# Incidence of aflatoxin $B_1$ in the Egyptian cured meat basterma and control by γ-irradiation

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In the present studies trials have been carried out to investigate the occurrence of aflatoxin $B_1$ in the Egyptian cured meat basterma and to control such contamination by γ-rays. Basterma was prepared from fresh salted meat coated with spice paste and stored at room temperature. The total mould counts of basterma samples varied from $10^3$ to $10^6$ cfu/g in summer months and from $10^2$ to $10^5$ cfu/g in winter months. *Aspergillus, Penicillium, Mucor, Rhizopus, Fusarium* and *Cladosporium* were the most common fungal genera isolated from basterma samples and its components. Basterma samples contained total aflatoxins at levels from 2.8 to 47 $\mu g \cdot kg^{-1}$. Aflatoxins were determined in the spice paste at levels from 9.6 to 120 $\mu g \cdot kg^{-1}$ and in pepper (285.6 $\mu g \cdot kg^{-1}$), garlic (224.4 $\mu g \cdot kg^{-1}$), fenugreek (194.2 $\mu g \cdot kg^{-1}$), coriander (166.4 $\mu g \cdot kg^{-1}$) and capsicum (42.4 $\mu g \cdot kg^{-1}$). At an irradiation dose level of 3 kGy, only one sample each of pepper, fenugreek, and spice paste were contaminated with aflatoxins and all basterma samples and its components were free from aflatoxins at an irradiation dose level of 5 kGy.

## 1 Introduction

Meat and meat products are an important source of food for the human being as they are the most concentrated and easily assimilated of the nitrogenous foods [1]. Contamination of meat and meat products are common due to ubiquitous distribution of such microorganisms which lead to spoilage and/or food-borne mycotoxicosis [2, 3]. The environment in slaughter houses, butcher shops and refrigerators are considered as the main source of fungal contamination of meat [4-7]. Aflatoxins are toxic and thermostable chemical compounds produced by *Aspergillus flavus* and *A. parasiticus* in different field crops [8]. On the other hand, the producing animals are usually compelled to feed on unchanging formula even after the feed has become contaminated by fungi and mycotoxins, so the ingested aflatoxin $B_1$ will stay in tissues of meat animals as a result of consumption of toxic feed [9–12]. Spices and some food additives were investigated as the main important source of toxigenic moulds and mycotoxins in different processed meat products [13–16]. Radiation processing has been researched extensively and food irradiated up to doses of 10 kGy did not cause special or nutritional problems [15, 17–19, 36].

Basterma is a dried cured meat product popularly known in Egypt and some other countries bordering the Mediterranean sea. Its widely distributed consumption is attributed to the high biological value of its protein and mineral contents [1, 20–22]. Basterma is prepared from fresh beef coated with the spicy mixture, common salt and water to form a paste. The paste is adhesively applied over the surface of the cured meat then hanged to air-dry for a couple of days until repenning [20]. The present investigation has been carried out to reveal the incidence of moulds and aflatoxins in the basterma samples (meat and spices) as well as the possible role of γ-rays to reduce such contamination.

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## 2 Materials and methods

### 2.1 Samples

A total of 40 basterma samples (20 of each in summer and winter season) as well as 60 spices samples (10 of each) used in the basterma industry such as coriander, fenugreek, peeled garlic, capsicum and pepper were collected from different shops in different localities in Cairo and Giza governorate. All samples were collected in clean and dry polyethylene bags and then transferred directly to the laboratory, under aseptic conditions for further investigation of moulds and aflatoxins.

