INTRODUCTION

*Sesamum indicum* L. or sesame but commonly known as benniseed, is widely grown in tropical and subtropical regions of the world. It is mostly used in edible oils, spices, insecticides, medicines, soap, green manure and ornaments. It is estimated that sesame seed contains 50–60% oil, 8% protein, 5.8% water, 3.2% crude fiber, 18.0% carbohydrate, and 5.7% ash and it is very rich in minerals such as calcium, phosphorus and vitamin E (Mbah and Akueshi, 2001; Enikuomehin, 2005).

The problem of mycotoxins in seeds is a most serious issue in developing countries because their climatic conditions, agricultural practices and storage conditions are considered conducive for fungal proliferation and toxin production in the field or in the store (Fapohunda et al., 2012). The effects of fungal invasion on seeds include a reduced germination potential, development of visible moldiness, discoloration, unpleasant odor, loss of dry matter, heating, chemical and nutritional changes, loss of quality and the production of mycotoxins which are hazardous to

ABSTRACT

The fungal load, total aflatoxins (B1, B2, G1 and G2) and ochratoxin A (OTA) contamination of 36 samples of *Sesamum indicum* L. grains from Abaji, Gwagwalada, Kubwa and Karu in the Federal Capital Territory, Abuja, Nigeria were investigated. A total of 135 fungal isolates belonging to five genera—namely, *Aspergillus*, *Curvularia*, *Penicillium*, *Fusarium* and *Ascochyta*—in decreasing order of prevalence were isolated from the non-irradiated grains. Only 34 isolates were obtained from the irradiated seeds at 3 kGy. *Aspergillus* spp. were observed in all the non-irradiated grain samples. Some fungal species were observed in irradiated grains treated with 3 kGy but none in the grains irradiated with 6–15 kGy. There was no consistent and no significant (*P* > 0.05) reduction in the total aflatoxins and ochratoxin A contents of irradiated samples from the four markets at 3 to 12 kGy. However, all the sesame grains exposed to irradiation at 15 kGy had comparatively the least total aflatoxins and ochratoxin A contents. Multiple mycotoxin analysis and the nutritional quality of the irradiated mold-free grains should be further investigated.

**Keywords:** Abuja, aflatoxin total, fungi, ochratoxin A, sesame seeds
humans and livestock. Many factors are involved in enhancing the formation of mycotoxins including: plant susceptibility to fungi infestation, suitability of fungal substrate, temperate climate, moisture content and physical damage to seeds due to insects and pests.

Aflatoxins (B1, B2, G1, G2, M1 and M2) are naturally occurring mycotoxins that are produced by many species of the fungal genus Aspergillus, and most notably by Aspergillus flavus and A. parasiticus. Following intake, aflatoxins are metabolized into a variety of products such as aflatoxicol, aflatoxin Q1, aflatoxin P1, and aflatoxin M1 in the liver by the cytochrome P450 group of enzymes (Berdanier et al., 2007). In addition, another metabolite, called aflatoxin epoxide, can be formed, which can induce DNA mutations ultimately leading to hepatic carcinoma. Chronic exposure also leads to a high risk of developing liver cancer, as aflatoxin metabolites can intercalate into DNA and alkylate the bases through its epoxide moiety (Bugno et al., 2006). Ochratoxin, produced mainly by the fungi A. ochraceus and Penicillium verrucosum, can be found in a wide variety of commodities such as barley, soy products and coffee. Though the ochratoxin amounts may be relatively low, often they are not rapidly removed from the body and levels may accumulate in the blood and other selected tissues in humans or animals that have consumed contaminated food (Ayejuyo et al., 2008). Ochratoxin is primarily a kidney toxin (that can cause Balkan endemic nephropathy, Vrabcheva, et al., 2004) but if the concentration is sufficiently high, there can be damage to the liver as well. Often, tumors are associated with this disease (Marin et al., 2009).

