ACCELERATORS APPLICATION FOR RADIATION PROCESSING OF FOODSTUFFS

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Abstract

During last couple decades in Russia an interest in the electron-beam sterilization technology has been significantly renewed. The electron beam irradiation occurs at electron energies in the range from 3 up to 10 MeV with dose of 30 kGy. A special research interest is an exploring the possibility to reduce electron energy and dose characteristics upon foods irradiation. The aqueous suspensions with Escherichia coli and Staphylococcus aureus have been used as the research objects.

Whole treatment process has been carried out on an industrial electron accelerator UELV-10-10-C-70 located in the A.N. Frumkin Institute of Physical chemistry and Electrochemistry at the Russian Academy of Sciences. Beforehand partially filled and sealed 10 ml vials containing the sample suspensions with microorganisms have been installed on an accelerator line in two different positions: vertical and horizontal. The samples were irradiated with doses of 3, 5, 7 and 10 kGy. Microbiological investigations of irradiated objects have been carried out in accordance with the Russian State Standards 30726-2011 and GOST 10444.2-94 by the most probable number of colony forming units (CFU) method.

As an investigative result, the microorganism radioresistance index D10 has been determined. It makes it possible to evaluate amount of these microorganism types upon contaminated foodstuffs irradiation. It has been established that during exposure the horizontal position of the vials was more effectively. It may be explained due to simultaneous influence of two different though interrelated reasons: the direct radiation and radiation-induced ozone.

In recent years, Russia has been a renewed interest in radiation technologies. The application of radiation technologies at agriculture and food industry is a global trend [1]. Radiation sterilization technology and food processing have a high degree of efficiency, high performance, accuracy of dosing radiation and possibility to irradiate packaged products. Radiation processing occurs without significant heating of the product, which allows to sterilizethermolabile objects. Radiation facilities have low operating costs and compliance with accepted environmental standards. According to the International Commission on Radiological Protection every year on Europe market receives more than 200 000 tons of irradiated foods.

In the USSR, feasibility studies on radiation processing of food began with the beginning of the 60s of the last century. The studies were conducted at the ‘A.N. Bach Institute of Biochemistry’ of Academy of Sciences, in research institutes of Union Academy of Agricultural Sciences of the USSR, ‘Institute of Nutrition’ of Academy of Medical Sciences and ‘F.F. Erisman Research Institute of Hygiene’. At that time, the lead organization for the study of radiation effects on the food served Institute of Canning and Vegetable Drying Industry (now Russian Research Institute of Canning Technology), which had gamma-installation based on the activity of the ^{60}Co irradiator 300 Curie. The investigations [2, 3] have shown promising applications of radiation method to prolong the shelf life of food products. At [4] it was shown the relevance and timeliness of the use of electron-beam sterilization technology using high current electron accelerator.

In contrast to sterilization by gamma radiation, electron radiation does not use radioactive isotopes. Electron accelerators have appeared in the 50s of the last century, but their use at that time was not economically justified. With the development of technologies for the creation of high-current electron accelerators (energy, beam current and pulse duration increase) value of electron beam sterilization decreased to quite an acceptable level. This has caused interest in the electron beams from the food industry. Irradiation occurs when the energy of the electrons in the range of 3 to 10 MeV. At these energies electrons no education isotopes in food and the penetration depth of the electrons is sufficient for their penetration into the product packed in containers ready for shipment.

High dose rates of electron irradiation allows to influence them for several seconds as opposed to hours of exposure to the product with gamma radiation. Short-term impact of accelerated electrons reduces the possible effects of oxidation product. This minimizes radiation and thermal disturbances in products and packaging material. Accelerators it is possible to vary the energy of the electrons and bremsstrahlung. Reduction of energy leads to the minimization of damage to the products during radiation treatment. In addition, the cost of operation of the accelerator and the capital cost of the creation of radiation-accelerator center is much smaller.