### 2.2 Isolation and identification of moulds

Ten grams from each sample was carefully and aseptically weighed and homogenized with 90 mL of sterile saline solution (0.85%) for about 2 min using a sterile homogenizer (Braum Type). This homogenate represents the dilution of $10^{-1}$; the mixture was allowed to stand for 2 min before decimal dilutions ($10^{-2}$ up to $10^{-6}$) were done in sterile saline solution. One mL from each of the prepared dilutions was spread on the surface of sterile petri dishes in duplicates containing 5 mL sterilized Czapek-Dox agar, then plates were incubated at 25 °C for 5–7 days. After the incubation periods, each mould growth was picked up and transferred onto Czapek-Dox agar slopes, then kept at 22–25 °C for further identification wich was carried out according to Pitt and Hocking [23].

### 2.3 Determination of aflatoxins

Aflatoxins $B_1$, $B_2$, $G_1$ and $G_2$ residues in the samples were detected by thin-layer chromatography (TLC) method [2, 24] and confirmed by HPLC [25].

#### 2.3.1 Aflatoxin standard solution

Aflatoxins $B_1$, $B_2$, $G_1$ and $G_2$ were obtained from Sigma Chemical (St. Louis, MO, USA). The reference resolution was prepared by mixing aflatoxins with benzene: acetonitrile (9:1 v/v) to give concentrations of 1 $\mu g \cdot mL^{-1}$ for $B_1$, $B_2$, and $G_1$ and 0.4 $\mu g \cdot mL^{-1}$ for $B_2$ and $G_2$.

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#### 2.3.2 Separation and detection of aflatoxins

Basterma samples were homogenized and then 100 g were weighed into 500 mL wide-mouth glass stopper Erlenmeyer flasks. Ten mL of citric acid solution (20%) was added (for protein denaturation) and mixed thoroughly with glass rod. After 5 min, the mixture was stirred again and mixed with 20 g diatomaceous earth (to expedite filtration and promote clarity of the filtrate). Dichloromethane ($CH_2Cl_2$) (200 mL) was added, then the flasks were shaken vigorously on a wrist-action shaker for 30 min. The mixture was filtered through fast filter paper into 300 mL Erlenmeyer flasks containing 10 g anhydrous sodium sulfate. The flasks were swirled gently for about 2 min, the contents were filtered, the filtrate was evaporated to near dryness and saved for column chromatography. The concentrated filtrate was dissolved in 4 × 25 mL dichlormethane then added to the chromatographic column 22 × 300 mm containing 2 g silica gel and 2 g $NaSO_4$. The column was washed with 25 mL toluene:glacial acetic acid (9:1 v/v), 25 mL hexane, and 25 mL hexane:ether:acetonitrile (6:3:1 v/v/v) and washes were discarded. The aflatoxins were eluted with 40 mL $CH_2Cl_2$:acetone (4:1 v/v) and the elute was evaporated to near dryness on a steam bath. Using micropipettes at 2 cm from the bottom of a TLC plate, the plates were allowed to run for 16 cm from the baseline in a solvent of chloroform:hexane:petroleum ether:benzene:acetone (60:10:10:10:10 v/v). The dried plates were examined under UV light (366 nm). Aflatoxin concentrations were determined by comparing the $R_f$ and intensity of fluorescence of the aflatoxin standards with the unknown samples. The concentrations were determined by HPLC on a Waters apparatus with a Delivery system model 600, and scanning fluorescence detector (Ex. 365, Em. 450 nm).

#### 2.3.3 Aflatoxin residues in the spice samples

Aflatoxins were analyzed by TLC [14, 24] as modified by the Department of Microbiology, Faculty of Veterinary Medicine, Cairo University, Giza, Egypt (Prof. Dr. M. Rafai, personal communication).

##### 2.3.3.1 Sample preparation, extraction and cleanup

Ground spices (50 g) were blended for 3 min at high speed with 200 mL acetonitrile:4% potassium chloride (90:10 v/v). The mixture was then filtered with suction into a 50 mL filter flask through a Whatman No. 1 filter paper and the filtrate was transferred to a 500 mL separatory funnel. The extract was defatted four times with 50 mL isooctane and cleaned by washing with 15 mL distilled water. Toxins were extracted with 25 mL chloroform, then sequentially filtered through anhydrous $Na_2SO_4$ and evaporated until almost dry. The residue was dissolved in chloroform and reserved for TLC.

