INFLUENCE OF GAMMA RADIATION ON THE NUTRITION COMPOSITION AND CONTAMINATION BY AFLATOXIGENIC *Aspergillus* ON PEANUTS

Laury Francis Costa¹, Edvane Borges da Silva², Idjane Santana de Oliveira³

¹Departamento de Energia Nuclear-UFPE
Av. Prof. Luiz Freire,1000 - Cidade Universitária,
CEP: 50740-540, Recife - PE
ladyaeka@hotmail.com, lauryfrancis@gmail.com

²Departamento de Energia Nuclear-UFPE
Av. Prof. Luiz Freire,1000 - Cidade Universitária,
CEP: 50740-540, Recife - PE
edvborges@yahoo.com

³Centro Acadêmico de Vitória-UFPE
Rua Alto do Reservatório, S/N – Bela Vista
CEP: 55608-680
Vitória de Santo Antão – PE
idjaneoliveira@yahoo.com

ABSTRACT

Care in food storage, such as temperature and humidity control, assist in the prevention of fungal diseases in peanuts. The development of filamentous fungi in food and feed can result in the production of toxins known as mycotoxins. Ionizing radiation can be used as a preventive method against food security, promoting the inhibition of sprouting, delayed maturation, reduced microbial load, elimination of pathogenic microorganisms, sterilization, disinfection in grains, cereals, fruits and spices. This study aimed to evaluate the effects of gamma radiation on the nutritional composition and growth inhibition of *Aspergillus* aflatoxigenic in samples of peanuts. Samples were collected directly from a small producer (Petrolândia-PE) and Pernambuco Central of Supply (CEASA) and then packed within / without pods and subjected to irradiation by cobalt-60 pump at doses of 0, 6, 9, 12 and 15 kGy, in triplicate. The material was divided into two parts: a) to conduct a nutritional analysis of non-irradiated and irradiated material, and b) for fungal analysis, before and after irradiation. The results showed that the samples originated from the CEASA-PE had the highest rates of contamination with peanut, not only subjected to irradiation, but also for those samples subjected to doses of 6, 9 and 12 kGy. The dose of 15 kGy was the most efficient in controlling *Aspergillus* aflatoxigenic for both origins because it failed to eliminate the action of fungi, regardless of treatments. Only one non-irradiated sample, originated from CEASA-PE, showed positive production of aflatoxins in LCA. There weren’t differences in the values of the nutritional composition, with increasing radiation dose. Irradiation combined with good storage conditions, was a reliable process for conservation of peanuts, because it prevents the growth of fungi, particularly *Aspergillus* aflatoxigenic, also avoiding the production and subsequent presence of aflatoxin in food, making it safer for consumption. The peanuts obtained from Petrolândia had moisture, ash, protein and carbohydrates levels statistically significant at 5%, while CEASA peanuts just had ash level significant when exposed to ionizing radiation.

Keywords: peanut, aflatoxigenic *Aspergillus*, aflatoxin, nutritional composition
1. INTRODUCTION

The peanut is a legume native from Americas, Central and South America, grown in tropical regions, subtropical and warm temperate, very important in the diet of humans and cattle. It is a major oilseeds cultivated in Brazil. This fact is due to its characteristics such as prolificacy, high forage productivity, high levels of crude protein and digestibility and excellent palatability, adaptability to a wide variety of environments, resistance to heavy grazing coupled with great competitiveness when combined with grasses [10, 11].

In the agro of the Brazilian Northeast, the peanut stands out because of its easy handling, short cycle and attractive price in the market, constitute an additional source of income and aggregative because the various forms of products that can be processed, and that encourage regional agribusiness[17].

Despite all the attractive features that encourage its cultivation, groundnut, like other legumes and other vegetables, is subject to various processes of biodegradation during planting, harvesting, transport and storage. Seeking to minimize the losses of various types of foods, using different conservation processes such as dehydration, salting, smoking, freeze drying, controlled atmosphere storage, sterilization, pasteurization and, ultimately, the gamma radiation [14].

