soluble protein (albumin). The residue was then extracted successively in a similar manner with 1.0 M NaCl, 70% ethanol or 0.2% NaOH. The supernatant of each extract was collected separately and used to estimate the salt-(globulin), alcohol-(prolamin) or alkali-(glutelin) soluble fraction. The residue remaining after successive extractions represents the insoluble proteins.

Statistical analysis: Each sample was analyzed in triplicate and the values were then averaged. Data were assessed by the analysis of variance (ANOVA) described by Snedecor and Cochran (1987) and by Duncan' multiple range test (1955) with a probability P = 0.05.

Results and Discussion

Proximate composition: The results of the effect of gamma irradiation on proximate composition of maize and sorghum grains are shown in Table 1. These results indicated that there were no significant differences in oil, protein and fiber contents between the irradiated and non-irradiated grains, however, significant decrease was observed in moisture content of both maize cultivars and ash content of Maize 75 cultivar. These results are in agreement with previous work in the effect of gamma irradiation on other similar products. Bhattacharjeea *et al.* (2003) found that irradiation with 0.25, 0.5, 0.75 and 1.0 KGys, had no significant effect on the proximate composition of cashew nuts. Similarly, Al-bashir (2004) reported that irradiation up to 2 KGys did not cause any significant change the proximate composition of walnuts.

Table 1: The effect of gamma irradiation on proximate composition % of maize and sorghum grains

Treated cultivars	Dose KGys	Moisture %	Ash %	Oil %	Protein %	Fiber %
Maize 75	0.0	6.4±0.2^{a}	2.07±0.2^{a}	4.20 ±0.2^{a}	8.4±0.09^{a}	0.9±0.05^{a}
Maize 75	2.0	1.8±0.00^{b}	1.7±0.2^{b}	4.9±0.05^{a}	8.9±0.00^{a}	0.8±0.09^{a}
Maize 6616	0.0	6.7±0.3 ^{a}	2.4±0.05^{a}	4.9±0.05^{a}	7.3±0.09^{a}	0.8±0.05^{a}
Maize 6616	2.0	1.8±0.02^{b}	2.3±0.06^{a}	5.2±0.2^{a}	7.4±0.05^{a}	1.2±0.14^{b}
Sorghum	0.0	8.7±0.2^{a}	2.4±0.3^{a}	4.6±0.3^{a}	14.1±0.9^{a}	7.8±0.22^{a}
Sorghum	2.0	7.2±0.5^{a}	1.8±0.08^{b}	4.5±0.3^{a}	4.3±0.6^{a}	5.6±0.6^{a}

Means in the same column with different letter s are significantly different P ≤ 0.05 according to Least Significant Test LSD

Table 2: The effect of gamma irradiation on minerals content mg/100g of maize and sorghum grains

Treated cultivars	Dose KGys	Ca mg/100g	Na mg/100g	K mg/100g	P mg/100g	Fe mg/100g	Zn mg/100g
Maize 75	0.0	21.6 ±1.1^{a}	1.5 ±0.3^{a}	9.3 ±0.6^{a}	222 ±0.03^{a}	1.8 ±0.5	0.5±0.1^{a}
Maize 75	2.0	20.2 ±0.8^{a}	1.8 ±0.09^{a}	10.8 ±0.7^{a}	230 ±0.52^{a}	1.3 ±0.2^{b}	0.5±0.04^{a}
Maize 6616	0.0	16.2 ±0.1^{a}	1.8 ±0.19^{a}	10.8 ±0.6^{a}	260 ±0.17^{a}	1.8 ±0.2^{a}	0.5±0.07^{a}
Maize 6616	2.0	16.4 ±0.2^{a}	1.2 ±0.15^{b}	10.8 ±0.2^{a}	275 ±0.00^{a}	1.7 ±0.2^{a}	0.4±0.09^{a}
Sorghum	0.0	19.5 ±1.02^{a}	1.0 ±0.24^{b}	10.5 ±0.7^{b}	189 ±0.30^{b}	4.6 ±0.9^{b}	0.6±0.04^{a}
Sorghum	2.0	19.2 ±0.58^{a}	1.6 ±0.26^{a}	13.6 ±0.23^{a}	178 ±0.00^{a}	2.6 ±0.2^{a}	0.7±0.1^{a}

Means in the same column with different letter s are significantly different P ≤ 0.05 according to Least Significant Test LSD

Minerals and minerals bio-availability: Table 2 shows minerals content of maize and sorghum grains. No substantial change in proximate constituents amongst the samples with exception of significant increase in Na, K, P and Fe of the sorghum. For mineral bioavailability the results show that no significant change was observed, except in Ca and K in both maize and sorghum cultivars (Table 3).

Tannins and phytic acid: Table 4 shows the results of the effect of gamma irradiation on tannins and phytic acid content in maize and sorghum cultivars flour. The results showed that irradiation reduced significantly the phytic acid contents, this findings is agreed with that of Duodu *et al.* (1999) who reported that cooking and gamma irradiation caused significant reduction in phytic acid level of sorghum. Similarly, treatment of soybean seeds with gamma irradiation, alone or in combination with soaking reduced the level of phytate compared to untreated seeds (Sattar *et al.*, 1990). This reduction is may be due to chemical degradation of phytate to the lower inositol phosphates and inositol by the action of free radicals produced by the radiation (De Boland *et al.*, 1975). Another possible way of phytate reduction during irradiation could have been through cleavage of the phytate ring itself. For tannin content, the results show decrease in tannin content of maize cultivars, while significant increase was observed in sorghum as affected by gamma irradiation. Abu-Tarboush (1998) reported that dose of 10 and 7 KGys significantly reduced the tannin content of Shahlla sorghum variety from 0.35 to 25 mg of catechin equivalent/100 g but not that of Hamera variety.