##### 2.3.3.2 Development of the chromatogram

Each residue from the contaminated samples was dissolved in 0.5 mL AR-$CHCl_3$ and 25 mL was spotted on TLC plates (Silica gel G), as well as aflatoxin standards (10 mL). The TLC plates were allowed to run for 16 cm from the baseline in a solvent of chloroform:acetone (90:10 v/v). The dried plates were examined under UV light (366 nm). Aflatoxin concentrations were determined by comparing the $R_f$ and intensity of fluorescence of the aflatoxin standards with the unknown samples. The concentrations were determined by HPLC as decribed previously.

### 2.4 Irradiation treatment

The process of irradiation was carried out at the National Center for Radiation Research and Technology (NCRRT), Atomic Energy Authority (Nasr City, Cairo, Egypt). The irradiation facility was cobalt-60 γ-chamber 40000A India. The average dose rate was 64.0 Gy/min at the time of the experiment. Spice samples were exposed to increasing doses of γ-irradiation as 0.0, 1.0, 3.0 and 5.0 kGy at ambient temperature. Four groups of experimentally made basterma products were prepared under the light of the Egyptian Standard Specification No. 1688/1991 [20]. The first group was used as control and contained the unirradiated spices, the other three groups contained 1, 3 and 5 kGy irradiated spices. All basterma product samples were stored for 2 weeks at room temperature, and the samples were examined for mould and aflatoxin contaminations.

## 3 Results and discussion

### 3.1 Incidence of moulds basterma samples and its components

Table 1 shows that the mould counts of the basterma coat samples were higher than in the meat samples. The mould counts of basterma samples and its components were higher in summer than in winter. The range of mould counts varied from $10^3$ to $10^6$ cfu/g, when samples were collected in summer, whereas the mould counts varied from $10^2$ to $10^5$ cfu/g in the winter season. It is evident that all basterma samples and their components (100%) collected during the summer months (June, July and August) were contaminated with moulds, whereas the rate of mould contamination was comparatively less (75%) in samples collected in winter (November, December and January). Moulds could contaminate meat during slaughtering and handling in slaughter houses, where air wall and equipments play an important role in contamination of meat with fungi [4, 5, 21, 26, 27]. In the processed meat products as basterma, the higher mould count may be attributed to the addition of spices. The rate of contamination of all spices used in basterma processing during this study (Table 1) had mould counts ranging between $10^4$ to $10^6$ cfu/g. Pepper, fenu-

**Table 1.** Total mould count of basterma samples and its components

| Samples | Total mould count (cfu/g)[a] | |
|---|---|---|
| | Summer | Winter |
| (A) Before processing[a]: | | |
| Raw meat | $1.7 \pm 0.3 \times 10^3$ | $1.2 \pm 0.4 \times 10^2$ |
| Pepper | $4.2 \pm 0.2 \times 10^5$ | $9.9 \pm 0.8 \times 10^4$ |
| Coriander | $2.7 \pm 0.3 \times 10^5$ | $3.5 \pm 0.7 \times 10^4$ |
| Fenugreek | $1.7 \pm 0.2 \times 10^6$ | $2.8 \pm 0.2 \times 10^3$ |
| Capsicum | $8.1 \pm 0.4 \times 10^6$ | $1.8 \pm 0.3 \times 10^5$ |
| Garlic | $3.4 \pm 0.2 \times 10^4$ | $4.9 \pm 0.3 \times 10^3$ |
| Peeled garlic | $1.2 \pm 0.2 \times 10^4$ | $3.6 \pm 0.2 \times 10^3$ |
| (B) After processing[b]: | | |
| Basterma paste (coat) | $4.2 \pm 0.5 \times 10^4$ | $2.5 \pm 0.3 \times 10^2$ |
| Meat | $2.4 \pm 0.2 \times 10^3$ | $2.6 \pm 0.2 \times 10^2$ |
| Coat and meat | $2.5 \pm 0.1 \times 10^4$ | $2.6 \pm 0.4 \times 10^2$ |