Food irradiation is a preventive method and food security is a process where food already packaged or in bulk is subjected to a controlled amount of radiation aimed at the inhibition of sprouting, delayed maturation, reduced microbial load, elimination of microorganisms pathogens, sterilization, disinfection in grains, cereals, fruits and spices [15].

Sterilization using radiation provides a diet free of pathogens present on the surface or within the food due to poor hygiene or natural process of decomposition [15].

Due to improper storage of plant products, there are still losses of 20 to 80% of total production. Care in storage, mainly to control humidity and temperature, aid in the prevention of fungal diseases on peanut seeds, both for fresh consumption and for industrial products [12].

The development of filamentous fungi in food and feed can result in the production of toxins known as mycotoxins, which cause toxic response in vertebrates when ingested in low concentrations. Among the mycotoxins, can cite a group called aflatoxin. The human exposure to aflatoxins can occur via breathing, during harvest, track, bagging, cleaning, storage and processing of contaminated grains [12].

The presence of high levels of aflatoxins in peanuts and its derivatives has serious problems for Brazil. The removal of mycotoxins can be obtained using physical, chemical or biological strategies are based on physical or chemical inactivation of the toxin. Among the physical methods, one can cite the use of gamma radiation [19].

Aflatoxigenic Aspergillus is a fungi group that produces aflatoxins and includes some strains of Aspergillus flavus, Aspergillus parasiticus and, more rarely, Aspergillus
nomius. They develop favorably in environments with a relative humidity of 85% and ambient temperature of 27 °C [21].

This study aimed to evaluate the effects of gamma radiation on nutritional composition and inhibition of fungal growth in peanut, analyzing the dose that increases the shelf life without significant changes in its nutritional composition. To this end, we considered the following specific objectives: assessing the effects of gamma radiation doses employed and determine their influence on the nutritional composition of peanuts, evaluation of influence of the doses used in the inhibition of contamination of peanuts by Aspergillus aflatoxigenic; check the dose enable and inhibit fungal growth, while not changing the nutritional composition of peanuts.

2. METHODOLOGY

2.1 Collection and separation of samples

The peanuts were obtained from two origins: a) given by a small farmer from Petrolândia city, located in the interior of Pernambuco state, b) samples from São Paulo State and acquired in CEASA in Recife-PE (Food Supply Centre of Pernambuco), in July, 2010.

The peanuts were purchased without and within the pods, were wrapped in plastic wrap and properly identified with labels, which included: origin, dose, presence or absence of treatment with sodium hypochlorite and number of repetition. All tests were in triplicate.

The material was divided into two parts: the first with five packages with 200 grains of each location to perform the nutritional composition and the second part, about 5 packets of peanuts with pods and 5 packets of peanuts without pods of each place, for fungal analysis. Figure 1 shows the peanuts packed in PVC packaging.

![Figure 1: Peanuts with/without pods packaged and identified for the irradiation process.](image)

2.2 Experimental procedure
2.2.1 Peanuts irradiation

The packed samples were subjected to irradiation of cobalt-60 bomb, Gammacell 60Co source (model 220-MDS Nordion Excel), in the Department of Nuclear Energy – DEN-UFPE, using doses of 0 (control), 6, 9, 12 and 15 kGy, on November, 2010.

2.2.2 Analysis of aflatoxigenic Aspergillus.

For the analysis of fungal contamination, samples were separated in triplicate with and without beans, with and without disinfection by sodium hypochlorite 0.4%, according to the dose and origin of the sample. These tests were performed at the Laboratory of Microbiology and Immunology, Centro Acadêmico de Vitória-UFPE.

For each dose, 30 grains were analyzed. The procedure consisted of distribution of 10 grains in each petri dish, size 150x15mm, in culture medium DRBC (Agar Dichloran Rose Bengal Chloramphenicol) plus crystalline sodium amoxicillin (500 mg/L of medium), allowing only the growth of fungal peanuts.

Disinfection of some of the grains was made using sodium hypochlorite, 0.4% for 2 minutes before plating on DRBC. The plates were incubated at 25ºC, for 5 to 7 days, and then evaluated the rate of infection of grains by aflatoxigenic Aspergillus.

After a period of one week, from the fungal growth in the grains, in DRBC, fungi were carried out for CYA culture media (Yeast Czapeck medium agar) and PDA (Potato Dextrose Agar).