***In vitro* protein digestibility:** Table 4 shows the effects of gamma irradiation on the *in vitro* protein digestibility of maize and sorghum lours. Digestibility was significantly affected by irradiation; the digestibility of maize cultivars was increased significantly, while the digestibility of sorghum was reduced significantly. Fombang *et al.* (2005) reported that protein digestibility of BR 7 sorghum flour was not significantly ($p > 0.05$) affected by gamma irradiation. With Madjeri sorghum and PAN 6043 maize, however, digestibility decreased somewhat with irradiation in the wet medium but not so much in the dry medium.

Protein fractions: The effect of gamma irradiation (2.0 KGys) on protein fractions of maize and sorghum cultivars flour are shown in Table 5. For both maize cultivars no significant differences were observed in all fractions, except in prolamins and glutelins of Maize 75. While for sorghum significant increase in globulins, prolamins and glutelins was observed. Fombang *et al.* (2005) reported that Albumin and globulin contents of uncooked BR-7 sorghum flour decreased significantly with irradiation in both dry and wet medium. In uncooked Madjeri sorghum and maize flours, Albumin and globulin contents content was basically unaffected by irradiation in dry medium but decreased significantly with irradiation in the wet medium. Change in protein fraction may be related to some cross-linking or aggregation of proteins as a result of gamma irradiation which could affect nitrogen solubility (Ciesla *et al.*, 2000).

Conclusion: The irradiation treatment of maize and sorghum (2.0 kGy) induced no significant statistical change in proximate composition, minerals content and minerals bio-availability. For protein fractions, in both maize cultivars no significant differences were observed in all fractions, except in prolamins and glutelins of Maize 75. While for sorghum significant increase in globulins, prolamins and glutelins was observed. The

Table 3: The effect of gamma irradiation on mineral bioavailability % of maize and sorghum grains

Treated cultivars	Dose (Kgys)	Ca %	Na %	K %	P %	Fe %	Zn %
Maize 75	0.0	65.6±2.7^{a}	26.2±1.4^{a}	39.9 ±1.3^{a}	29.7±0.00^{a}	28.2±0.96^{a}	45.1±1.5^{a}
Maize 75	2.0	53.2±0.41^{b}	26.7±0.78^{a}	23.3±0.00^{b}	29.8±0.05^{a}	28.6±0.78^{a}	45.2±1.3^{a}
Maize 6616	0.0	59.2±0.00^{a}	24.7±1.3^{a}	24.7±2.2^{b}	14.5±0.06^{a}	28.9±0.24^{a}	45.3±2.3^{a}
Maize 6616	2.0	63.6±0.00^{a}	27.8±2.5^{a}	33.9±1.08^{a}	14.8±0.20^{a}	26.9±0.8^{a}	45.8±0.68^{a}
Sorghum	0.0	29.1±0.66^{b}	34.6±2.2^{a}	59.8±1.4^{b}	28.7±0.00^{a}	25.0±2.3^{a}	54.0±2.2^{a}
Sorghum	2.0	59.4±1.4^{a}	30.0±0.5^{a}	73.6±0.00^{a}	26.2±0.45^{a}	23.4±1.9^{a}	54.8±1.9^{a}

Means in the same column with different letter s are significantly different P ≤ 0.05 according to Least Significant Test LSD

Table 4: The effect of gamma irradiation on tannins, phytic acid content mg/100g and invitro protein digestibility IVPD % of maize and sorghum grains

Treated cultivars	Dose KGys	Tannins mg/100g	Phytic acid mg/100g%	IVPD
Maize 75	0.0	33.3±0.00^{a}	451.3±0.00^{a}	77.0±2.00^{b}
Maize 75	2.0	33.1±0.00^{a}	382.6±3.5^{b}	81.0±0.3^{a}
Maize 6616	0.0	33.3±7.80^{a}	670.7±5.6^{a}	72.0±1.6^{b}
Maize 6616	2.0	30.0±0.03	^{b}330.6±1.8^{b}	87.0±0.9^{a}
Sorghum	0.0	228.3±8.44^{b}	874.0±4.9^{a}	51.5±2.5^{a}
Sorghum	2.0	334.1±4.8^{a}	525.8±1.2^{b}	46.4±1.4^{b}

Means in the same column with different letter s are significantly different P ≤ 0.05 according to Least Significant Test LSD

Table 5: The effect of gamma irradiation on protein fractions % of maize and sorghum grains

Treated cultivars	Dose KGys	Albumins %	Globulins %	Prolamins %	Glutelins %
Maize 75	0.0	22.6±0.9^{a}	15.2±0.3^{a}	15.6±0.00^{a}	42.9 ±0.73^{b}
Maize 75	2.0	23.4±0.3^{a}	13.1±0.9^{a}	11.5±0.3^{b}	48.0±0.13^{a}
Maize 6616	0.0	23.0±0.8^{a}	14.9±0.3^{a}	15.4±0.4^{a}	30.6±0.72^{a}
Maize 6616	2.0	22.9±0.6^{a}	13.7±0.3^{a}	13.3±0.2^{a}	33.5±0.74^{a}
Sorghum	0.0	28.7±0.6^{b}	9.9±0.9^{b}	14.8±1.0^{b}	24.1±0.31^{a}
Sorghum	2.0	35.1±0.9^{a}	12.4±0.7^{a}	18.6±0.45^{a}	22.0±0.99^{a}

Means in the same column with different letter s are significantly different P ≤ 0.05 according to Least Significant Test LSD

results also revealed that gamma irradiation reduced the phytic acid and tannins contents significantly. The *in vitro* protein digestibility of maize cultivars was increased significantly, while the digestibility of sorghum was reduced.

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