In Russia since 1980 designed and built for industrial radiation processes over 200 accelerators (excluding accelerators for medicine, fault detection and imaging). At the moment are in operation for more than 80 linear electron accelerator. In [5] provides an overview of the

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developed and used electron accelerators for radiation processing plants. The advantages of linear electron accelerators are:

- Ability to control the parameters of the installation;
- The directionality of energy transfer;
- The service life of more than 20 years without major repairs;
- Reduced requirements for permits and protection;
- The problem of "nuclear proliferation";
- The low cost of the process of irradiation on the accelerator.

One of the industrial electron accelerators for radiation processing electron is in the A.N. Frumkin Institute of Physical chemistry and Electrochemistry RAS. Accelerator UELV-10-10-C-70 is a multi-purpose source of ionizing radiation and intended for use in industrial radiation processes [6-8]. Currently this accelerator is used in research on electronic sterilization model media with solutions of microorganisms. Using this accelerator is possible to develop technical requirements and regulations of processing agricultural products and products of its processing.

Currently, at the international level is set a number of documents regulating of radiation treatment of food products. This accelerated the introduction of radiation treatment abroad. Russia, unlike in European Union and the United States is at early stage of formation of the market of radiation technologies processed products. One of the major problems in the development of this sector is outdated legal framework, as well as partial or complete absence of the required standards for irradiation of certain foods. Also technical regulations and specifications of radiation treatment are not developed. Preparation of modern regulatory framework in Russia is engaged Ltd. «Center Atommed" [9]. The need for development and improvement of regulatory framework of radiation food processing technology due to the following factors:

- presence and growth of dissemination of radiation technologies in the market consumption of food and agricultural products;
- need to introduce standardizing requirements for products obtained with the use of radiation technologies (defined by general health, sanitation, hygiene, consumer and other requirements);
- necessity ensure reproducible model of radiation effects in the process of product life cycle (requirements for reproducibility of the dose of irradiation conditions, modes of storage products, etc.);
- need to ensure radiation safety radiation facilities and production lines;
- requirements of unification project, design and equipping of radiation facilities, systems for monitoring and control exposure.

Strict requirements for managing necessitated the adoption of general international standard ISO 14470:2011. This standard ensures compliance with the latest requirements under irradiation of food, which is used to improve the quality and safety of food processing. The standard is intended for manufacturers, the operators on the irradiation, regulators activities, customers, and most importantly – consumers. The main objectives of ISO 14470: 2011 are as follows:

- Ensure that the requirements of food irradiation in accordance with current standards and practices;
- Provide technical regulations between the client and the operator of the irradiation;
- Create documentation and control systems for processing of food irradiation.

Currently, the Russian legal framework of industrial radiation technologies is divided into the following levels: legal level of control (changes in the number of federal laws, government regulations and the preparation of technical regulations), technical level (licensing, standardization and training sanitary rules and norms) and technological level (development orders, manuals, technical manuals, regulations and sets of documents). The basic standard for radiation processing of food products developed as part of the project documentation for the customs union of Russia, Belarus and Kazakhstan on the basis of pre-existing norms of radiation safety and standards adopted by the European Union.

In preparation for establishment of draft technical regulations in 2013 at A.N. Frumkin Institute of Physical chemistry and Electrochemistry RAS on the accelerator UELV-10-10-C-70 in conjunction with the Russian Research Institute of Canning Technology conducted a series of studies on the irradiation of sealed ampoules with model solutions with microorganisms by an electron beam with different irradiation doses. Modeling environments allow to determine the impact of the alleged doses and installradioresistance of traditional microorganisms. Of great interest is relatively low irradiation doses up to 10 kGy.

Accelerator UELV-10-10-C-70 has the energy of the electron beam 10±0,4 MeV electron radiation dose rate at distance 1 m from the exhaust flange window 3 kGy/s. Accelerator used a circular conveyor for transporting irradiated samples before scanning electron beam. Monitoring the radiation dose carried out by means detectors based on single-use polymer films and spectrophotometer. Range measurement of absorbed dose varies at the range from 5 to 50 kGy and the error does not exceed 12%. Smaller doses can be estimated by interpolating the results obtained.