The aflatoxigenic Aspergillus isolated in PDA medium were transferred to the culture medium LCA (Coconut Milk Agar) to observe the production of fluorescence related to aflatoxin B or G (Green and Blue, respectively). The reading of the plates to show the production of aflatoxins in LCA was performed with a 365nm UV lamp.

After 7 months, samples of peanuts, with and without pods, which were packed and stored in a dry place during that time, and had not been distributed in culture medium DRBC, they were distributed in the culture medium AFPA (Aspergillus flavus and parasiticus Agar), where was observed a yellow / orange color only in aflatoxin-producing Aspergillus. For this analysis, it wasn’t used the treatment with hypochlorite, because the medium is specific to the growth of aflatoxigenic Aspergillus.

For each radiation dose, 30 peanuts (10 grains for each plate) were plated in culture medium AFPA, and taken to incubation at 25 °C, for 5 to 7 days, subject to the same scheme of distribution of grain in DRBC. It can be seen in figure 2.
The method DRBC, although the incubation time of five to seven days, allows better visualization of fungi from foods due to the following characteristics: Rose Bengal, which restricts the diameter of fungal colonies, allowing slow-growing colonies also develop, low pH, which inhibits the dispersal of fungi; dichloran, which helps in reducing the diameter of the colonies and chloramphenicol, an antibiotic that inhibits the growth of bacteria [8].

AFPA is a medium recommended for rapid detection and counting of A. flavus and A. parasiticus, which are potential producers of aflatoxin. This medium has advantages: improved production of color on the reverse of the plate due to the concentration of ferric citrate and the addition of yeast extract (the colonies of A. flavus and A. parasiticus develop an intense yellow / orange on the reverse of the colonies and it is a distinguishing feature of these species), growth rate improved from A. flavus due to the balance of peptone and yeast extract in addition to enhanced inhibition of bacteria and fungi growing fast due to a mixture of dichloran and chloramphenicol [6].

3.2.3 Nutritional composition

For the nutritional composition of peanuts, it took about 100g of the material used for each dose and control sample (non-irradiated). We analyzed the levels of protein, lipids, carbohydrates, minerals, moisture and total energy intake. The methodology for each test was based on the protocol of the Institute Adolfo Lutz (2005), except only the carbohydrate and total energy intake, which were made by calculation. The procedures were performed at the Laboratory of Food Analysis and Experimentation (LEAAL) Department of Nutrition, Federal University of Pernambuco-UFPE. The analytical methods were as follows:

3.2.3.1 Moisture content

The moisture content was measured by gravimetric method, based on the weight loss of samples submitted to heating at 105 °C to constant weight (method 985.14, A.O.A.C, 2000).

3.2.3.2 Lipid Fraction
The lipid fraction was obtained by the method of extraction of intermittent flow, using ethyl ether as solvent under reflux in Soxhlet apparatus (method 963.15, AOAC, 2000).

3.2.3.3 Total Protein

The determination of total protein was performed using the Kjeldahl method based on acid digestion of organic matter followed by distillation, nitrogen is then measured by titration. The nitrogen value is multiplied by the factor 6.25 (method 992.15; AOAC, 2000).

3.2.3.4 Ashes

To obtain the ash (ash) was used the gravimetric method, based on the determination of the weight loss of samples subjected to incineration at 550 °C (method 923.03; AOAC, 2000).

3.2.3.5 Total Carbohydrates

The carbohydrates were obtained by difference, by the sum of the contents of moisture, protein, ether extract and ash, subtracted from 100.

3.2.3.6 Total Caloric Value (V.C.T)

The total caloric value is obtained by calculating the values obtained involving proteins, lipids and carbohydrates from the following expression:

\[ VCT = (P \times 4) + (L \times 9) + (C \times 4) \]

Where: P = total protein, L = fat and C = carbohydrate. For 1g of protein equals 4 calories, 1g of fat equals 9kcal and 1g of carbohydrates equals 4kcal. Unit used: kcal

3 RESULTS AND DISCUSSION

3.1 Analysis of the presence of aflatoxigenic Aspergillus

In Table 1 there are infection rate about Aspergillus aflatoxigenic in DRBC, in samples of peanut irradiated with / without pods, with and without prior treatment with hypochlorite, for samples obtained from the CEASA and Petrolândia- PE.
Table 1: Infection percentage by aflatoxigenic *Aspergillus* in CEASA and Petrolândia peanuts, irradiated with/without pods and hypochlorite treatment, in DRBC.