Food irradiation is a mechanized process of exposing foodstuffs to carefully controlled amounts of energy in the form of high-speed particles. It is a physical, non-thermal method of preserving food by eliminating or reducing microorganisms in oil rich foods, spices and also starch rich foods. The choice of the mode of irradiation operation depends on the type of product, quantity of product, shape, size, bulk density and the required dose (Refai et al., 1996; Mokobia and Anomohanran, 2005). Gamma facilities are the major food irradiation facilities worldwide. For instance, 27 of the 33 food irradiation facilities approved by the Economic Union (EU) in 2010 were Co-60 gamma facilities and 6 were electron beam (Ahari et al., 2010; Hossein et al., 2012). Gamma irradiation has higher penetration than electron beams. Therefore, it is suitable for treating large bulk packages of food which is required under the growing international trade in food commodities that must meet strict quarantine quality standards (Sadecka et al., 2007). Many studies have shown that irradiation is a safe process and therefore in 1994, the World Health Organization declared that the irradiation of food was safe from a nutritional and toxicological point of view (Diehl, 1995; Dwyer et al., 2003; Junqueira-Gonc-alves et al., 2012). Irradiation technology is reported to be easy to apply, clean and environment-friendly (Kodia, 1999). Some importers of Nigerian sesame complained of unacceptably high levels of mycotoxins especially aflatoxins (Makurdi, 2009). The current study aimed at assessing the efficacy of irradiation technology for the control of molds and mycotoxins in sesame grain seed. The objectives of this study included the investigation of the mycoflora load, total aflatoxins (Aflatotal) and ochratoxin A (OTA) contents in the raw and irradiated sesame seeds marketed in the Federal Capital Territory, Abuja, Nigeria.

MATERIALS AND METHODS

Materials

All chemicals used were of international AnalaR grade unless otherwise stated. This included: antibiotics—streptomycin and chloramphenicol (Sigma, Aldrich); and mycotoxins standards— aflatoxins B1, B2, G1 and G2, ochratoxin A (OTA)
reference standards obtained from Romer Labs Singapore Pte Ltd.

**Sampling**

Statistically representative samples were randomly collected from the markets in June, 2010. Sampling of commodities was conducted according to the method employed by Bainton *et al.* (1980). A total of 36 samples of marketed sesame grains were collected from Abaji (9), Kubwa (9), Gwagwalada (9) and Karu (9). Samples were collected from separate stalls by thorough mixing of the contents of market containers to obtain homogeneity and representative samples collected from the top, middle and bottom of the containers. Between 0.5 and 1 kg of each sample of the various *S. indicum* seeds was collected. The samples were put in polythene bags, sealed and transported to the Nuclear Technology Centre, Sheda-Abuja, where they were stored at −4 °C until analysis.

**Isolation and identification of fungi**

Fungi were isolated and cultured according to the methods of Smith and Moss (1985) and Halfon-Meiri and Barkai-Gola (1990). Samples were thoroughly mixed to obtain homogeneity and 10 g each were randomly selected, surface-sterilized using 5.25% sodium hypochlorite solution (Reckitt and Colman) and washed aseptically with 10 successive 100 mL volumes of sterilized distilled water before plating on the Sabraud dextrose agar (SDA). The plates were incubated at 28 °C for 5–7 d. Each of the fungi that emerged was subcultured onto a fresh SDA slant in a 15 mL slant bottle to obtain a pure culture. Each pure culture was characterized and identified on the basis of its morphological and microscopic characteristics following the identification keys of Klich (2002) for *Aspergillus* spp., Pitt and Hocking (1999) for *Penicillium* and Nelson *et al.* (1983) for *Fusarium* spp. Isolates were subcultured on potato dextrose agar slants and stored at 4 °C until further analyzed.

**Determination of Colony Forming Unit (CFU)**

Using a blender (Series EQOLE1025; Roamer Labs; Union MO, USA), each milled sample was subjected to a six-level serial dilution technique in which 1 g was diluted in a 9 mL ringer solution, vortexed and subsequently, 1 mL of the suspension was transferred to a 9 mL ringer solution and vortexed. Then, 1 mL of each suspension was inoculated on solid SDA in 90 mm Petri dishes and incubated at 28 °C. Between the 5th and 7th day of incubation, all colonies were counted using a colony counter and the results were presented as the number of fungal colonies per gram of sample calculated and expressed in colony-forming units per gram (cfu.g⁻¹).

