ELECTRON BEAM IRRADIATION EFFECTS ON SOME PACKAGED DRIED FOOD ITEMS

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Abstract. This work describes the application of electron beam irradiation on some food items used in sport training diets: fiber rich cookies, fruit cereal bars, instant dehydrated asparagus soup and instant Brazilian corn pudding. Each kind of sample contained 3 groups of 15 units each. Irradiation was performed with an electron beam accelerator Dynamitron (Radiation Dynamics Inc.) model JOB 188, with doses of 5 and 10kGy. For the evaluation of irradiated samples a methodology based on the Analytical Norms of the Instituto Adolfo Lutz, one of the South American Reference Laboratories was employed. The microbiological and sensory analyses of the diverse irradiated samples are presented. Electron beam irradiation resulted in significant reduction of the fungus and yeast load but caused differences on sensory characteristics. A careful dose choice and special irradiation conditions must be used in order to achieve sensory requirements needed for the commercialization of these irradiated food items.

1. Introduction

The capability of electron beam ionizing irradiation to decontaminate organic and inorganic materials is well established. Spacecraft components and materials for planetary protection are decontaminated efficiently by electron beam ionizing irradiation [1]. Also, electron beam radiation is used for the suppression of microbe contaminants and the sterilization of peat [2].
Food pasteurization using electrical irradiation is the wave of the future for shelf-life preservation and food safety as suggested by some authors [3][4]. The challenges of feedings astronauts during space missions can be accomplished with the aid of some food irradiated to commercial stability all ambient-temperature shelf-stable for 12-18 months [5].
For radical sports practitioners, small nutritious snack foods are needed. At the same time, food preparation must guarantee long shelf life and be compact or lightweight for easiness of carrying. Commercial individually packaged foods can be used either for sports practitioners like adventure racing or eventually as military rations. Irradiation processing of foods is an important preservation technology. High-voltage electron beams generated from linear accelerators are an alternative to radioisotope generators as they require much shorter exposure times (seconds vs. hours for gamma irradiation) to be effective and are currently used to pasteurize meat products among others food items.

This work describes the application of electron beam irradiation on some food items used in sport training diets. The results of microbiological and sensory analyses of the diverse irradiated samples are presented.

2. Material and Methods

2.1. Material

Four samples were employed: fiber rich cookies. fruit cereal bars, instant dehydrated asparagus soup and instant Brazilian corn pudding usually used as alternative military rations or sport training diets. The fiber rich cookies were packaged individually in polypropylene film, weighting 15g ±10% with 1.5% humidity, 3% mineral residue and 10% fiber. Fruit cereal bars were packaged individually in metalized bi-oriented polypropylene film, weighting around 25g, containing dehydrated banana, crisp cereal, rice and maize flour, malt extract with 10% humidity and 2% mineral residue. Instant dehydrated asparagus soup pouches contained cereals and vegetables, flour, powder milk with 10% humidity, 3% protein, 4% fat, 60% carbohydrates and 12% mineral salts. Instant Brazilian corn pudding samples weighting around 25g were packaged in aluminum pouches contained powder milk, sugar, maize flour with 2% humidity.
Each one of the 4 samples was divided in 3 groups (0, 5 and 10kGy) of 15 units. The samples were evaluated within the 1st, 3th and 6th month after irradiation.

2.2. Electron beam Irradiation

Samples were irradiated using an EB accelerator Dynamitron (Radiation Dynamics Inc.) model JOB 188 with doses of 5 and 10kGy, track speed 3.36 m. min^{-1}. Fiber rich cookies and fruit cereal bars were irradiated both sides. According to the density and thickness of the diverse samples (Table I) different energy and current were applied (Table II). Perspex Harwell Amber dosimeter were placed in the same tray.