<table>
<thead>
<tr>
<th>DOSE (kGy)</th>
<th>PODS</th>
<th>HYPOCLORITE (0,4%)</th>
<th>CEASA INFECTION (%)</th>
<th>PETROLÂNDIA INFECTION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N</td>
<td>n</td>
<td>23,3</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>N</td>
<td>y</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>0</td>
<td>Y</td>
<td>n</td>
<td>23,3</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>Y</td>
<td>y</td>
<td>13,3</td>
<td>0</td>
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<tr>
<td>6</td>
<td>N</td>
<td>n</td>
<td>0</td>
<td>0</td>
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<tr>
<td>6</td>
<td>N</td>
<td>y</td>
<td>0</td>
<td>0</td>
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<tr>
<td>6</td>
<td>Y</td>
<td>n</td>
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<td>0</td>
</tr>
<tr>
<td>6</td>
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<td>Y</td>
<td>3,3</td>
<td>0</td>
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<td>9</td>
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<td>n</td>
<td>13,3</td>
<td>0</td>
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<tr>
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<td>y</td>
<td>6,6</td>
<td>0</td>
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<td>Y</td>
<td>n</td>
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<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Y</td>
<td>16,6</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>N</td>
<td>n</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>N</td>
<td>y</td>
<td>13,3</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>n</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>y</td>
<td>0</td>
<td>0</td>
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<tr>
<td>15</td>
<td>N</td>
<td>n</td>
<td>0</td>
<td>0</td>
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<tr>
<td>15</td>
<td>N</td>
<td>y</td>
<td>0</td>
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<td>Y</td>
<td>n</td>
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<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>y</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Legend: N: without pods; Y: with pods. n: without hypochlorite; y: with hypochlorite

It was noted that non-irradiated samples showed growth of aflatoxigenic *Aspergillus* surveyed in CEASA and Petrolândia. However, samples of CEASA had the highest infection percentage, not only with peanut subjected to irradiation, but also for those samples subjected to doses of 6, 9 and 12 kGy. Comparing these results with those obtained directly from a producer from Petrolândia-PE, transport and/or storage conditions in samples from Sao Paulo, and bought in the CEASA-PE, may not have obeyed the ideal conditions.

It was observed that, mostly, treatment with hypochlorite was effective in reducing the infection by aflatoxigenic *Aspergillus* in peanuts that was in the DRBC.

The results presented on samples from CEASA-PE showed that radiation was effective in controlling the action of aflatoxigenic *Aspergillus* only to the dose of 12 kGy, in peanuts that were in the pod. This indicates that the pod can have protective action against the colonization of fungi. The radiation could also inhibit the germination of seeds (Figure 3).
Radiation inhibited the growth of fungi in all irradiated samples from Petrolândia-PE. Infection percentage by aflatoxigenic *Aspergillus* in samples obtained of Petrolândia-PE were 13% (without hypochlorite) and 6% (with hypochlorite), only in non-irradiated peanuts. As the samples were obtained directly from a farmer, did not undergo the same conditions of transport and storage of those samples obtained from CEASA-PE. The presented data showed that the ideal conditions for transportation and storage along ionizing radiation can prevent the spread of aflatoxigenic *Aspergillus*.

According to the study by Alves et al. (2011), not-irradiated groundnut seeds had 60% germination in braided polyethylene storage, and loss of germination increased with increasing dose of irradiation, except for a dose of 0.5 kGy for this type of packaging. There was a strong reduction in the germination of seeds from the dose of 2.5 kGy. They claim that low doses of radiation have the ability to stimulate biosystems, reversing the effect with increasing dose, which may explain the result of increased germination for the irradiation of 0.5 kGy (theory called Hormesis). In this study, all not-irradiated peanuts, from CEASA or Petrolândia, showed germination.