**Determination of Aflatotal and OTA content in sesame grains**

**Sample preparation and extraction**

Samples of about 0.5 kg each were put in sealed plastic bottles and transported to the NAFDAC Central Laboratory, Oshodi, Lagos, Nigeria. Representative samples were obtained and finely ground until the powder could pass through a 20-mesh screen using a Series II® EQOLE1025 mill (Roamer Labs; Union MO, USA). The subsample portion was thoroughly mixed and 20 g of each sample was weighed out into a clean jar. Then, 100 mL of 70/30 (v/v) methanol/water extraction solution was added and the jar was tightly sealed. It was then shaken for 3 min using an EQOLE 1300 timer (Roamer Labs; Union MO, USA). Each sample was allowed to settle, and then the top layer of extract (that is, the crude Aflatotal and OTA) was filtered through a Whatman No 1 filter. The filtrate was collected and maintained at pH 6–8 in order to obtain an accurate result.

**Assay for Aflatotal and OTA determination**

The AgraQuant Total for the Aflatotal and OTA assays is a solid phase direct competitive
enzyme-linked immunosorbent assay (ELISA) (Romer Labs. Manual, 2007). The extracted sample and enzyme-conjugated Aflatoxin and OTA were mixed and added to the antibody-coated microwell. One dilution well was required for each standard of a vial each of 1.5mL, (that is 0, 2, 5, 10, 20 and 40 ppb) for the aflatoxins and (0, 1, 2,4,10 and 20 ppb) for OTA; and the 72 extracted samples. Equal numbers of Antibody Coated Microwell strips were placed in a microwell strip holder. Aflatoxin and OTA in samples and control standards were allowed to compete with enzyme-conjugated Aflatoxin and OTA for the antibody binding sites by incubating them at room temperature for 10 min. The contents in the microwells were discarded and the wells were washed five times by filling each of them with deionized water. The bottom of the microwells was dried by tapping on absorbent paper towel after the fifth wash. An enzyme substrate (100 μL) was then added into each well, incubated for 5 min until the blue color developed. The intensity of the color is inversely proportional to the concentration of aflatoxin/ochratoxin in the sample or standard. A 100 μL stop solution was then added which changed the color from blue to yellow. The microwells were measured optically by a microplate reader (statFax®303 Plus; Awareness Technology Inc.; Palm City, FL, USA) with an absorbance filter of 450nm and a differential filter of 630nm. The optical densities (ODs) of the samples were compared to the ODs of the standards and an interpretative result was determined and recorded. Air bubbles were eliminated prior to reading strips as they may affect analytical results.

**Irradiation procedures**

Irradiation of sesame grains was carried out in the gamma irradiation facility (GS 1000) at the Nuclear Technology Centre (NTC), Nigeria Atomic Energy Commission, Sheda Abuja, Nigeria. It is a category IV (wet storage source) Multipurpose Industrial Irradiation Facility with six different modes of operation. It consists mainly of an irradiation room with steel reinforced concrete walls with a thickness of about 1.8m to house the Co-60 radioactive source of current activity of about 5.5 x 10^15 Bq (=170 KCi). The sesame samples were moved into the irradiation room on a conveyor system for irradiation (Hvizdzak et al., 2010). Irradiation was carried out in the stationary mode of operation with the possibility of varying the rate (0.05–5Gy.hr⁻¹) depending on the location and distance from the source.

**Statistical analysis**

The mean ± standard deviation, analysis of variance and Duncan’s multiple range test were computed for data collected using SPSS statistical software (version 10.0, SPSS Inc. Chicago, IL, USA). The statistical level of significance was fixed at \( P < 0.05 \).

