SURFACE TREATMENT OF SPECIAL HIGH-PROTEIN PRODUCTS USING LOW ENERGY BEAMS FROM MACHINE SOURCES

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Abstract

Special high-protein foods suitable for diabetics must be treated in such a way as to ensure the complete absence of microorganisms and bacteria. It is also important that this treatment does not change the nutritional value of the product. Among new decontamination technologies, low-energy e-beam (LEEB) treatment has proven to be an effective inactivation of bacteria with minimal impact on food quality. The aim of the paper is to analyse the influence of LEEB on microbiological properties and nutritional values of high-protein foods.

1. INTRODUCTION

According to the Serbian Diabetes Registry, over 710,000 people in Serbia suffer from this disease. They need a special diet, with the lowest possible carbohydrate content. It is well known that proper and healthy food is a prerequisite for good health.

In cooperation with a local food company, we have developed high-energy products that would be ideal for diabetics, athletes, individuals on a particular diet and anyone who cares about health. Some examples of developed high-protein products are original protein evening bread, protein burgers, protein crackers, protein chips, protein biscuits, cocoa cream with no added sugars, protein bagels and scones, protein tortillas and pancakes, protein drinks. These products are innovative because they do not use traditional raw materials, but specially designed high-protein, whey. All the products are sugar-free.

Firstly, the products were treated with gamma radiation, which guarantees the absolute absence of all microorganisms and harmful substances in said products, and significantly extends the shelf-life span. Nevertheless, it has been determined that treatment with ionizing radiation can affect the change in the nutritional values of the product. To avoid changes in nutritional value after irradiation, low energy electron beam (LEEB) was used for preservation of high-protein products. Recent developments in LEEB technology have revolutionized aseptic packaging. Advancements in electron beam technology are shrinking the footprint of the devices used to generate ionizing radiation. With the relatively recent development of reliable, compact, cost-effective, LEEBs, a new class of in-line applications is now possible. The benefits of high-speed, high efficacy treatments, with no chemicals and at room temperature, are now realized across a variety of packaging applications. Such developments are also attractive to the food industry.

The aim of the paper is to analyse the influence of LEEB on the physical and chemical parameters of the preservation of high-protein foods suitable for diabetics.

2. MATERIALS AND METHODS

2.1. Gamma irradiation

Irradiation was performed with gamma rays in a Radiation facility for industrial sterilization and conservation at the Vinca Institute of Nuclear Sciences in Belgrade. Radiation doses of 1 kGy, 3 kGy, 5 kGy, 7 kGy, and 10 kGy were used. The average irradiation dose rate was about 10 kGy·h^{-1}. The delivered radiation dose's accuracy is controlled using the ECB/oscilloscope dosimetric system. The measurement of the absorbed radiation dose was performed at 20°C.

2.2. LEEB irradiation

For irradiation of protein product samples with low energy e-beam, Laatu machine from producer Buhler Croup, was used. Laatu offers a chemical-free solution with reduced running costs thanks to its low energy consumption and minimal or no product waste. In Table 1 is shown specification of the Laatu e-beam. Irradiation dose was 10 kGy.

TABLE 1. TECHNICAL SPECIFICATIONS OF LAATU

Voltage	Voltage With supply frequency 50 Hz: 400Y/230 VAC With supply frequency 60 Hz: 400Y/230 VAC + 460 VAC
Power ≤30	≤30 kW
Product throughput (product dependent)	up to 1,000 kg/h
Air exhaust (depending on installation)	up to 8,100 m3
Ambient temperature	+5 ... +40 °C
Relative humidity, non-condensing (during operation)	10 ... 70 %

2.3. Microbiological analysis

In the accredited microbiology laboratory, the initial contamination and the number of microorganisms, total molds, and bacteria in the samples were examined. The method used to determine these parameters was Ph. Eur. 7.0 (2.6.12. – microbiological examination of nonsterile products (total viable aerobic count), and 2.6.13. – Microbiological examination of non-sterile products (total viable aerobic count)) [1]. Microbiological analyses were performed before irradiation and after gamma irradiation with different radiation doses. The used diluent (buffered peptone water) and nutrient media for the development of microorganisms (tryptone soy agar, Rose Bengal agar, iron sulfide agar) are following international standard ISO 11737-1: 2018 [2].