TABLE I. DENSITY AND THICKNESS OF THE SAMPLES

Sample	**Calculated density** (g/cm^3)	**Thickness** (cm)
Fiber rich cookies	0.486	1.51
Fruit cereal bars	0.816	1.32
Dehydrated asparagus soup	0.744	0.30
Instant Brazilian corn pudding	0.802	0.38

TABLE II. ELECTRON BEAM ENERGY AND CURRENT EMPLOYED

Sample	**Energy** MeV	**Current** mA
Fiber rich cookies	1.119	2.4
Fruit cereal bars	1.449	2.8
Dehydrated asparagus soup	0.994	2.2
Instant Brazilian corn pudding	1.198	2.5

2.3. Microbial analyses

To determine the microbiological profile conventional methods of plating and Most Probable Number (MPN) by the multiple tubes technique were used following the Norms of the Brazilian Instituto Adolfo Lutz, a regional reference laboratory and according also to the American Public Health Association [6]. Yeast and moulds, total coliforms, fecal coliforms, *Bacillus cereus* and *Staphilococcus aureus* were assayed. In none of the samples fecal coliforms, *Bacillus cereus* or *Staphilococcus aureus* were present.

2.4. Sensory evaluation

Sensory acceptability of a control (non-irradiated) samples and two irradiated ones (5 and 10kGy) was determined (n = 48). The Control Difference overall test [7] included sensory characteristics for appearance, aroma, texture and flavor attributes.

3. Results and Discussion

The prepackaged food items treated with doses of 5 and 10kGy of electron beam (EB) radiation showed decreased microbiological populations as shown in Tables III, IV, V and VI for packaged fiber rich cookies, packaged fruit cereal bars, packaged dehydrated asparagus soup and packaged irradiated Brazilian corn pudding respectively.

TABLE III. MICROBIOLOGICAL CHARACTERISTICS OF IRRADIATED PACKAGED FIBER RICH COOKIES

Time (months)	**Radiation dose** 0kGy	5kGy	10kGy
0	Yeast and moulds count: 10/g Total *E.coli:* Non-Detectable	<10/g ND	<10/g ND
3	Yeast and moulds count: <10/g Total *E.coli*: ND	<10/g ND	<10/g ND
6	Yeast and moulds count: <10/g Total *E.coli:* ND	<10/g ND	<10/g ND

The dried food items analyzed in this work were containing in the manufacturer original polypropylene films. Polypropylene is the most common commercial polymer of good mechanical and thermal properties however conventionally stabilized polypropylene is degradable upon radiation processing at dose about 25 kGy. There are, however, several techniques in the design of propylene polymers and their formulations that remedy these problems [8]. All irradiated samples presented an expected decrease of microbiological counts for yeast and moulds and total coliforms. As no further contamination occurred, it can be said that the packaging of all the irradiated samples endured the processing up to the time of analysis, 6 months after EB irradiation.

TABLE IV. MICROBIOLOGICAL CHARACTERISTICS OF IRRADIATED PACKAGED FRUIT CEREAL BARS

Time (months)	**Radiation dose** 0kGy	5kGy	10kGy
0	Yeast and moulds count: 10/g Total *E.coli:* ND	<10/g ND	<10/g ND
3	Yeast and moulds count: <10/g Total *E.coli:* ND	<10/g ND	<10/g ND
6	Yeast and moulds count: 20/g Total *E.coli*: ND	<10/g ND	<10/g ND

TABLE V. MICROBIOLOGICAL CHARACTERISTICS OF IRRADIATED PACKAGED DEHYDRATED ASPARGUS SOUP

Time (months)	**Radiation dose** 0kGy	5kGy	10kGy
0	Yeast and moulds count: $6.5x10^2$/g Total *E.coli* (MPN): 43/g	<10/g ND	<10/g ND
3	Yeast and moulds count: $6.5x10^2$/g Total *E.coli* (MPN): 50/g	50/g ND	<10/g ND
6	Yeast and moulds count: $1.7x10^2$/g Total *E.coli* (MPN): 23/g	<10/g ND	<10/g ND

TABLE VI. MICROBIOLOGICAL CHARACTERISTICS OF IRRADIATED PACKAGED BRAZILIAN CORN PUDDING

Time	**Radiation dose**		
(months)	0kGy	5kGy	10kGy
0	Yeast and moulds count: <10/g Total *E.coli* : ND	<10/g ND	<10/g ND
3	Yeast and moulds count: 30/g Total *E.coli* : ND	<10/g ND	<10/g ND
6	Yeast and moulds count: 10/g Total *E.coli* : ND	<10/g ND	<10/g ND

Sensory evaluation of irradiated samples indicated that irradiation impacted aroma and flavor attributes. Testers were invited to express a judgment of pleasantness ranging from '1 Dislike Very Much' to '5. Like Very Much' to indicate their preference. The non-irradiated samples scored 4 and 5. The whole panel gave low scores to irradiated products about aroma and flavor. Texture and appearance remained as those of the unirradiated ones.