**RESULTS**

**Fungi isolated from sesame in Abuja, Nigeria**

Table 1 shows the fungal species and their occurrence in sesame grain samples collected from markets in four Area Councils in Abuja, Nigeria. The incidence data are presented as fungal isolates found per total number of samples. A total of 135 out 169 (79.88%) of the isolates were obtained from the non-irradiated samples (control). The other 20.12% of isolates were identified from sesame samples irradiated with a dose of 3 kGy (Table 1). No fungus was isolated from any sesame grains irradiated with 6–15 kGy. Naturally infected sesame seeds from Gwagwalada had the highest fungal load (60 isolates mainly made up of Aspergillus and Curvularia) while those from Abaji had the least load of 15 isolates. Out of the 10 fungal species, 6 were from the genus Aspergillus. Curvularia was the most common isolate followed by A. niger. The least common fungal species isolated were Ascochyta spp. and P. oxalicum (four isolates each).
Table 1  Absolute frequency of fungal species in non-irradiated and gamma-radiated sesame seeds from Abuja, Nigeria.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dose absorbed per sample (kGy)</th>
<th>CFU g.mL⁻¹ (× 10²)</th>
<th>Aspergillus niger</th>
<th>A. flavus</th>
<th>A. ochraceus</th>
<th>A. tamarii</th>
<th>A. candidus</th>
<th>A. sclerotionum</th>
<th>Ascochyta spp.</th>
<th>Fusarium verticilloides</th>
<th>Penicillium oxalicum</th>
<th>Curvularia spp.</th>
<th>Total</th>
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** = Not detected; CFU = Colony-forming units.
Values are the mean of three samples.

Detection of Aflatoxin and OTA in irradiated and non-irradiated seeds

Aflatoxin and OTA were detected in both irradiated and in non-irradiated samples. The reduction in the aflatoxin total (Aflatoxin) content was not consistent with an increasing...
dose of irradiation (Table 2). However, there was a significant difference between the non-irradiated and irradiated (15 kGy) sesame grains from Abaji, Gwagwalada and Kubwa. There was no significant difference in the Aflatoxin content in the non-irradiated and the irradiated sesame grains (from 6 to 12 kGy) from Abaji. There was a consistently high reduction in the Aflatoxin content in the sesame grains irradiated at 15 kGy.

The reduction in OTA content was not consistent with the increasing dose of irradiation (Table 3). However, there was a significant difference between the non-irradiated and irradiated (15 kGy) sesame grains from all four locations. There was no significant difference in the OTA content in the non-irradiated and irradiated sesame grains (from 3 to 6 kGy) from Kubwa. There was no significant reduction in the OTA content in the irradiated grains from Gwagwalada as the irradiation dose increased from 6 to 15 kGy.

![Figure 1](image-url)  
Comparative mean incidence of toxigenic fungal species in fresh and irradiated (3 kGy) sesame seeds from markets in Abuja, Nigeria. (Genus names for fungi: A. = *Aspergillus*; F. = *Fusarium*; P. = *Penicillium*).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Values (mean ± SD; n = 3) of Aflatoxin total content in sesame seeds in Abaji, Gwagwalada, Karu and Kubwa markets in Abuja, Nigeria.</th>
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<tbody>
<tr>
<td>Dose (kGy)</td>
<td>Abaji</td>
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<tr>
<td>0</td>
<td>0.60 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>3</td>
<td>0.40 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>6</td>
<td>0.50 ± 0.02&lt;sup&gt;ab&lt;/sup&gt;</td>
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<tr>
<td>9</td>
<td>0.13 ± 0.03&lt;sup&gt;bc&lt;/sup&gt;</td>
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<tr>
<td>12</td>
<td>0.55 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>15</td>
<td>0.09 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
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</table>

<sup>abc</sup> = Means with the same superscript letter in a column are not significantly different at $P > 0.05$ by Duncan’s multiple range test.
DISCUSSION

Differences in the incidence of toxigenic fungi from various locations in this study were in line with the findings of Makun et al. (2010) who identified different mycotoxigenic fungal species in rice fields, stores and markets from different locations in Niger State, Nigeria. Most toxigenic molds grow very well when exposed for long periods in open markets, without protective packaging, proper temperature maintenance, and moisture control. Aspergillus spp. were the most dominant fungal contaminants of Nigerian food commodities in the current study as has also been well documented by Bankole and Mabekoje (2004) and Atehnkeng et al. (2008). The very high incidence of Curvularia and Aspergillus can be explained by their easy survival in soil and plant debris and insects (Jamime-Garcia and Cotty, 2004) which serve as a reservoir of inoculum for infection of grain in the field. Toxin-producing fungi may invade at any time during pre-harvest, harvest, post-harvest handling and in storage (Vinod et al., 2008).