a) Mean of 10 samples ± SE
b) Mean of 40 samples ± SE



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**Table 2.** Incidence of isolated mould genera in the examined basterma samples and its components

| Samples | % of positive contaminated samples | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Aspergillus* | *Penicillium* | *Mucor* | *Rhizopus* | *Fusarium* | *Cladosporium* | *Foma* |
| (A) Before processing[a]: | | | | | | | |
| Raw meat | 0 | 0 | 10 | 10 | 0 | 10 | 0 |
| Pepper | 90 | 40 | 10 | 70 | 10 | 0 | 0 |
| Coriander | 100 | 50 | 30 | 30 | 0 | 0 | 0 |
| Fenugreek | 100 | 20 | 70 | 50 | 0 | 0 | 0 |
| Capsicum | 100 | 20 | 70 | 50 | 0 | 0 | 0 |
| Garlic | 30 | 20 | 0 | 80 | 0 | 0 | 0 |
| Peeled garlic | 0 | 10 | 0 | 30 | 0 | 20 | 0 |
| (B) After processing[b]: | | | | | | | |
| Basterma paste (coat) | 50 | 75 | 40 | 30 | 0 | 15 | 0 |
| Meat | 30 | 50 | 25 | 25 | 5 | 0 | 0 |
| Coat and meat | 50 | 70 | 30 | 25 | 5 | 7.5 | 5 |

a) 10 samples from each
b) 40 samples from each

**Table 3.** Levels of aflatoxin residues in individual basterma 40 samples ($\mu g \cdot kg^{-1}$) after processing

| Samples | Summer | | | | | | Winter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Serial No.[a] | B1 | B2 | G1 | G2 | Total | Serial No.[a] | B1 | B2 | G1 | G2 | Total |
| Basterma paste (Coat) | 2 | 33.3 | 33.3 | 0.0 | 0.0 | 66.6 | 2 | 18.2 | 18.2 | 0.0 | 0.0 | 36.4 |
| | 8 | 4.4 | 4.4 | 4.4 | 4.4 | 17.6 | 6 | 4.5 | 4.5 | 0.0 | 0.0 | 9.0 |
| | 12 | 4.8 | 4.8 | 0.0 | 0.0 | 9.6 | 11 | 3.2 | 5.0 | 3.2 | 3.2 | 14.6 |
| | 14 | 18.2 | 18.2 | 9.0 | 9.0 | 29.0 | 12 | 12.0 | 12.0 | 0.0 | 0.0 | 24.0 |
| | 15 | 40.0 | 40.0 | 20.0 | 20.0 | 120.0 | 14 | 7.0 | 7.0 | 4.1 | 4.1 | 22.2 |
| | 16 | 15.0 | 15.0 | 9.0 | 9.0 | 48.0 | | | | | | |
| | 17 | 10.0 | 5.0 | 5.0 | 5.0 | 25.0 | | | | | | |
| | 20 | 4.0 | 25.0 | 0.0 | 0.0 | 54.4 | | | | | | |
| Meat[b] | 3 | 6.2 | 6.2 | 6.2 | 6.2 | 24.8 | 14 | 5.5 | 5.5 | 5.5 | 5.5 | 22 |
| Coat and meat | 2 | 2.8 | 0.0 | 0.0 | 0.0 | 2.8 | 2 | 8.2 | 8.2 | 0.0 | 0.0 | 16.4 |
| | 3 | 6.7 | 6.7 | 0.0 | 0.0 | 13.4 | 11 | 12.0 | 12.0 | 0.0 | 0.0 | 24.0 |
| | 11 | 2.5 | 2.5 | 0.0 | 0.0 | 5.0 | 12 | 14.5 | 14.5 | 0.0 | 0.0 | 29.0 |
| | 12 | 10.4 | 10.4 | 0.0 | 0.0 | 20.8 | 147 | 5.0 | 0.0 | 2.5 | 2.5 | 10.0 |
| | 14 | 5.6 | 5.6 | 5.2 | 5.2 | 21.6 | 16 | 2.3 | 4.0 | 7.2 | 72 | 20.7 |
| | 15 | 3.2 | 0.0 | 0.0 | 0.0 | 3.2 | 20 | 3.6 | 3.6 | 0.0 | 0.0 | 7.2 |
| | 16 | 8.6 | 8.6 | 6.9 | 6.9 | 31.0 | | | | | | |
| | 17 | 12.6 | 14.0 | 10.2 | 10.2 | 47.0 | | | | | | |

