Effect of Gamma Radiation on Chemical Constituents of Sorghum (Sorghum *bicolor*) During Storage

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Abstract

Sudanese sorghum grain (Tabat) had exposed to high doses of gamma irradiation (10, 30kGy), so as to improve its storage stability. Proximate composition, tannin and phytic acid contents of irradiated and non irradiated samples were assayed every 2 month (0, 2, 4, 6. 8months). The results showed that there were no significant differences between irradiated and non irradiated samples in protein, fat and carbohydrates content of sorghum grain. A significant decrease in moisture, ash, carbohydrates, tannin and phytic acid was observed as storage period progressed.

Key words: Gamma irradiation, proximate composition, tannine, phytate

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1. Introduction

Sorghum (*Sorghum bicolor L. Moench*) is one of the major food crops of the semi-arid regions of Africa and Asia, and is the fifth among the world cereals and one of the most important foods in low-income and some of the high-income countries (Abdelseed *et al*., 2011). It ranks, following wheat, maize, rice and barley in production area. Among cereals, sorghum today is the cereal expanding in Asia and Africa, where the people are typically poor and food resources are limited, sorghum is used as a major source of protein and energy

(ICRISAT, 2009). The nutrient composition of sorghum grain indicates that it is a good source of energy, proteins, carbohydrates, vitamins and minerals (Dicko *et al.,* 2006; Afify *et al*.,2012).

The yield and quality of sorghum produced worldwide is affected by a wide array of biotic and a biotic constraint (ICRISAT, 2004; Naïma; *et al*., 2009).

Cereal grains are usually stored as dry seeds and forms an enormous serve of food however large quantities of grain are damaged annually as a result of moulds contamination and insect attacks (Kapu *et al.,* 1989).

For control of insects and moulds in stored product, chemicals, biological and physical control, or a combination of these techniques were used (Brooker, 1992). UNEP (2000) reported that, 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. 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 (Banda,1990).

There are many reports demonstrating that thermal processing methods improve the nutritional quality of foods. However, there is a scarcity of information relating to the effects of processing with ionizing energy. Therefore, the present work was carried out to investigate the effects of radiation process on nutritional quality of sorghum cultivar flour during the storage period.

2. Materials and methods

2. 1. Materials. Whole grains of a sorghum (Sorghum bicolor (L) Moench) cultivar namely Tabat was purchased from White Nile State, during the harvesting season of 2010-2011.Grains were packed into jute sacks and stored at (30 $\pm$ 5°c) for further use .

2.2. 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 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 10, 30 KGry. Non-irradiated seeds served as control. Irradiated and non-irradiated samples of sorghum grain were stored at room temperature for analysis.

2. 3. Changes in constituents of irradiated sorghum grain during storage:

The moisture and protein content of sorghum grain was determined according to the standard method of the Association of Official Analytical Chemists (AOAC, 1990). Crude fat and ash content in sorghum grain was determined according to the standard analytical method of the Member Companies of Corn Refiners Association, Inc (MCCRA, 1995). The carbohydrate content of the sorghum grain was calculated by subtracting the total sum of protein, ash, fat and moisture as percentage from 100.

% Carbohydrate = 100 - (%protein +% ash+% moisture+ %fat)

2. 4. 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 colour intensity equivalent to that given by tannins after correction for blank.

2. 5. 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.

2. 6. Statistical analysis of data

Data generated were subjected to SAS. Two-factor RCD was performed; where Factor A = irradiation dose and factor B = storage period with 3 reps.

Means were then separated according to DMRT as reported by Gomez(1994).

Results and Discussion

3. 1. Proximate Composition

Moisture content: Table 1 shows changes in moisture content of irradiated sorghum grains as affected by storage period. The moisture content of the grain decreased significantly ($p<0.05$) from 9.87 ±0.06 to 7.78± 0.04 % in 4 months storage period. The decrease in moisture of the grains was more in high dose treatment. Hassan *et al*. (2009) gave moisture level of 7.2 and 8.7 % for sorghum treated with 2 KGy dose and untreated grains, respectively. Raihanatu *et al*. (2011) gave extremely low level of moisture (2.5to 4.0 %) in Nigerian varieties of sorghum grain. Gamma radiation, which Presents high and homogeneous penetration competence in tissues, does not significantly increase the temperature of food during the processing, a rather beneficial condition (Evangelista, 2000; Farkas, 2006).

