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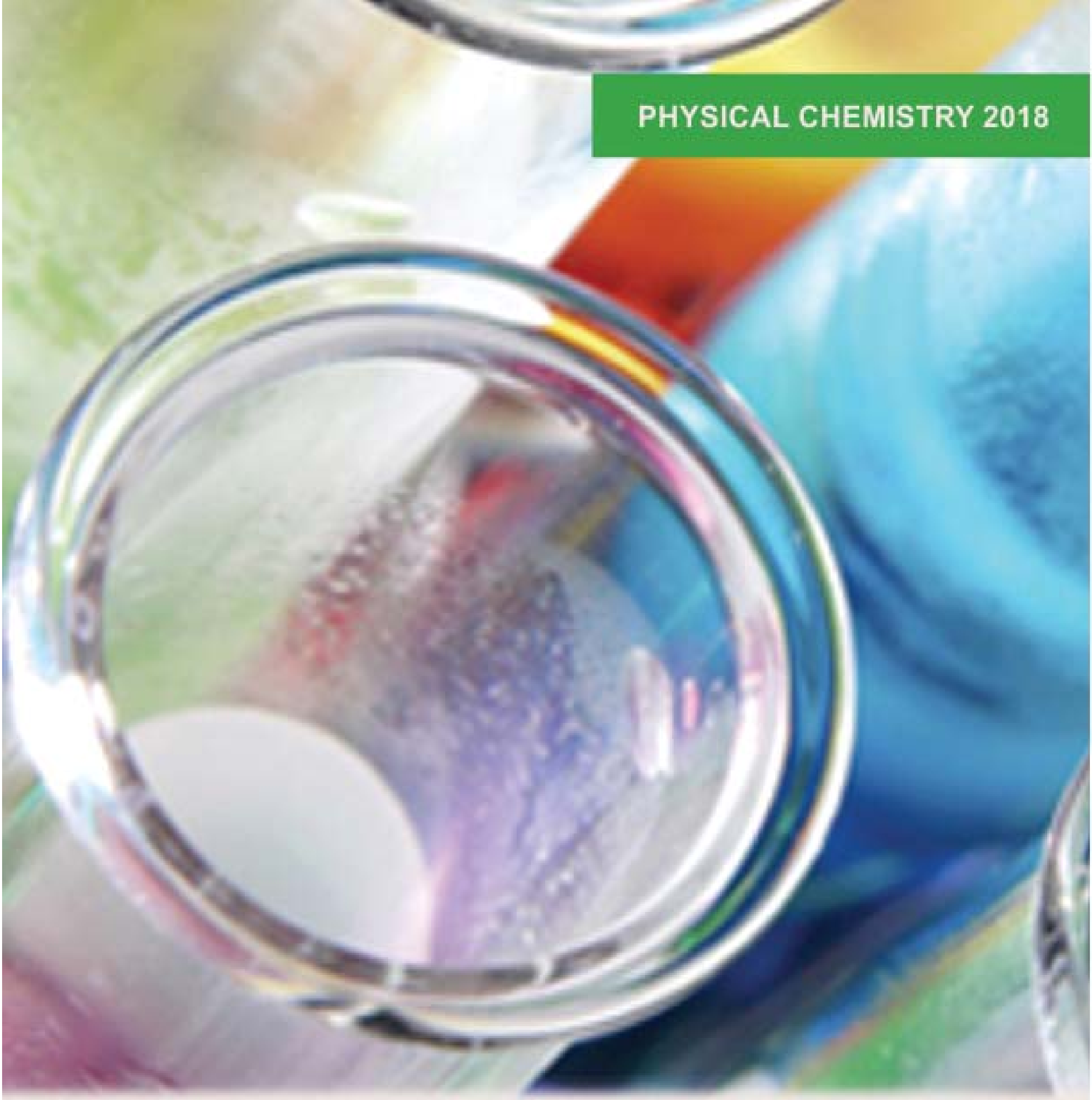

6[th] *Workshop*

SPECIFIC METHODS FOR FOOD SAFETY AND QUALITY

September 27th 2018, Vinča Institute of Nuclear Sciences, Belgrade, Serbia

PROCEEDINGS

SPECIFIC METHODS FOR FOOD SAFETY AND QUALITY

6th WORKSHOP: SPECIFIC METHODS FOR FOOD SAFETY AND QUALITY

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Editor
Dr Vesna Vasić

Reviewers
Dr Sandra Petrović
Dr Andreja Leskovac
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FOOD STERILIZATION BY IONIZING RADIATION

S. Dimović[1], V. Stanić[1], M. Šljivić-Ivanović[1] and D. Milojkov[2]

[1] *Vinča Institute of Nuclear Sciences, University of Belgrade, P.O. Box522, 11001 Belgrade, Serbia. (sdimovic@vin.bg.ac.rs)*
[2] *Faculty of Technology, Department of Materials Engineering, University of Novi Sad, Bulevar Cara Lazara 1, 21000 Novi Sad, Serbia.*

INTRODUCTION

In addition to the usual methods for food preservation, the use of radiation is increasingly widespread. The beginnings of radiation use date from the end of the 19th century, but more intensive application is noticed only after the Second World War [1]. Most of the research was carried out to determine the stability and food safety.