a) Serial of positive samples
b) Raw meat before processing was free from aflatoxins.

greek, coriander and capsicum contained the highest mould count. Aziz *et al.* [14] stated that most spices may serve as suitable vehicles and that they could be a potential source of food contamination. These results are similar with those reported by some investigators [13, 18]. The different mould genera isolated from basterma samples and its components are presented in Table 2. It is clear that *Aspergillus, Penicillium, Mucor, Rhizopus, Fusarium* and *Cladosporium* were the most common fungal genera isolated from the basterma samples and its components. In a previous study, El-Gazzar [6] reported the presence of *Penicillium, Aspergillus* and *Mucor* in basterma samples with a percentage of 42.7, 31.1 and 5.9%, respectively. In addition, Hassanien [21] examined 75 samples of meat products as luncheon and basterma, and he found that *Aspergillus, Penicillium, Cladosporium, Fusarium, Mucor, Trichoderma, Geotrichum* and *Scopulariopsis* spp. were the most commom fungal genera isolated from all meat products. Also, Roushdy *et al.* [11] found that *Aspergillus ochraceus, Penicillium verucosum, Mucor* sp. and *Cladosporium* sp. were the most common mould species isolated from meat and meat products. Several investigators [1, 4, 7, 26, 35] reported that *Aspergillus flavus, A. niger, A. candidus, A. fumigatus, A. nidulans, A. glaucus, Alternaria* spp., *Penicillium* spp. and *Rhizopus* could be isolated from fresh meat and cold stored meat. Aziz *et al.* [14] examined a total of 84 medicinal plants and spices for mould contamination. The authors found that *Aspergillus flavus, A. parasiticus, A. niger, Fusarium* and *Penicillium* spp. occurred most often in the spice samples.

It was evident from the above-mentioned results that as with many agricultural products, spices are exposed to a wide range

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**Table 4.** Levels of aflatoxin residues detected in the examined spices 10 samples ($\mu g \cdot kg^{-1}$)

