Effect of Using Gamma Radiation on Storability and Sensory Acceptability of Sudanese Sorghum

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ABSTRACT
An attempt was made to extend the shelf life (storage stability) of sorghum grains by using gamma radiation source (Co60) as a mean of preservation by applying 10 and 30 KGy dose to the grains. Irradiated sorghum grains and control sample were stored at room temp. (30 ± 5°C) and relative humidity of 30 ± 5 %, and examined during storage the changes in physical properties insect and broken kernels accounted and organoleptic properties of Sudanese traditional food (Aceda) The number of insect in the 10KGy irradiated grains was only one insect per Kg compared to 140 insect per Kg of the control (non irradiated grains).

The culinary properties of sorghum porridge prepared form irradiated and non irradiated grains reflected deterioration in taste, flavor and texture of porridge prepared from the control grain (non irradiated) and suitability of using10KGy dose for preservation of sorghum grain during storage.

Keywords: Gamma Irradiation, Insect Infestation, Affected Kernels, Sorghum Porridge, Sensory Evaluation

I. 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 (Abdel seed et al., 2011).

Sorghum wheat is an important cereal crop and ranks third in production after maize and rice around the globe. It is the second most important winter cereal in the world crop by resource limited farmers under traditional management conditions in SAT regions of the Africa.

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). It is mostly grown as a subsistence dry land crop by resource limited farmers under traditional management conditions in SAT regions of the Africa.

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 Enujiugh, et al., 2012).

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 (Brooker, 1992). Fumigation with ethylene bromide, methyl bromide, ethylene oxide, aluminum phosphate 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 Gamma radiation technology is a physical technique in food processing that seems to have the ability to kill insects and eliminate microbes and moulds to acceptable levels (Hallman, 2001).

Food irradiation has been recognized as a reliable and safe method for preservation of food. It improves the hygienic quality and nutritional value of the food (Diehl, 2002; ALkaisey et al., 2003). Food irradiation has the potential to answer global challenges in the way foods are processed and preserved, providing issues related to food safety and shelf-life can be overcome effectively. Currently, food irradiation is approved in more than 60 countries and there has been a notable growth in production and trade of irradiated foods since 2010 (Eustice, 2017).
Irradiation of cereals and legumes has emerged as a new grains are summarized below and highlighted in technology for combating the problems created by the insects and pests. The main advantage of the gamma irradiation technique is that it can be given after the product has been packed, thereby restricting the chances of cross contamination nutritive value, sensory acceptability and other related quality parameters of the cereals and related products can be retained if the doses are optimized and the product is irradiated at the optimized doses. Codex Alimentarius Commission and the World Health Organization (WHO) have adopted the standards for Irradiation of foods, which are practiced by more than 42 countries. Literature studies conducted for the effects of gamma irradiation on different cereals grain (Eustice, 2017 (Hamid et al., 2016).

Microorganisms, enzymes, insects and vegetable sprouting have different degrees of sensitivity to radiation, and that justifies the need for dosage diversification to reach efficiency (Evangelista, 2000). There is an ordinary scientific interest to learn the effects of realistically high doses of radiation on foods (Kilcast, 1994). However, not only foods are not ordinarily irradiated with doses superior to 10 KGy, but actually most foods are exposed to much smaller dose.

II. MATERIALS AND METHODS

2.1. Materials

A whole grain of sorghum (Sorghum bicolor (L) Moench) cultivar, Tabat, was purchased from White Nile State,. Grains were packed into jute sacks and stored at (30 ± 5°C) for further use.

2.2. Methods

2.2.1. Irradiation of Sorghum Grains

Sorghum grains were irradiated using gamma ray source (Experimental Coblt-60, Nordion gamma cell 220-excell) following the procedure described by Helinski et al. (2008), at the Sudanese Atomic Energy Corporation, Khartoum, Sudan. Sorghum grains were divided into three portions. Each was repacked into small sacks of 200 gm each. Two portions of the small sacks were irradiated using the (coblt-60) source of doses of 10KGy and 30KGy, and the third one was left as a control. All irradiated and non irradiated sorghum samples were then stored at 30 ± 5°C , (30±5 % RH) for shelf life studies. Samples were then withdrawn at 2 months interval (2, 4, 6,…..etc) to investigate the effect of radiation on insect and broken kernels count and sensory evaluation

2.2.2. Preparation of Sorghum Porridge

50g of flour was placed in a beaker, 200ml water was added then starters (fermented) were always prepared added to the mixture and stirred well. The batter was left for further fermentation to the next day.

The porridge was then prepared according to the traditional method (cooked and poured in bowel) and after cooling subjected to the sensory evaluation.