Santos et al. (2010) submitted peanut seeds, variety Havana, to various doses of irradiation and concluded that treatment with gamma radiation adversely affected the vigor and germination of peanut doses of 0.5 and 1.5 kGy resulted in loss germination, the dose of 3 kGy prevented the use of seeds for planting and doses above 12 kGy totally committed vigor and seed germination. In this study, from 6 kGy had complete inhibition of germination of grains from Petrolândia and CEASA.

Prado et al. (2006), analyzing irradiated peanuts, beans irradiated realized that there was disinfected and a reduction of fungal infection at 5 kGy and the total destruction of fungi and 10 kGy, after 180 days storage at room temperature. In grains irradiated and not externally disinfected with hypochlorite were determined in function of storage time, the population of fungi increased with the dose of 1 kGy, a reduction in the dose of 5 kGy and total elimination by applying 10 kGy; different which was observed in this study, in which the doses were more effective 12kGy (with pods) and 15kGy (with / without pods) for peanuts CEASA.
In both samples, other fungi were found in small quantities due to contamination by air or from the pods, and isolated in PDA medium and CYA: *Trichoderma, Penicillium, Cladosporium, Rhizopus, Aspergillus niger*.

Gonçalez (2008) conducted a study in Junqueirópolis-SP, demonstrating that the presence of *A. flavus* in the soil of the planting site contributed to aflatoxin contamination in peanut shells on the ripe fruit before the harvest. He reported that the main fungi isolated peanut pods were *Fusarium spp.* (78.75%), *Rhizopus ssp.* (14.1%) and *A. flavus* (11.75%), *A. niger* (2.5%), *Trichoderma spp.* (0.8%), *Penicillium spp.* (0.7%). The results found by him is very close to the results observed in this study. The peanut pods are used for making poultry litter, dairy and cattle feed as a source of fiber for ruminants, so study the mechanisms of toxigenic fungal contamination from the shells is important in developing preventive measures.

### 3.2 Analysis of aflatoxin production in the LCA

The sample that produced fluorescence in the middle LCA, aflatoxin production, was only the nont-irradiated sample, obtained from the CEASA-PE, unshelled, treatment with hypochlorite. All other *Aspergillus* isolates showed no fluorescence, indicating that almost 100% of the isolates are not toxigenic.

The LCA provides means better conditions for growth of aflatoxigenic *Aspergillus* due to the availability of protein, carbohydrates predominantly sucrose, lipids, fiber and ash in milk, coconut, besides expressing medium and high fluorescence intensity after 48 hours of incubation [4]. But it also means that only indicates presence or absence of aflatoxin, it is not possible to quantify.

Mallmann et al (2003), analyzing 664 samples of peanuts, using chromatography, found that 31.33% of the samples sold in Rio Grande do Sul were contaminated with aflatoxins. Of these, 47.1% were contaminated above the level permitted by legislation (20 mg / kg), and most of these samples came from informal producers who marketed their product without supervision.

### 3.3 Analysis of aflatoxin production through AFPA

In Petrolândia samples, we observed that the gamma radiation inhibited the growth of fungi in all irradiated samples and showed a low rate of infection by Aspergillus aflatoxigenic in non-irradiated samples, shelled or unshelled, 20% the average rate of infection. The data are presented in Table 2.
Table 2: Infection rate by aflatoxigenic *Aspergillus* in AFPA of peanuts obtained from Petrolândia-PE.

<table>
<thead>
<tr>
<th>DOSE (kGy)</th>
<th>VAGEM</th>
<th>INFECTION (%)</th>
<th>Others fungi(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N</td>
<td>13,3</td>
<td>30</td>
</tr>
<tr>
<td>0</td>
<td>Y</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Legend: N: without pods ; Y: with pods.

In samples of CEASA, the infection rate for aflatoxigenic *Aspergillus* was 43.3% and 40%, respectively, for peanuts not-irradiated, with/without pods, 3.0% for the dose of 6 kGy and 5.0% for 15kGy, according to Table 3.

Table 3: Infection rate by aflatoxigenic *Aspergillus* in AFPA of peanuts obtained from the CEASA-PE.