Some authors [9] studied the radiosensitivity of the most common pathogens and some non-pathogens encountered in fruits. Three pathogens: *Escherichia coli* O157:H7 933, *Listeria monocytogenes* ATCC 51414, and *Salmonella Poona* were inoculated into model food systems (10% w/w gelatin) and exposed to doses up to 1.0 kGy using a 2 MeV Van der Graaf linear accelerator. *L. monocytogenes* was the more radiation-resistant pathogen (D_{10}= 1.09 kGy) and a non-pathogen *E. coli* K-12 MG1655 could be a suitable surrogate for e-beam studies with *L. monocytogenes* as the indicator pathogen, as the surrogate was still more radiation-resistant and could therefore be used to indicate decontamination of the target pathogens under EB irradiation. Other researchers [10] describe the elimination of *L. monocytogenes* of vacuum-packed dry-cured ham by EB irradiation and samples treated with up to 4kGy were deemed sensory acceptable for trading. .

Recent work describes the inactivation by EB irradiation of several microorganisms in foods. Hong et al. [11] found that *E. sakazakii*, *B. cereus*, and *S. typhimurium* evaluated in powdered weaning food were eliminated by irradiation at 16, 8, and 8 kGy, respectively. The D_{10}-values of *E. sakazakii, B. cereus,* and *S. typhimurium* inoculated on powdered weaning food were 4.83, 1.22, and 0.98 kGy, respectively.

Gomes et al. [12] established that EB irradiation of fresh broccoli with doses up to 3kGy maintained the overall quality of the product. Johnson & Resurreccion [13] found that even a 3kGy dose of EB irradiation affected sensory profiling of poultry frankfurters except texture.

Han et al. [14] demonstrated that EB irradiation serves as a controlling factor for release of active compounds, with potential applications in the development of antimicrobial packaging systems.

Zhu et al. [15] showed that the use of antimicrobial additives combined with 1.0 or 2.0 kGy EB irradiation are a promising technology for the control of *L. monocytogenes* in ready-to-eat turkey breast rolls, considering the microbial safety and sensory characteristics. Sanchez-Bel et al [16] studied almonds after treatment with accelerated electrons at doses of 3, 7, and 10 kGy, during a storage period of 5 months. In the sensory analysis, the tasters did not find sensory differences between the controls and those irradiated at doses of 3 or 7 kGy, whereas almonds irradiated at 10 kGy exhibited a rancid flavor and a significant decrease in general quality.

In the area of food technology it is essential that product sensory quality be monitored to fall within acceptable ranges based on consumer perceptions of product quality. In the present work, irradiation produced changes in product identity; all irradiated samples were significantly different in overall acceptability in terms of taste and odor but not in texture, with no significant differences between the ratings of the two doses.

As part of good manufacturing practice, manufacturers must always consider the effects of changes in their manufacturing processes, as it is responsibility of the packaging suppliers to obtain approval for their materials and ensure that any treatment, including irradiation, does not harm the suitability of the packaging material.

4. Conclusions

Electron beam irradiation in dose of 5 and 10kGy was able to decrease or eliminate microbiological risks when applied on packaged fiber rich cookies. fruit cereal bars, instant dehydrated asparagus soup and instant Brazilian corn pudding. The microflora of these irradiated packaged dried food items was always extremely low or below the detection limit. On the other hand, mean sensory ratings for all irradiated samples were considered ‘non-acceptable’. Packaging of the irradiated samples endured the processing as no posterior contamination was found up to 6 months. Further studies are required to determine the irradiation optimum conditions to permit the application of this treatment with full consumer acceptability.

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