Table 1 Changes in moisture content (%) of irradiated sorghum grain during storage

Irradiation dose(KGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	$9.87^{a}\pm0.06$	$8.05^{f}\pm0.06$	$7.78^{g}\pm0.04$	$8.21^{e}\pm0.05$	$9.01^{b}\pm0.06$
10	$9.80^{a}\pm0.10$	$7.63^{h}\pm0.04$	$7.58^{i}\pm0.03$h	$8.02^{f}\pm0.04$	$8.67^{c}\pm0.05$
30	$9.80^{a}\pm0.10$	$7.53^{i}\pm0.02$	$7.50^{i}\pm0.03$	$7.96^{f}\pm0.06$	$8.36^{d}\pm0.05$
Lsd0.05	0.09133**				
SE±	0.03162				

Protein content Table 2 shows changes in protein content of irradiated sorghum grain during storage. The protein content increased significantly ($P\leq0.05$) throughout the storage period from 9.95% at the beginning of the storage to 13.05% after 8 months. It seemed that the irradiation process had an effect on the protein level of the treated samples. Tresina and Mohan (2012) studied the effect of gamma irradiation of *Vigna unguiculata* sub sp. *unguiculata* seeds (black coloured seed coat) at various doses (2, 5, 10, 15 and 25 kGy) on proximate composition, and he observed a significant increase of crude protein at all doses, on the other hand this result is different from the findings obtained by Hassan *etal.* (2009) who stated that gamma irradiation has no effect on protein level in sorghum grain. Abdelwhab *et al.* (2009), and Bamidele and Akanb (2013) stated that the protein content of dry bean and Pigeon Pea flour, irradiated at doses of 15 KGy decreased significantly.

Table 2 Changes in protein content (%) of irradiated sorghum grain during storage

Irradiation dose (KGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	9.95^{c}±0.01	10.45^{c}±0.05	10.45^{c}±0.05	12.13^{b}±0.15	13.05^{a}±0.78
10.0	9.95^{c}±0.01	10.40^{c}±0.30	10.40^{c}±0.30	12.59^{ab}±0.07	12.79^{a}±0.78
30.0	9.95^{c}±0.01	10.18^{c}±0.10	10.18^{c}±0.10	13.15^{a}±0.24	12.81^{a}±0.73
Lsd0.05	0.6149*				
SE±	0.2129				

Mean ± SD values having same superscript letter with columns and rows are insignificantly different (P≤0.05).

Fat content: Table 3 shows changes in fat content of irradiated sorghum grain during storage. There were significant changes in the fat content of the irradiated and non irradiated sorghum grains during storage period. At the beginning of the storage period, the fat content was found to be 2.80, 2.79 and 2.79 for non irradiated, 10 and 30 irradiated samples, respectively. There were no significant differences in the fat content of the irradiated and non irradiated samples during the storage period and was found to be 2.92, 3.38 and 3.29 respectively, at the end of the storage period (8 months). A fluctuation in fat level of the grain was observed in both irradiated and control sorghum grains. Al-Bashir (2004) and Hassan *et al.* (2009) reported that gamma irradiation dose of 2.0 KGys has no effect on fat level of sorghum grains. Abdelwhab *et al.* (2009) ; Bamidele and Akanb (2013) observed an increase in fat content of dry velvet bean and Pigeon Pea flour irradiated at doses of 15KGy, and attributed the increase of fat to the effect of gamma irradiation on the small molecule of the flour which are broken down during storage.