2.2.3. Insect Count of Sorghum Grain during Storage

300g of sorghum grains were sieved using Tyler Standard Screen Scale testing sieve. The total number of adult insects was counted and expressed as number per Kg (Stoll, 1996).

2.2.4. Kernel Damaged by Insects

Number of grains with a visible insect damage in 100g- grain samples were counted and recorded as a percentage (AACC, 1986).

2.2.5. Sensory Evaluation and Acceptability of Sorghum Porridge

The organoleptic evaluation of sorghum porridge assessed according to the hedonic scale method described by Iwe (2002). Ten semi-trained panelist from Food Research Center at Shambat were chosen to judge on the organoleptic attributes of Sudanese sorghum porridge (appearance, flavor, taste, texture and overall acceptability) at 2 months sorghum storage for irradiated (10 and 30KGy) and non irradiated samples. Sum of scores from each session were assessed statistically (P ≤ 0.05) for selection of more acceptable sample using sensory evaluation sheet.

2.2.6. 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 and Gomez (1984).

Data of organoleptic evaluation of the different types of sorghum porridge were subjected to the analysis of variance procedure and the means were separated at 0.05 levels according to the method described by Snedecor and Cochran (1987).

III. RESULTS AND DISCUSSION

3.1. Effect of Irradiation on Insect Level of Sorghum Grain during Storage

Table (1) shows the insect number of sorghum grain as affected by gamma irradiation during storage. A significant (P ≤ 0.05) increase in insect and larvae count was observed during the storage period from 0 larvae and 15 insect at the beginning of the storage to 8 larvae and 140 insects at the end of storage period (8 months), respectively. Irradiation of sorghum samples at 30KGy resulted in complete disinfestations up to 6 months. Tilton et al. (1978) and Urbain (1986) stated that, gamma radiation (1.00±0.2 K Gy) destroys all the metamorphic stages of insects and sterilizes the adults of 32 known granary insect. Marathe et al. (2002) observed complete disinfestations on wheat flour irradiated at 0.25 KGy. Kabbashi et al. (2012) used gamma irradiation in the control of T.castaneum insect on wheat flour and they mentioned that, irradiation had negatively affected T.castaneum.
Table 1: Shows the Insect Number of Sorghum Grain as Affected by Gamma Irradiation during Storage

| Irradiation Dose (KGY) | Storage Period (Months) | 0     | 2     | 4     | 6     | 8     |
|------------------------|-------------------------|-------|-------|-------|-------|-------|
| Control 0.00            | 15 insect, 1 larva      | 53 insect, 32 larvae | 65 insect, 47 larvae | 107 insect, 5 larvae | 140 insect, 8 larvae |
| 10.0                   | Nil                     | Nil   | Nil   | 2 larva | Nil   | 1 insect, |
| 30.0                   | Nil                     | Nil   | Nil   | Nil   | 2 insect |

However, all the doses used failed to completely eliminate the eggs from natural infestation, the viviparity of these eggs showed a decreasing trend as the irradiation dose increased. That means, mortality of insects from natural infestation is directly proportional with the dose.

3.2. Changes in Infected Seeds Content % of Irradiated Sorghum Grain during Storage

Table (2) shows the infected seeds of sorghum as affected by gamma irradiation during the storage period. The 30KGY irradiation resulted in absence of damaged seeds up to 6 months of storage, where as infected seeds content (%) of untreated samples increased significantly from zero at the beginning of storage to 12.89% at the end of storage (8 month).

Table 2: Shows the Infected Seeds of Sorghum as Affected by Gamma Irradiation during the Storage Period

| Irradiation Dose (KGY) | Storage Period (Months) | 0     | 2     | 4     | 6     | 8     |
|------------------------|-------------------------|-------|-------|-------|-------|-------|
| Control 0.00            | 0.0                     | 0.0   | 3.80  | 6.63  | 12.98 |
| 10.0                   | 0.0                     | 0.0   | 0.0   | 1.30  | 3.91  |
| 30.0                   | 0.0                     | 0.0   | 0.0   | 0.0   | 2.48  |

3.3. Sensory Evaluation and Acceptability of Irradiated Sorghum Porridge

Table (3 to 8) show changes in sensory attributes (flavor, taste, color, texture, bitterness, and overall quality) of a traditional porridge prepared from irradiated and non irradiated stored sorghum grain. Table (3) shows changes in color of sorghum porridge as affected by the irradiation dose and storage of grain. At the end of the storage sorghum porridge made from 10KGY irradiation dose showed superior score compared to others, where as the level of 30KGY was significantly (P≤0.05) decreased the color of porridge.

There were no significant (P≤0.05) differences between the flavors of sorghum porridge prepared from irradiated or non irradiated grains at the beginning of storage (Table 4). As the storage period progressed, the flavor partially faded out and the poorest scores were obtained at the end of the storage (8 months). After 6 months of storage, high dose of irradiation (30KGY) had significantly (P≤0.05) faded the flavor level whereas at the same time porridge of 10KGY irradiated sample showed superior scores compared to other ones.