<table>
<thead>
<tr>
<th>DOSE (kGy)</th>
<th>PODS</th>
<th>INFECTION (%)</th>
<th>Others fungi(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N</td>
<td>43,3</td>
<td>30</td>
</tr>
<tr>
<td>0</td>
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<td>40</td>
<td>30</td>
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<tr>
<td>6</td>
<td>N</td>
<td>6,6</td>
<td>10</td>
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<td>0</td>
<td>27</td>
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<tr>
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<td>N</td>
<td>0</td>
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<td>12</td>
<td>Y</td>
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</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

Legend: N: without pods ; Y: with pods.

We also observed the growth of *Aspergillus niger* and other fungi in not-irradiated samples from Petrolândia and CEASA.
In Figure 4 there is a not-irradiated sample (A and B), which is quite evident orange color aflatoxigenic *Aspergillus* and difference for the fungus *Aspergillus niger* which has a different color in front of the plate (black) and no orange coloring on the reverse of the plate. This result shows that the differential staining using the AFPA greatly facilitates the identification, isolation and calculating infection percentage by aflatoxigenic *Aspergillus*.

![Figure 4: A, B: Not-irradiated peanut sample in AFPA, showing aflatoxigenic Aspergillus isolation in front and reverse of plate. C: Peanuts, seven months after irradiation at dose of 9kGy.](image)

### 3.4 Nutritional composition of peanuts.

In the following figures, graphs can be observed separately, allowing a more focused comparison between the sample in CEASA and Petrolândia. Probably the varieties of peanuts are different for the two origins, soil characteristics which were collected after harvesting and storage may have influenced the amount of nutrients.

According to Campbell et al, (2011), the fatty acid composition in peanut grains varies among cultivars, and the relationship between oleic and linoleic acids determines the shelf life of peanuts or products containing peanuts in its composition.

Studies on the effects of ionizing radiation in macronutrients (carbohydrates, lipids and proteins) showed no significant variations in doses up to 10 kGy. Among micronutrients, essential amino acids, essential fatty acids, minerals and most vitamins are not affected under normal conditions of irradiation. Few vitamins such as B1 and E are partially decomposed. To minimize losses of these vitamins, you should decrease the concentration of oxygen during irradiation and storage by using vacuum packaging and nitrogen atmosphere [15].

It was used the Mann-Whitney-Wilcoxon statistical test to the results of the nutritional composition. It is an appropriate nonparametric test that compares the means of two samples, requiring only that they are independent and random, and that the variables are ordinal or numerical.
The moisture content of CEASA had a minimum value of 2.76 g/100g (12kGy) and maximum value of 3.12 g/100g (9kGy). While peanuts from Petrolândia the minimum value was 3.14 g/100g (12kGy) and the maximum value was 3.48 g/100g (not-irradiated). The variable moisture from CEASA did not change significantly at 5% level, but the sample from Petrolândia was significant.

The moisture content of peanuts obtained of Petrolândia showed a slight decrease from the control sample until the highest dose. As the sample obtained from CEASA, values increased at 9kGy, but those are below the value of control in other doses, can be seen in Figure 5. The values found in this study corroborate the study by Alves et al (2011), who said that for the factors dose and packaging the influence of moisture was small compared with the time being due probably to these variations, like relative humidity and temperature during storage.

Moisture is of great economic importance as it reflects the content of a solid product and its perishability. When outside of the technical recommendation, it results in losses in the chemical stability, deterioration in the microbiological, physiological changes (sprouting) and overall quality of food [20].
The ash content of CEASA had a minimum value of 2.51 g / 100g (unirradiated) and maximum value of 2.63 g/100g (15kGy). While peanuts from Petrolândia the minimum value was 2.67 g/100g (not-irradiated) and the maximum value was 2.75 g/100g (15 kGy). The variable ash from CEASA and Petrolândia changes significantly at 5% level.

With regard to ash content, peanuts from Petrolândia showed higher values than values found for CEASA peanuts. Despite showed the lowest ash content in the sample is irradiated, yet in the material from Petrolândia the lowest value exceeds the maximum value reached by CEASA peanut.