| Samples | Serial No.[a)] | Determined aflatoxin residues | | | | |
|---|---|---|---|---|---|---|
| | | $B_1$ | $B_2$ | $G_1$ | $G_2$ | Total |
| Pepper | 1 | 63.8 | 63.8 | 0 | 0 | 127.6 |
| | 2 | 85.1 | 85.1 | 0 | 0 | 170.2 |
| | 3 | 93.7 | 93.7 | 0 | 0 | 187.4 |
| | 4 | 40.7 | 40.7 | 40.7 | 40.7 | 162.8 |
| | 5 | 13.8 | 13.8 | 13.8 | 0 | 41.4 |
| | 6 | 10.4 | 13.0 | 0 | 0 | 23.4 |
| | 7 | 13.6 | 13.6 | 13.6 | 13.6 | 54.4 |
| | 8 | 13.0 | 13.0 | 13 | 13 | 52.0 |
| | 9 | 17.3 | 17.3 | 17.3 | 17.3 | 69.2 |
| | 10 | 81.6 | 81.6 | 61.2 | 61.2 | 285.6 |
| Coriander | 4 | 14.2 | 14.2 | 14.2 | 14.2 | 56.8 |
| | 5 | 8.7 | 8.7 | 8.7 | 8.7 | 34.8 |
| | 9 | 41.6 | 41.6 | 41.6 | 41.6 | 166.4 |
| Fenugreek | 1 | 42.5 | 0 | 0 | 0 | 42.5 |
| | 4 | 41.6 | 41.6 | 55.5 | 55.5 | 194.2 |
| | 5 | 0 | 0 | 21.2 | 21.2 | 42.4 |
| | 6 | 5.3 | 5.3 | 0 | 0 | 10.6 |
| | 10 | 63.8 | 31.9 | 31.9 | 31.9 | 159.5 |
| Capsicum | 10 | 0 | 0 | 21.2 | 21.2 | 42.4 |
| Garlic | 1 | 6.8 | 8.1 | 30.6 | 40.8 | 86.3 |
| | 3 | 8.3 | 10.4 | 10.4 | 10.4 | 39.5 |
| | 4 | 40.8 | 40.8 | 40.8 | 40.8 | 163.2 |
| | 5 | 61.2 | 40.8 | 61.2 | 61.2 | 224.4 |
| | 6 | 40.8 | 40.8 | 40.8 | 40.8 | 163.2 |
| | 7 | 51.02 | 30.6 | 40.8 | 40.8 | 163.22 |
| Garlic peeled | 0 | 0 | 0 | 0 | 0 | 0 |

a) Serial of positive samples as indicated in Table 3

of environmental contamination during collection as well as processing and in the retail market due to the presence of dust, waste water, feces from birds, rodents or even insects [13]. So, spices may present a risk to public health because they are often added to foods that undergo no further processing or are eaten raw. These findings are similar to those reported by Aziz and Youssef [2] and Abdel-Rahman [13].

### 3.2 Incidence of aflatoxins in basterma samples and its components

Results given in Table 3 reveal that 40% of the basterma coat samples collected in summer months were contaminated with aflatoxins and only 25% of samples were contaminated in winter months. In summer season, 8 samples were contaminated with total aflatoxins at levels from 9.6 to 120 $\mu g \cdot kg^{-1}$, only one meat sample had total aflatoxins at a level of 24.8 $\mu g \cdot kg^{-1}$ and 8 of coat and meat samples together contained total aflatoxins at levels from 2.8 to 47 $\mu g \cdot kg^{-1}$. In winter season, the total aflatoxins ($\mu g \cdot kg^{-1}$) decreased in all basterma samples. Table 4 shows that aflatoxins residues could be detected in pepper (100%), coriander (30%), fenugreek (50%), capsicum (10%) and garlic (60%). From this table, it is clear that the total aflatoxin residues detected in pepper samples reached up to 285.6 $\mu g \cdot kg^{-1}$, followed by garlic (224.4 $\mu g \cdot kg^{-1}$), fenugreek (194.2 $\mu g \cdot kg^{-1}$), coriander (166.4 $\mu g \cdot kg^{-1}$) and capsicum (42.4 $\mu g \cdot kg^{-1}$). In this study aflatoxins residues were not detected in all raw peeled garlic samples. Abdel-Rahman [4] reported that production of aflatoxins in summer is higher than in winter, depending on the growing strain of mould, storage time, temperature and/or surrounding humidity. The presence of aflatoxin residues in processed meat is still a matter of considerable concern, especially since aflatoxins have been shown to be carcinogenic [2, 3, 9]. The natural occurrence of aflatoxins in different spices (pepper, fennel, coriander, cumin, and cardamom red pepper) was previously reported [13–15].