Table (5) shows changes in taste of sorghum porridge. The highest scores were observed at the beginning of the storage at which there was no significant (P≤0.05) differences among the irradiated and non irradiated samples. The taste was adversely affected (P≤0.05) towards the end of the storage (8 months), however porridge of 10KGYs irradiated samples showed superior scores compared to 30KGY irradiated and non irradiated ones. The same observation was reported by Mohamed et al. (2010) with millet flour.

Table (6) shows changes in texture (consistency) of the traditional sorghum porridge as affected by gamma irradiation of sorghum grain.

The results indicated that after 2 month of storage, increasing the irradiation dose resulted in a significant (P≤0.05) decrease in the texture of sorghum
porridge towards the end of storage. At the end of storage (8 months) porridge of 10KGYs irradiated samples obtained a significantly (P≤0.05) higher scores than porridge of 30KGY and the non irradiated samples.

Table (7) shows changes in bitterness of sorghum porridge as affected by sorghum irradiated dose and storage. The significantly (P≤0.05) higher scores were observed at the beginning of the storage of the grain and there were no significant differences between irradiated and non irradiated samples. The bitterness then decreased irregularly towards the end of storage (8 months).

Table (8) shows the general acceptability of sorghum porridge as affected by sorghum irradiation dose during the storage. The highest acceptability scores were observed at the beginning of the storage on treated and non treated based porridge samples. After 2 months of storage, irradiation with 30KGY dose improved sorghum porridge overall acceptability, yet, overall acceptability of irradiated and non irradiated samples decreased significantly as the storage progressed, whereas the lowest scores were observed at the end of the storage for non treated and 30KGYs irradiated samples. Bamidele and Akanb (2013). Stated that, moinmoin, a traditional Nigerian food made form pigeon pea flour, irradiated at 20 KGy was partially acceptable in appearance and color but fully acceptable in mouth feel.

Table 3: Acceptability of Sorghum Porridge Color Based on Irradiation Stored Sorghum Grains

| Irradiation Dose (KGY) | Storage Period (Months) | 0    | 2    | 4    | 6    | 8    |
|----------------------|-------------------------|------|------|------|------|------|
| Control 0.0          |                         | 8.20 ±1.23 | 7.30<sup>ab</sup> ±1.06 | 7.50<sup>ab</sup> ±1.43 | 6.30<sup>bcd</sup> ±1.64 | 5.60<sup>cde</sup> ±1.78 |
| 10                   |                         | 8.20<sup>a</sup> ±1.23 | 6.20<sup>bcd</sup> ±1.55 | 6.80<sup>bcd</sup> ±1.40 | 6.60<sup>bc</sup> ±1.58 | 6.30<sup>bcd</sup> ±1.42 |
| 30                   |                         | 8.20<sup>a</sup> ±1.23 | 7.10<sup>b</sup> ±1.37 | 5.40<sup>cd</sup> ±1.71 | 5.10<sup>d</sup> ±0.88 | 5.60<sup>cde</sup> ±1.84 |
| Lsd<sub>0.05</sub>   |                         | 1.279<sup>+</sup> |
| SE±                  |                         | 0.4572 |

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

Table 3: Acceptability of Sorghum Porridge Flavor Based on Irradiated Stored of Sorghum Grains

| Irradiation Dose (KGY) | Storage Period (Months) | 0    | 2    | 4    | 6    | 8    |
|----------------------|-------------------------|------|------|------|------|------|
| Control 0.0          |                         | 8.20 ±1.23 | 7.30<sup>ab</sup> ±1.06 | 7.50<sup>ab</sup> ±1.43 | 6.30<sup>bcd</sup> ±1.64 | 5.60<sup>cde</sup> ±1.78 |
| 10                   |                         | 8.20<sup>a</sup> ±1.23 | 6.20<sup>bcd</sup> ±1.55 | 6.80<sup>bcd</sup> ±1.40 | 6.60<sup>bc</sup> ±1.58 | 6.30<sup>bcd</sup> ±1.42 |
| 30                   |                         | 8.20<sup>a</sup> ±1.23 | 7.10<sup>b</sup> ±1.37 | 5.40<sup>cd</sup> ±1.71 | 5.10<sup>d</sup> ±0.88 | 5.60<sup>cde</sup> ±1.84 |
| Lsd<sub>0.05</sub>   |                         | 1.279<sup>+</sup> |
| SE±                  |                         | 0.4572 |