Compared to the thermal sterilization, the radiation technique was developed later, and found less or limited application in the conservation of foods [2]. It should be noted that electromagnetic radiation is used not only for the destruction of microorganisms, but also for:

- destruction of insects,
- culinary food processing (microwave ovens),
- slowing down certain biochemical activities (preventing germination)
- improving certain technological parameters of some foods (improving the rehydration of dried fruits and vegetables).

The radiation of a short wavelength (approximately 30 nm) is characterized by high energy, so it has a pronounced mutagenic and lethal effect. This radiation acts in two ways, either directly with nucleic acids or by forming the very reactive radicals that can react easily with various organic compounds, making them unavailable to microorganisms. Free radicals are ionized molecules - most commonly water molecules.

Besides electromagnetic radiation (X - rays, gamma rays and cosmic rays), alpha and beta - (corpuscular) radiation can also perform ionization of molecules. By using ionizing radiation, only a small part of the energy is transformed into heat. Compared to thermal sterilization, this amounts to less than 2%, i.e. the temperature of the food does not rise more than 2 ° C, which is why this treatment is called cold sterilization.

The first procedure for the application of ionizing radiation in the conservation of the food was patented in France 1930. The further development of radiation technology as a method of protecting food was impeded by the cost of cost, the size of the equipment and the difficulties surrounding the handling of radioactive sources [3]. In the application of ionizing radiation, the radioisotopes 60Co and 137Cs, and fast electrons are used.

Effects of food irradiation

The beneficial effect of the radiation of the food depends on the absorbed radiation dose. Useful effects of food irradiation are divided into [3,4]:

1. **Radapertization**- complete destruction of microorganisms
2. **Radurisation**- reduction in the number of microorganisms
3. **Radicidation** - inactivation of microorganisms hazardous to human health
4. **Disinfestation**
    - Destroying insects, larvae and eggs
    - Control of physiological processes

Radapertization is the effect of useful radiation in which microorganisms that cause food spoilage are completely destroyed, and foods that are treated can be stored at room temperature. For this effect, relatively large radiation doses of greater than 10 kGy are used, and are most often used for the sterilization of meat and meat products.

Radurisation and radicidation are the effects of useful radiation achieved at doses from 1 to 10 kGy. This category of radiation is applied in order to reduce the number of bacteria that are the cause of spoilage or disease triggers. In this way, products from eggs, meat, fish, poultry and fruits are tested. These radiation categories effectively destroy microorganisms with a slight change in the quality and smell of foods.

Disinfestation - destruction of insects and parasites and slowing of maturation are the effects of useful radiation, achieved at doses of 0.2 -3 kGy. It successfully destroys insects and parasites, preventing the germination and slowing down the fruit's ripen. Chemical agents used in the fight against insects are effective, but they have some disadvantages. The disadvantages are reflected as development of the insect resistance to chemicals. Also, the insect eggs remain undamaged, and the residues of chemical agents remain in the food pose a threat to human health.

Health aspect of food irradiation

In examining the health safety of irradiated food, the greatest attention is paid to [5,6]:

- the influence of radiation on nutritional value of foods
- the possible synthesis of toxic substances under the influence of radiation
- the possible synthesis of carcinogenic substances in irradiated food
- the possibilities of irradiated food to become radioactive

It was found that radiation of energy below 10 MeV does not result in the induced radioactivity of any element. From a health point of view, it is important to determine that there are no toxic products in the irradiated food.

In order to label the irradiated food as harmless, four excluded criteria must be met:

1. Induced radioactivity
2. Pathogenic microorganisms and their toxins
3. Significant loss of nutrients and
4. Toxic, mutagenic or carcinogenic radiolytic products

The FDA (Food and Drug Administration) suggested that [7]:

1. Foods irradiated up to 1 kGy are considered to be healthy and harmless to food
2. Foods irradiated with doses over 1 kGy should be tested for the presence of toxic compounds
3. Foods irradiated up to 50 kGy if consumed in an amount less than 0.01% of the total daily food requirement - can be consumed without any examination

Food that is exposed to radiation is necessarily marked by a world-renowned symbol called "radura" (Figure 1.).

Figure 1. Radura symbol.

Influence of radiation on microorganisms

There are foods (powdered foods, additives, spices, cocoa powder, bite, grains, etc.), which are often contaminated with highly resistant microorganisms [8]. If high temperatures are applied to their sterilization, the basic organic properties are disturbed. However, the decontamination of these foods by ionizing rays is very effective, and with proper application, does not induce changes in nutritional and physical characteristics.