The protein content of CEASA peanuts had a minimum value of 31.09 g/100g (6 kGy) and maximum value of 31.82g/100g (12kGy). Petrolândia peanuts have as minimum value 31,66 g (not-irradiated) and maximum value was 33,01 g (15 kGy). The variable protein from CEASA did not change significantly at 5% level, but the sample from Petrolândia was significant.

For the protein, non-irradiated peanuts from Petrolândia had values equal to the CEASA. However, it can be observed that all samples from Petrolândia submitted to gamma radiation had higher values than the control, exceeding the values of CEASA enough at all doses, as seen in Figure 7.
The lipid content of CEASA had a minimum value of 42.25 g/100g (12 kGy) and maximum value of 45.29 g (9 kGy); while Petrolândia peanuts the minimum value was 43.49 g/100g (6 kGy) and the maximum value was 45.57 g/100g (15 kGy). The variable lipids from CEASA and Petrolândia did not change significantly at 5% level.

The values obtained for the lipid content from Petrolândia were higher than the values found for the sample of CEASA; the only exception is in the dose of 6 kGy. At the doses 9 and 15 kGy of peanuts from Petrolândia lipid levels have approximately 45 g/100g in excess of the not-irradiated sample, and overcoming all the values found in peanuts CEASA, as shown in Figure 8.

When comparing the peanut cultivars IAC Tatu ST-886 and IAC-Runner subjected to gamma radiation, Campbell et al (2011) concluded that irradiation altered the fatty acid profile, while the percentage of saturated fatty acids, increased the percentage of fatty unsaturated fatty acids and increased the percentage of linoleic acid (precursor of fatty acids of very long chain) that operate in the development and functioning of the brain and retina. Therefore the increase in lipid content caused by radiation can be considered beneficial.
The carbohydrate content of CEASA had a minimum value of 17.31 g/100g (9 kGy) and maximum value of 20.52 g/100g (12 kGy). While peanuts from Petrolândia the minimum value was 15.52 g/100g (15 kGy) and maximum value was 17.51 g/100g (6 kGy). The variable carbohydrate from CEASA did not change significantly at 5% level, but the sample from Petrolândia was significant.

About carbohydrates, CEASA peanuts showed higher values than Petrolândia peanuts, but the range of values with increasing doses was very similar, as shown in Figure 9. CEASA not-irradiated sample and doses of 6 and 15 kGy showed values very close. While all irradiated peanuts in Petrolândia had lower values than the control value (not irradiated). Thus, the radiation produced decreased carbohydrate content in the samples only from Petrolândia.

The total caloric value of CEASA peanuts had the minimum value of 589.61 kcal (12kGy) and maximum value of 603.09 kcal (9kGy). While Petrolândia peanuts the minimum value was 593.01 kcal (6kGy) and the maximum value was 604.25 kcal (15 kGy). The variable total caloric value from CEASA and Petrolândia did not change significantly at 5% level.

In peanuts from CEASA, the total caloric value was gradually increasing to reach maximum value at a dose of 9kGy, and it is near the control value at the highest dose. For Petrolândia peanuts the total caloric value has higher values at doses of 9 and 15 kGy. Peanuts from CEASA and Petrolândia had values of approximately 603 kcal at a dose of 9kGy.

In some studies was proved that changes induced by ionizing radiation are so small, so that was not enough to change the nutritional composition of peanut samples.

4. CONCLUSION

The control samples showed high rates of budding and fungal growth, either of Aspergillus or fungi of pods and air.
The samples submitted to radiation showed no budding, but at lower doses some samples showed growth of other fungi.

Doses 9, 12 and 15 kGy are effective to prevent infestation by aflatoxigenic Aspergillus (A. flavus and A. parasiticus), but may not prevent contamination by other fungi from the pod.

When carried in pods, peanuts have a higher resistance to the action of fungi.

Irradiation combined with good storage conditions, proved to be a reliable process for conservation of peanuts, because it prevents the growth of fungi, particularly aflatoxigenic Aspergillus.

The peanuts obtained from Petrolândia had moisture, ash, protein and carbohydrate levels statistically significant at 5%, while CEASA peanuts just had ash level significant when exposed to ionizing radiation.

5. REFERENCES


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