Mean±SD value(s) having different superscript letter(s) in columns and rows are insignificantly different (P≤0.05).
**Table 5: Acceptability of Sorghum Porridge Taste Based on Irradiated Stored of Sorghum Grains**

| Irradiation dose (KgY) | Storage Period (Months) |
|------------------------|-------------------------|
|                        | 0          | 2          | 4          | 6          | 8          |
| Control                | 7.70<sup>bc</sup> ±1.89 | 7.50<sup>abc</sup> ±1.43 | 6.50<sup>abcd</sup> ±2.12 | 5.00<sup>de</sup> ±1.89 | 4.10<sup>e</sup> ±1.85 |
| 10                     | 7.70<sup>bc</sup> ±1.89 | 7.00<sup>abc</sup> ±1.33 | 6.20<sup>abcd</sup> ±1.69 | 5.70<sup>de</sup> ±2.06 | 6.10<sup>abc</sup> ±1.97 |
| 30                     | 7.70<sup>bc</sup> ±1.89 | 7.90<sup>a</sup> ±0.88 | 6.00<sup>bc</sup> ±1.70 | 4.80<sup>de</sup> ±1.69 | 4.90<sup>de</sup> ±2.13 |
| Lsd<sub>0.05</sub>     |                        | 1.59<sup>*</sup>    |                        |                        |                        |
| SE±                    |                        | 0.5684          |                        |                        |                        |

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

**Table 6: Acceptability of Sorghum Porridge Texture Based Irradiated Stored Sorghum Grains**

| Irradiation dose (KgY) | Storage Period (Months) |
|------------------------|-------------------------|
|                        | 0          | 2          | 4          | 6          | 8          |
| Control                | 8.20 ±0.92 | 7.10<sup>bc</sup> ±1.60 | 6.60<sup>abcd</sup> ±1.90 | 5.40<sup>de</sup> ±2.01 | 5.30<sup>de</sup> ±1.77 |
| 10                     | 8.20 ±0.92 | 6.30<sup>bcd</sup> ±1.42 | 6.00<sup>abcd</sup> ±2.11 | 6.10<sup>bcde</sup> ±2.23 | 6.50<sup>ab</sup> ±1.78<sup>d</sup> |
| 30                     | 8.20 ±0.92 | 7.50<sup>ab</sup> ±1.08 | 5.80<sup>bcde</sup> ±2.20 | 4.20<sup>e</sup> ±1.81 | 5.60<sup>cde</sup> ±1.78 |
| Lsd<sub>0.05</sub>     |                        | 1.496<sup>*</sup>    |                        |                        |                        |
| SE±                    |                        | 0.5349          |                        |                        |                        |

Mean±SD value(s) having different superscripts letter(s) in columns and rows are insignificantly different (P≤0.05).

**Table 7: Acceptability of Sorghum Porridge Bitterness Based on Irradiated Stored Sorghum Grains**

| Sample (KgY) | Storage Period (Months) |
|--------------|-------------------------|
|              | 0          | 2          | 4          | 6          | 8          |
| Control      | 7.80 ±1.55 | 5.70<sup>bc</sup> ±2.98 | 6.30<sup>de</sup> ±1.57 | 5.30<sup>bc</sup> ±1.57 | 4.30<sup>e</sup> ±2.16 |
| 10           | 7.80 ±1.55 | 5.10<sup>bc</sup> ±2.38 | 5.50<sup>de</sup> ±1.84 | 5.60<sup>bc</sup> ±2.12 | 4.40<sup>bc</sup> ±1.35 |
| 30           | 7.80 ±1.55 | 5.60<sup>bc</sup> ±1.96 | 5.40<sup>bc</sup> ±1.65 | 4.30<sup>e</sup> ±1.89 | 4.70<sup>bc</sup> ±1.57 |
| Lsd<sub>0.05</sub> |                | 1.672<sup>*</sup>    |                        |                        |                        |
| SE±          |                        | 0.5977          |                        |                        |                        |

Mean±SD value(s) having different superscript letters(s) in columns and rows are insignificantly different (P≤0.05).
Mean±SD value(s) having different superscript letters(s) in columns and rows are insignificantly different (P≥0.05).

### IV. CONCLUSIONS

Sudanese sorghum grains variety Tabat purchased from White Nile State were subjected to two doses of gamma radiation (10 and 30KGY) to study the effect of irradiation on the storage quality of the grains. The following points were concluded form the work:

- There were insignificant differences in flavors of sorghum porridge made from irradiated and non-irradiated grains, yet high dose of irradiation (30KGY) had significantly decreased acceptability of flavor at 6 months storage.
- After 4 months of storage 30KGYs irradiated sample showed inferior scores in general acceptability compared to 10KGY and non-irradiated ones. Irradiation also adversely affected the color and texture of porridge during the storage. The overall acceptability of porridge prepared from 10KGY irradiated sorghum grains had gained the highest scores throughout the storage period.

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