Table3. Changes in fat content (%) of irradiated sorghum grain during storage

Irradiation dose (KGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	2.80^{b}±0.06	3.12^{cde}±0.04	2.85^{gh}±0.09	3.35^{a}±0.04	2.92^{fg}±0.08
10.0	2.79^{h}±0.06	3.22^{be}±0.10	3.09^{de}±0.01	3.28^{ab}±0.00	3.38^{a}±0.02
30.0	2.79^{h}±0.06	3.07^{de}±0.01	3.14^{cd}±0.12	3.02^{ef}±0.12	3.29^{b}±0.02
Lsd0.05	0.1055**				
SE±	0.03651				

Mean ± SD values having same superscript letter (s) with columns and rows are insignificantly different (P≤0.05).

Ash content: Table 4 shows changes in ash content (total mineral matter) of irradiated sorghum grain as affected by storage. Significantly (P≤0.05) low value (1.04±0.17 %) of ash content was observed at the end of the storage period. Hassan *et al.* (2009) gave similar levels of ash in Sudanese sorghum cultivars treated with 2KGy dose. Abdelwhab *et al.(2009)* reported a decrease in ash content of velvet bean seed exposed to gamma irradiation at a dose range of 0–30 KGy, while Bamidele and Akanb (2013) reported an irregular decrease in ash of Pigeon Pea by irradiation.

Table 4 Changes in ash content (%) of irradiated sorghum grain during storage

Irradiation dose (KGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	1.59^{ab}±0.01	1.63^{a}±0.03	1.49^{abc}±0.01	1.58^{ab}±0.05	1.14^{ef}±0.20
10.0	1.59^{ab}±0.02	1.45^{bc}±0.06	1.58^{ab}±0.02	1.60^{ab}±0.02	1.26^{de}±0.04
30.0	1.59^{ab}±0.02	1.49^{abc}±0.11	1.56^{ab}±0.06	1.39^{cd}±0.06	1.04^{f}±0.17
Lsd0.05	0.1395*				
SE±	0.0483				

Mean ± SD values having same superscript letter(s) in columns and rows are insignificantly different (P≤0.05).

3.2. Tannin content: Table 5 shows changes in tannins content (mg/100g) of irradiated sorghum grain during storage. After 2 months of storage the tannin values were found to be 8.0, 5.5 and 5.0 mg/100g for non irradiated, 10 and 30KGy irradiated samples, respectively. Tannin content of raw flour significantly (P ≤ 0.05) decreased by irradiation and the level of reduction increased with increase in radiation dose and storage period. The same observations were reported by Ahmed *et al.* (2013) for millet and sorghum grains. Musa *et al.* (2011) stated that, the reduction in tannin content is very favorable since this anti-nutritional factor has the capacity for decreasing protein digestibility. The reduction in tannins content was attributed to the chemical degradation by the action of the free radicals produced by the irradiation process.

3. 3.Phytic acid content: Table 6 shows the phytic acid content (mg/100g) of irradiated sorghum grain as affected by storage. At the beginning of the storage period, irradiation of sorghum grain by 10KGy dose significantly (P ≤ 0.05)

Table5. Changes in tannins content (mg/100g) of irradiated sorghum grain during storage

Irradiation dose (kGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	$8.67^{b}±0.12$	$8.00^{c}±0.00$	$9.00^{a}±0.00$	$0.50^{h}±0.00$	$0.15^{i}±0.00$
10.0	$8.67^{b}±0.12$	$5.50^{d}±0.20$	$4.50^{f}±0.50$	$0.50^{h}±0.00$	$0.31^{hi}±0.01$
30.0	$8.67^{b}±0.12$	$5.00^{e}±0.00$	$3.00^{g}±0.00$	$0.50^{h}±0.00$	$0.31^{hi}±0.01$
Lsd0.05	0.2473**				
SE±	0.08563				

Mean ± SD values having same superscript letter in columns and rows are insignificantly different (P≤0.05).