2.4. Nutritional properties

The samples of high protein products were analyzed to determine their content of total fat, protein, carbohydrates, sugars, and dietary fiber after gamma irradiation. These analyses were performed before irradiation and after gamma irradiation with the highest used radiation dose of 10 kGy.

2.4.1. Determination of total fat content

Determination of total fat content in the high protein products samples is performed by Weibull-Stoldt - Standard application [3]. The sample is hydrolyzed using the Hydrolysis Unit E-416. The Soxhlet extraction is performed with the Extraction Unit E-816. The calculation of the samples' total fat is realized by the gravimetric method after the extract has dried to reach permanent weight. This application is in accordance with official methods (EN 98/64/EG, AOAC 963.15, §64 /§35 06.00-6).

2.4.2. Determination of carbohydrates and sugars content

Determination of total carbohydrate and sugars present in high protein products were performed using phenol sulphuric acid method [4]. This method is often used to determine the carbohydrate content of food [5]. The method is based on dehydration of glucose to hydroxymethyl furfural in a hot acidic medium. A yellow product with phenol is formed, which has a maximum absorption at 490 nm [6, 7].

2.4.3. Determination of dietary fiber

An enzymatic-gravimetric method was used to determine the content of dietary fiber in high protein products samples. The samples were first degreased and then treated with enzymes that mimic the process of digestion in the human small intestine. Digestible carbohydrates are then broken down into simple sugars, which are removed by precipitation and filtration. After that, only dietary fiber remains in the sample.

2.4.4. Determination of protein in h high protein products

Protein content before and after irradiation was determined using a standard ISO procedure, ISO 1871:2009 [8]. This standard provides general guidelines for the determination of nitrogen by the Kjeldahl method. The standard applies to food and feed products containing nitrogen compounds that can be directly determined by the Kjeldahl method [9].

3. RESULTS AND DISCUSSION

3.1. Effects of gamma irradiation on microbiological properties

To eliminate microorganisms, total molds, and bacteria from special high-protein products, samples were treated with the different doses of gamma irradiation, from 1 kGy to 10 kGy. Table 2 shows the microbiological results after treatment with different radiation doses.

TABLE 2. TOTAL NUMBER OF MICROORGANISMS, THE TOTAL NUMBER OF MOLDS AND DIFFERENT BACTERIA BEFORE AND AFTER THE INFLUENCE OF DIFFERENT DOSES OF GAMMA IRRADIATION.

Parameter	Dose (kGy)						Permissible value
	0	1	3	5	7	10	
Total number of microorganisms (cfu·g^{-1})	$5.6\cdot10^{7}$	$2.5\cdot10^{7}$	$4\cdot10^{4}$	$2\cdot10^{3}$	<1000	<1000	<1000
Total number of mold (cfu·g^{-1})	$5.4\cdot10^{4}$	$3.5\cdot10^{4}$	$5.6\cdot10^{3}$	130	<100	<100	<100
Salmonella sp. (cfu·g^{-1})	not present	not present	not present	not present	not present	not present	must not contain
E.coli (cfu·g^{-1})	350	300	20	not present	not present	not present	must not contain
Staphylococcus aureus (cfu·g^{-1})	150	90	15	not present	not present	not present	must not contain
Pseudomonas aeruginosa (cfu·g^{-1})	not present	not present	not present	not present	not present	not present	must not contain
Bacillus cereus (cfu·g^{-1})	5500	2100	300	<100	<100	<100	<100
Sulfitoreducing clostridia(cfu·g^{-1})	10	not present	not present	not present	not present	not present	must not contain

From Table 2, one can see that the radiation dose of 7 kGy is enough to eliminate the total number of microorganisms and molds below the permitted limit. On the other hand, a treatment of 3 kGy is enough to remove all bacteria from the sample.

3.2. Effect of gamma irradiation on nutritional values of samples

To determine if gamma irradiation treatment affects the samples' nutritional properties, analysis of the nutritional values in the non-irradiated sample and the sample irradiated with the highest used dose of 10 kGy were performed. The data are shown in Table 3.