In the fourth quarter of 2013 at the accelerator UELV-10-10-C-70 was exposure of sealed vials with model solutions of microorganisms. Vials have diameter of 10 mm and height of 60 mm. Gram-negative rod-shaped bacterium E. coli with the size of 1.1-1.5 × 2.0-6.0 mm and grammopozetiv coca Staphylococcus aureus spherical shape with a diameter of 0.5-1.5 mm are studed. In the study used daily cultures of these microorganisms dissolved in meat-peptone broth. Single irradiation of microorganisms carried by electrons with doses of 3, 5, 7, 10 kGy at two vials positions. In each experiment were used 3 ampoules with microorganism to reduce statistical

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errors. Microbiological examination of irradiated and control samples were carried out on the day after exposure. Control vials were stored under the same conditions as irradiated.

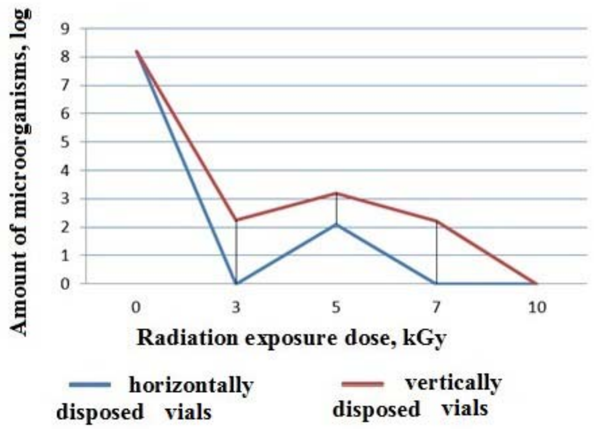

Figure 1: Microbiological characterization of the irradiation effect at E. coli.

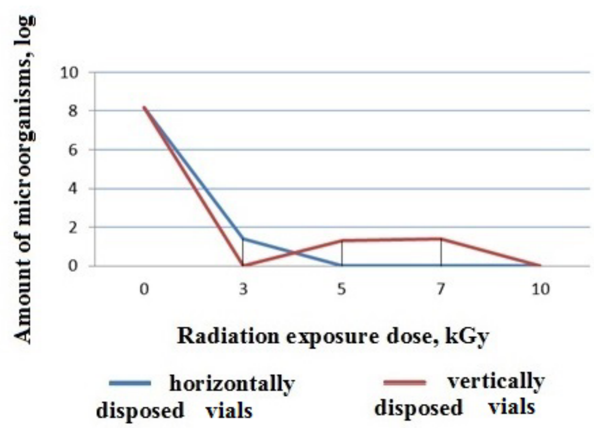

Figure 2: Microbiological characterization of the irradiation effect at S. aureus.

Microbiological investigations of irradiated objects have been carried out in accordance with the Russian State Standards 30726-2011 for E. coli and standard GOST 10444.2-94 for S. aureus. According to standards of the cultivation of microorganisms on dry nutrient agar should be 24 hours at 37° C. Studies were carried out by the most probable number of colony forming units (CFU) method. The results were taken into account in each test sample for two reps. The results of the study are presented in Fig. 1 for E. coli, and Fig. 2 for S. aureus. Figures present in logarithmic scale content surviving organisms from absorbed dose. It has been established that cultures of E. coli and S. aureus, exposed to radiation die by 80-100%. It has been established that during exposure the horizontal position of the vials is more effectively is more effective in comparison with the vertical. It may be explained due to simultaneous influence of two different though interrelated reasons: the direct radiation and radiation-induced ozone.

In the work shows the current trends of radiation processing technology of food production using particle accelerators in Russia. The urgency of establishing legal documentation is shown and terms of reference for further research are defined. The possibility of using the existing radiation accelerators for food irradiation is determined. In the course of research on the accelerator UELV-10-10-C-70 established the lethal dose for suspensions of microorganisms. This allows to estimate the dose required for irradiated foods at radiation sterilization.

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