Table 5 shows the comparison of the amounts of aflatoxins detected in the basterma samples and its components to the permissible limit, recommended by FDA (20 $\mu g \cdot kg^{-1}$). In this study, samples of pepper, coriander, capsicum, garlic 80% of fenugreek (Table 6), 75% of coat, 10% of meat and 37.5% of coat and meat (Table 5) exceeded the permissible limit [28].

### 3.3 Influence of γ-irradiation on the incidence of moulds and aflatoxins in basterma samples and its components

Table 7 shows that the viable count of moulds decreased by increasing the radiation dose levels. The effective dose for decreasing the mould counts was 3 kGy, for all basterma samples and its components, the moulds counts decreased by about 2–4 log cycles. On the other hand, it was noticed that at a dose level of 5 kGy, all samples were free from moulds. The efficacy of γ-irradiation for the decontamination of certain spices


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**Table 5.** Comparison between the total aflatoxins residues in the examined basterma samples 20 and recommended levels of FDA (20 μg·kg$^{-1}$)

| Parts of the samples | Summer | | | | | | Winter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total positive aflatoxins contaminated samples | | Total positive aflatoxins contaminated samples within limit | | Total positive aflatoxins contaminated exceeding the limit | | Total positive aflatoxins contaminated samples | | Total positive aflatoxins contaminated samples | | Total positive aflatoxins contaminated samples within limit | |
| | No. | (%) | No. | (%) | No. | (%) | No. | (%) | No. | (%) | No. | (%) |
| Coat | 8 | 40 | 2 | 25 | 6 | 75 | 5 | 25 | 2 | 40 | 3 | 60 |
| Meat | 1 | 5 | – | – | 1 | 10 | 1 | 5 | – | – | 1 | 10 |
| Coat and meat | 8 | 40 | 5 | 62.5 | 3 | 37.5 | 6 | 30 | 3 | 50 | 3 | 50 |

**Table 6.** Evaluation of the total aflatoxin residues in the examined spices samples in view of the recommended permissible limit of FDA (20 μg·kg$^{-1}$)

| Samples | Total positive aflatoxins contaminated samples | | Total positive aflatoxins contaminated samples within the limit | | Total positive aflatoxins contaminated samples exceeding the limit | |
|---|---|---|---|---|---|---|
| | No. | (%) | No. | (%) | No. | (%) |
| Pepper | 10 | 100 | – | – | 10 | 100 |
| Coriander | 3 | 30 | – | – | 3 | 30 |
| Fenugreek | 5 | 50 | 1 | 10 | 4 | 40 |
| Capsicum | 1 | 10 | – | – | 1 | 10 |
| Garlic | 6 | 60 | – | – | 6 | 60 |
| Peeled garlic | – | – | – | – | – | – |

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**Table 7.** Effect of γ-irradiation on the total mould count (cfu/g) of basterma samples and its components

| Samples | Irradiation dose levels (kGy) | | | |
|---|---|---|---|---|
| | 0 | 1 | 3 | 5 |
| Pepper | $2 \times 10^5$ | $3 \times 10^3$ | $2 \times 10^1$ | 0 |
| Coriander | $1.1 \times 10^5$ | $3 \times 10^3$ | $1 \times 10^2$ | 0 |
| Fenugreek | $1.1 \times 10^6$ | $1 \times 10^4$ | $1.8 \times 10^2$ | 0 |
| Capsicum | $2 \times 10^6$ | $1.8 \times 10^4$ | $1 \times 10^4$ | 0 |
| Garlic | $3 \times 10^3$ | $1.2 \times 10^2$ | $1 \times 10^1$ | 0 |
| Basterma paste (coat) | $1 \times 10^4$ | $8 \times 10^2$ | $7 \times 10^1$ | 0 |
| Meat | $3 \times 10^3$ | $2 \times 10^2$ | $2 \times 10^1$ | 0 |
| Coat and meat | $9 \times 10^3$ | $6 \times 10^2$ | $5 \times 10^1$ | 0 |