TABLE 3. NUTRITIONAL VALUES OF SAMPLES BEFORE IRRADIATION AND AFTER 10 KGY IRRADIATION

Parameter	Non-irradiated	Irradiated with a dose of 10 kGy	Measurement error
Total fat, %	14.5	9.2	3.0 %
Carbohydrate, %	31.3	32.0	5.8 %
Sugars, %	3.9	4.0	5.8 %
Dietary Fiber, %	17.9	18.0	2.5%
Protein, %	40.0	41.3	4.0 %

From Table 3, It has been determined that treatment with ionizing radiation can affect the change in the nutritional values of the product. Decrease in fat content could be due the action of high energy radiation on lipid molecules causing lipid peroxidation The biggest problem is that the proportion of carbohydrates increases, and the proportion of protein decreases after exposure to gamma radiation at a dose rate of 10 kGy/h. Increase in carbohydrate content was due to breakdown of oligosaccharides when samples were irradiated.
Decrease in protein content with gradually higher irradiation dose is because of high rate of metabolic activities.
Fig 1. shows the changes in the nutritional value of the product “Protein evening bread” depending on the radiation dose to which the samples were exposed.

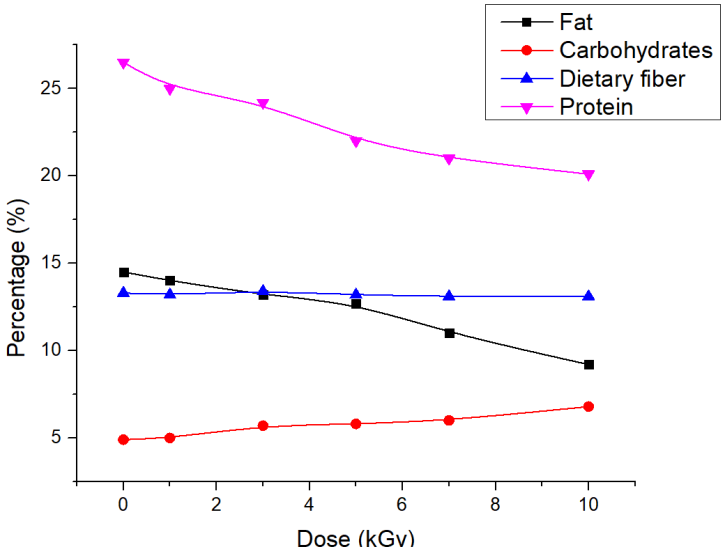

FIG 1. Changes in the nutritional value of the product “Protein evening bread” depending on the radiation dose of gamma irradiation

3.3. Effect of LEEB irradiation on microbiological properties and nutritional values of samples

To avoid changes in nutritional value after irradiation, LEEB was used for preservation of high-protein products. The use of low energy electrons has advantages over the use of gamma-rays or higher energy electrons for the direct irradiation of food. These advantages arise from details of the interaction processes which are responsible for the production of physical, chemical, and biological effects. Factors involved include:

- Depth of penetration,
- Dose distribution,
- Irradiation geometry,
- Costs.

Table 4. shows the microbiology and nutritional values of high-protein bread before irradiation and after LEEB treatment with dose of 10 kGy.

TABLE 4.

	Non-irradiated	Irradiated with LEEB (10 kGy)
Microbiological properties		
Total number of microorganisms	52000 cfu·g^{-1}	0
Molds	420 cfu·g^{-1}	0
Nutritional values		
Fat	14.5%	14.3%
Carbohydrates	4.9%	5.0%
of which sugars	1.6%	1.6%
Dietary fiber	13.3%	13.3%
Protein	26.5%	26.4%

Irradiation of the product surface with a Low Energy E-beam (LEEB) appeared as a possible ideal solution. Such a treatment would neutralize the microorganisms. Microorganisms are located on the surface of the product and are formed mainly during the handling of the product. On the other hand, the change of the nutritional values of the product under the influence of high-energy ionizing radiation would be avoided.

4. CONCLUSIONS

Advancements in electron beam technology are shrinking the footprint of the devices used to generate ionizing radiation. With the relatively recent development of reliable, compact, cost-effective, LEEBs, a new class of in-line applications is now possible. The benefits of high-speed, high-efficacy treatments, with no chemicals and at room temperature, are now realized across a variety of packaging applications. Such developments are also attractive to the food industry. The use of LEEB in the treatment of special high-protein products for diabetics has shown great potential for further development and application.

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