Irradiation above 3 kGy reduced the incidence of toxigenic fungi. Mold growth was completely inhibited in several foods and agricultural products at a radiation dose of 5 kGy while aflatoxin B1 was detoxified by 82–88% at 10 kGy (Lee et al., 2005; Goyal, 2011). Caillet et al. (2006) reported that irradiation in combination with other treatments may suppress the growth of surviving microorganisms during storage. Ferreira-Castro (2007) concluded from their studies that doses of up to 10 kGy are highly effective in Aspergillus flavus decontamination and have no adverse effects on the nutritional quality of cereal grains. Aziz et al. (2006) reported from their studies that total fungal counts increased 1.4 × 10^5 to 6.8 × 10^6 cfu per g grain in non-radiated grain samples compared to samples irradiated at 4 kGy (1.0 × 10^1 to 1.1 × 10^1 cfu per g grain) after 100 d of storage at room temperature and a radiation dose of 6 kGy that was considered to have inhibited mold growth completely. Gamma-radiation is legally permitted in 34 countries worldwide for microbial decontamination of dry food ingredients while 23 countries are commercially using this technology (Kume et al., 2009). Dried foods irradiation has been authorized at a maximum dose of 10 kGy and 30 kGy in Korea and in the United States, respectively (Chen, 1992).

Braghini et al. (2009) evaluated the effects of a range of gamma radiation doses on the growth of Alternaria alternata in artificially inoculated cereal samples. A comparison between the control group (0 kGy) and the groups irradiated with 2, 5 and 10 kGy showed a decrease of fungal counts at 2 and 5 kGy but a complete absence of growth was observed at 10 kGy for all four

<table>
<thead>
<tr>
<th>Dose (kGy)</th>
<th>Amount (parts per billion)</th>
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<td></td>
<td>Abaji</td>
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<tr>
<td>0</td>
<td>1.70 ± 0.01^a</td>
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<tr>
<td>3</td>
<td>0.96 ± 0.03^b</td>
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<tr>
<td>6</td>
<td>0.43 ± 0.03^bc</td>
</tr>
<tr>
<td>9</td>
<td>1.40 ± 0.06^ab</td>
</tr>
<tr>
<td>12</td>
<td>0.80 ± 0.02^b</td>
</tr>
<tr>
<td>15</td>
<td>0.16 ± 0.01^c</td>
</tr>
</tbody>
</table>

abc = Means with the same superscript letter in a column are not significantly different at *P* > 0.05 by Duncan’s multiple range test.
substrates. Also, Ferreira-Castro et al. (2007), who studied the effects of gamma radiation on corn samples artificially contaminated with *Fusarium verticillioides*, observed fungal growth in 80% of the samples irradiated to 5 kGy and complete decontamination at 10 kGy. Microbial resistance to gamma radiation depends on many factors such as the individual sensibility or the compounds of the substrate. Aziz and Moussa (2002) indicated that fungal flora are sensitive to gamma radiation and complete inhibition was achieved at a radiation dose of 5 kGy in different fruit samples.

The energy of ionizing radiation affects directly the microbial DNA molecules, causing damage to the fungal or bacterial cell. Other effects of radiation (known as indirect effects) include the interaction of energy with water molecules present in the substrate or food, producing free radicals and ions that attack the microorganism DNA, killing the microbes. Fungi are more resistant to radiation due to the natural radioprotective agents present in mycelia. The variation in gamma radiation resistance in filamentous fungus strains can be explained by multiple factors. The cell walls of some fungi contain appreciable fractions of lipids (up to 20%) as in the case of some *Aspergillus* species. In addition, intracellular fungal components (sulphydric compounds, pigments, amino acids, proteins and fatty acids) have been reported to be responsible for radioresistance in fungi (Salama et al., 1997).

The natural total aflatoxins and ochratoxins in sesame seeds sampled from Abuja markets, Nigeria were below the maximum limit of 20 ppb. kg\(^{-1}\) permitted by the EU, the Codex Alimentarius Commission and the National Agency for Food and Drug Administration and Control in Nigeria (Michael, 2009). In the EU member states, the maximum limits for total aflatoxins or ochratoxins for several foodstuffs are set in the Commission Regulation (EC) No 1881/2006 of 19 December 2006, as amended, on Setting Maximum Levels for Certain Contaminants in Foodstuffs. With regards to the total aflatoxins, the lowest EU limit is 4.0 μg. kg\(^{-1}\) for products such as groundnuts (peanuts) and tree nuts, dried fruit and processed cereal products. The total aflatoxins limit in foodstuffs in Australia is 15 ug.kg\(^{-1}\), in Nigeria and South Africa, it is 10 ug.kg\(^{-1}\) and in the USA, it is 20 ug.kg\(^{-1}\), while in India, it is as high as 30 ug.kg\(^{-1}\) (Codex Alimentarius Commission, 2011). In the EU, the lowest maximum limit for ochratoxins is 2.0 μg.kg\(^{-1}\), while the highest maximum limit is set at 80 μg.kg\(^{-1}\) for licorice extract for use in foods (Codex Alimentarius Commission, 2011). In the Codex Alimentarius Standard, an ochratoxin limit of 5 μg.kg\(^{-1}\) is set for raw wheat, barley and rye, only and these limits have been adopted in Nigeria and Kenya (Kawaguchi, 2012).