Table6: Changes in phytic acid content (mg/100g) of irradiated sorghum grain during storage

Irradiation dose (KGy)	Storage period (months)				
	0	2	4	6	8
Control 0.0	352.33 ^{e} ±2.70	179.66 ^{d} ±20.03	175.00 ^{g} ±7.00	189.66 ^{b} ±4.618	194.66 ^{a} ±13.27
10.0	257.33 ^{d} ±29.26	220.33 ^{a} ± 4.16	214.00 ^{e} ±12.28	202.66 ^{d} ±19.65	182.66 ^{g} ± 4.61
30.0	280.66 ^{b} ± 6.65	202.66 ^{d} ±19.65	177.00 ^{b} ± 8.66	172.66 ^{f} ±22.50	205.00 ^{c}±23.64
Lsd0.05	8.611 **.1**				
SE±	2. 2.083				

Mean ± SD values having same superscript letter in columns and rows are insignificantly different (P≤0.05).

decreased the phytates content from 257.33 at zero storage time to 182.66 mg/100g , then increased significantly at 30 KGy dose to 280.66 at the beginning of storage compared to the lower does (10KGy). ElShazali *et al*. (2011) observed an ineffectiveness of the irradiation in combination with cooking on the reduction /cleavage of phytate and they stated that, 2 KGy radiation dose alone was found to have a minor effect on ant-nutrients content of the whole and dehulled flour of millet cultivars. El-Niely (2007) stated that irradiation after processing has significantly (P ≤ 0.05) decreased the level of phytic acid of legumes. The reduction in phytic acid during the irradiation process is likely to be due to chemical degradation of phytate to the lower inositol phosphates and inositol by the action of free radicals produced by radiation or might be due to cleavage of the phytate ring itself (Siddhuraju et al., 2002). AL Kaisey *et al.* (2003) reported that phytic acid of broad bean was significantly reduced as result of irradiation using 10KGy. Idris (2005) gave 265 and 233 mg/100g values of phytic acid of two Sudanese sorghum lines (Wad Ahmed and Tabat, respectively). Ahmed (2011) observed that, the highest reduction in phytic acid was a result of irradiation using 15KGy for Dabar, Wad Ahmed and Karamaka sorghum grain. The results clearly showed that phytate content decreases with increase in dose of irradiation.

Carbohydrates content. 3.4. Table 7 shows the changes in carbohydrates content of irradiated sorghum grain during the storage. Irradiation of the sorghum grain had no significant effect on carbohydrates content before the storage. Increasing the storage period resulted in a decrease in carbohydrates content from 75.98% at the beginning of the storage period to 73.57% at the end of the storage (8months). Marathe *et al*., (2002) observed similarly, that CHO content of wheat flour was found to be 76.3 and 76.0 at the beginning of the storage for non treated and 1KGy irradiated samples then decreased to 74.9 and 73.6 after 6 months of storage, respectively (P≤0.05) low value (1.04±0.17 %) of ash content was observed at the end of the storage period.

Table7. Change in carbohydrates content (%) of irradiated sorghum grain during storage

Irradiation dose (KGy)	Storage period (months)				
	0	2	4	6	8
Control (0.0)	75.98^{abcd} ±1.23	76.21^{a} ± 1.44	77.43^{a} ±1.55	75.40^{bcd} ±1.23	73.57^{e} ±1.27
10	76.23^{abc} ± 1.46	77.45 ± 1.47	76.65^{ab} ±0.97	74.44^{de} ±1.65	74.86^{cde} ±2.26
30	75.87^{abcd} ± 1.21	75.93^{abcd} ±1.40	77.40^{a} ± 1.24	74.35^{de} ±1.50	75.00^{cde} ±2.73
$Lsd_{0.05}$	1.415*				
SE±	0.4899				

Mean ± SD values having same superscript letter (s) in columns and rows are insignificantly different (P≤0.05).

Irradiation has insignificant effect on the chemical composition (moisture, proteins, fats, ash, and carbohydrates) of sorghum grains.

Irradiation of sorghum grain resulted in a significant decrease in antinutrional factors (Tannine and Phytic acid), Tannin and phytate levels of irradiated sorghum grains decreased significantly compared to the non irradiated ones. The reduction continued as the storage period progressed.

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