has been reported by several investigators [15, 18] who mentioned that the mould contamination of ground pepper, cinnamon, fennel, anise, cumin, peppermint, coriander, and turmeric was inactivated by irradiation at dose levels from 4 to 6 kGy without causing significant chemical sensory alternations. Moreover, the sensitivity of fungi to ionizing radiation has been established by many investigators [29–33], who recorded that the dose required for complete inhibition of natural fungal flora contaminating different food and feed products ranged from 4 to 6 kGy. These observations are in agreement with the present results which showed that 5 kGy was the lethal dose for the isolated fungi in all basterma samples and its components. From Table 8 it is clear that at an irradiation dose level of 3 kGy only one sample each of pepper, fenugreek and basterma paste was contaminated with aflatoxin $B_1$ at concentrations of 8.6, 8.6 and 5.6 μg·kg$^{-1}$, respectively, and all basterma samples and its components were free from aflatoxins at an irradiation dose level of 5 kGy. Production of mycotoxins by toxinogenic moulds was influenced principally by water activity, temperature and irradiation dose, but decreasing the water activity and/or increasing the radiation dose clearly suppressed or eliminated mycotoxin formation [16].

Many researches have been carried out for possible commercial radiation sterilization of cured meat products, spices and different human food commodities [17, 19, 29, 34, 35]. The toxicological aspects of food irradiation have been studied more extensively than for any other food preservation technique. As a result of these studies, the toxicological safety and wholesomeness of foods irradiated up to a total average dose of 10 kGy will not be influenced [36–38]. On the basis of scientific evidence on the entity of irradiated foods, 41 countries have approved more than 100 irradiated items of groups of foods for consumption either on unconditional or restricted basis [35].

## 4 Concluding remarks

To produce foods of animal origin using extended quality definition, not only the product quality must be considered, but the quality of production processes must be also included. Therefore, production, transportation and sale of meat products must be performed with care to prevent any hazard. The incidence of moulds and aflatoxins in the basterma samples (meat and spices) and the possible role of γ-rays to reduce such contamination was investigated in the study. The results suggest that at an irradiation dose level of 5 kGy all basterma samples and its components were free from moulds and aflatoxins. The relationship of mycotoxins to food safety must be considered

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**Table 8.** Levels of aflatoxin $B_1$ residues in 10 γ-irradiated basterma samples and its components stored for 2 weeks at room temperature (25 °C)

| Samples | Irradiation dose levels (kGy) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 3 | | 5 | |
| | No. of positive samples | Aflatoxin $B_1$ ($\mu g \cdot kg^{-1}$) | No. of positive samples | Aflatoxin $B_1$ ($\mu g \cdot kg^{-1}$) | No. of positive samples | Aflatoxin $B_1$ ($\mu g \cdot kg^{-1}$) | No. of positive samples | Aflatoxin $B_1$ ($\mu g \cdot kg^{-1}$) |
| Raw meat | 0 | ND | 0 | ND | 0 | ND | 0 | ND |
| Pepper | 8 | 163.2 | 3 | 41.8 | 1 | 8.6 | 0 | ND |
| Coriander | 4 | 31.2 | 2 | 12.7 | 0 | ND | 0 | ND |
| Fenugreek | 6 | 87.5 | 4 | 25.6 | 1 | 8.6 | 0 | ND |
| Capsicum | 3 | 50 | 1 | 18.7 | 0 | ND | 0 | ND |
| Garlic | 2 | 10.4 | 0 | ND | 0 | ND | 0 | ND |
| Basterma paste (coat) | 6 | 25 | 4 | 17.8 | 1 | 5.6 | 0 | ND |
| Coat and meat | 4 | 17.9 | 1 | 4.3 | 0 | ND | 0 | ND |

ND, not detected

when methods of food preservation are being selected. γ-Irradiation of foods has been proposed as a mean of food preservation along with either sterilizing or pasteurizing doses.

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