In the current study, significant reductions in Aflatoxin and OTA were observed in sesame seed at an irradiation dose of 15 kGy. This finding disagrees with the report of Henson (1995) that irradiation does not destroy aflatoxins or bacterial toxins. Prendergast et al., (2009) reported that low-dose irradiation could decrease the competitive microflora that possibly assist the growth of food pathogens after irradiation. There have been some reports on aflatoxin decontamination by gamma radiation in different commodities. For example, Herzallah et al. (2008) reported that a radiation dose of 5 kGy decreased total aflatoxin contamination in chick feed by 10% and it further decreased to 35% when the samples were irradiated at 25 kGy. Padro et al. (2003) concluded that the percentage infection of peanuts with aflatoxins decreased significantly by increasing the radiation dose levels from 5 to 10 kGy and the molds were completely inhibited at an irradiation dose of 10 kGy. Furthermore, treatment of peanut seeds with gamma radiation (15, 20, 25 and 30 kGy) destroyed 69–74% of aflatoxin B1 in sample A and 55–62% in sample B, respectively. A reduction in AFB2 (97.60% and 94%) was more efficient than the reduction of AFB1 (68.95 and 46%) at doses of 2 and 6 kGy, respectively, in maize samples (Ghanem et al., 2010) who further reported that a radiation dose of 10 kGy resulted in complete
reduction of AFB1 and AFB2 in maize. Bhat et al. (2007) reported a significant reduction of AFB1 at a 10 kGy irradiation dose in Mucuna pruriens seeds. The reduction or destruction was attributed mainly to the radiolysis of water that leads to the formation of highly reactive free radicals, which readily attack the AFB1 at the terminal furan ring, producing products of low biological activity.

The effect of chemical reactions on irradiated food depends on the absorbed dose, dose rate and facility type, the presence or absence of oxygen and the temperature. Generally, most food micronutrients (mainly water-soluble and fat-soluble vitamins) and macronutrients (carbohydrates, proteins and lipids) are not affected by a 10 kGy-range ionizing dose with regard to their nutrient contents. However, with radiation doses above 10 kGy, the properties of fibrous carbohydrates can be degraded structurally and lipids can become somewhat rancid (Brewer, 2009; World Health Organization, 2009).

CONCLUSION

Aflatoxin and OTA in sesame seeds sampled from Abuja markets, Nigeria were below the maximum limit of 20 ppb.kg⁻¹ permitted by the European Union, Codex the Alimentarius Commission and the National Agency for Food and Drug Administration and Control in Nigeria. This study indicated that sesame seed borne fungi could be controlled by irradiation as no fungus was isolated from any sesame grain sample irradiated with 6–15 kGy. Furthermore, irradiation of sesame grains up to 15 kGy could lead to a significant \( P \leq 0.05 \) reduction in Aflatoxin and OTA. Since the irradiation could not completely destroy the toxin at this level of irradiation, the treatment combination of gamma irradiation with other feasible methods such as physical methods of separation, thermal inactivation, solvents extraction, grain drying, controlled atmosphere storage, microbial inactivation and fermentation and ammoniation should be tried for greater aflatoxin and ochratoxin decontamination. There should be a monitoring program to avoid fungal contamination of sesame seed in the field, in the store and through exposure of products in the market. The use of high-performance liquid chromatography or liquid chromatography mass spectrometry/mass spectrometry for efficient quantification of specific aflatoxins in sesame seed is necessary. Also, further investigation into the nutritional qualities of irradiated sesame seeds beyond 10 kGy is imperative.

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