The microbicidal effect of the same radiation dose can be viewed from several aspects, such as:

a) Specific radiation resistance - The microbicidal effect of radiation depends on the type of microorganisms

b) Concentration of microorganisms

c) Substrate Influence

In the absence of oxygen, the microbicidal effect on microorganisms has only the resulting radicals and therefore a higher radiation dose is required. With increase of an active acidity, a lower radiation dose to achieve the microbicidal effect of radiation is required. Furthermore, in dry substrates, microorganisms are more resistant to radiation.

Chemical anomalies in irradiated food

Free radicals are parts of molecules, groups of atoms, or individual atoms that possess an unparalleled electron. These forms are very unstable and therefore very reactive. Free radicals react with each other or with other molecules and attack cell membranes (proteins, phospholipids) and genetic material (DNA and RNA), that contributes to the appearance of certain diseases.

Since light-foods contain the large quantities of water, the most common free radicals in such foods are formed by the ionization of water.

In addition to $H^{\bullet}$ and $HO^{\bullet}$ radicals, other radicals such as methyl radical CH_3, an amine radical NH_2 and others are formed.

All the chemical changes that occur due to radiation arise as a result of:

a. Direct effect of radiation (interaction of ionizing air with food ingredients)
b. The indirect effect of radiation, which occurs through radiolytic waster products

Changes in the nutritional value of irradiated foods

The influence of radiation and chemical reactions on the nutritional value of the food depends primarily on the chemical composition of the food, the absorbed dose of radiation, the temperature, and the presence of oxygen [7].

Some vitamins (riboflavin, niacin, vitamin D) are quite resistant to radiation, while thiamin, vitamin A and vitamin E are quite sensitive, especially if the oxygen is not removed from the packaging.
The biological value of the protein, if irradiated with high doses, is slightly changed. As for coloring matter, it has been found that anthocyanin and lycopene are much more sensitive to radiation than carotene and chlorophyll.

The radiation influence on enzymes of non-microbiological origin

In abiotic procedures of food preservation, it is necessary to eliminate enzymes in addition to microorganisms. It has been found that the destruction of enzymes (especially oxidoreductase) by radiation is much more difficult than the destruction of microorganisms [8]. The required doses for inactivation of the enzymes are approximately 5 times higher than dose that terminates microorganisms. Because of the harmful changes in foods caused by the high doses of radiation, the radiation cannot be applied to extinguish enzymes.

Dose and purpose of radiation

Depending on the type of food and radiation dose, ionizing energy may have different useful functions, as shown in Table 1 [9].

The influence of radiation on the packaging material

Metal packaging suffers a certain change only in the case of radiation exceeding 600 kGy [10]. At doses larger than 100 kGy, the glass becomes brown. In the case of flexible plastic materials, there is a possibility of changing the physical properties, migration of some components normally found in such materials, or materials to some extent depolymerize.
Although these materials show no change if they radiate up to 20 kGy, the FDA permitted as the maximum dose of absorbed radiation of 10 kGy for: nitrocellulose, wax paper, polyolefin and polystyrene. For other polymeric materials, the allowed doses of absorbed radiation are 60 or 80 kGy.
For this purpose, the packaging does not require strength as for the thermal sterilization because there is no heating and no increase in the pressure. The packaging is needed to be impervious to microorganisms and resistant to the applied radiation dose.

Table 1. The use of ionizing energy depends on the type of food and radiation dose.

Dose(kGy)	Function	Irradiated products
Low doses (0.05-0.15 kGy)	Inhibition of germination	Potatoes, onions, ginger root
Low doses (0.5-0.5 kGy)	Disinfestation of insects and disinfection of parasites	Cereals and legumes, fresh and dried fruit, dried fish and meat, fresh pork
Low doses (0.5-1.0 kGy)	Deferment of physiological processes	Fresh fruits and vegetables
Medium dose (1.0-3.0 kGy)	Extension of life	Fresh fish, strawberries
Medium dose (1.0-7.0 kGy)	Removal of pathogenic and the spoilage agent microorganisms	Fresh and frozen seafood, fresh or frozen poultry and meat
Medium dose (2.0-7.0 kGy)	Improving the technological characteristics of food	Grapefruit (increase in yield of juice), dried vegetables (reduction of cooking time)
High doses (10-50 kGy)	Decontamination of verified food additives and ingredients	Spices, enzymatic preparations, natural rubber
High doses (30-50 kGy)	Industrial sterilization (combined with mild warming)	Meat, poultry, seafood, ready-to-eat dishes, sterilized dietary food for hospitals

CONCLUSION

Although food irradiation is an undeniably acceptable and fairly safe method of conserving, it has limitations and disadvantages. Sterilization radiation doses have a different effect on food components causing the organoleptic changes.

Compared to heating, radiation is less energy consumed. While the price of heat is rising, the price of radioactive isotopes and electronic accelerators is not changing or decreasing. The major disadvantage of radiation utilization is the increase in total world radiation.

Also, a high investment costs are needed and for economic reasons the devices are required to be exploited throughout the year.
A major problem in the conservation of food by radiation is still high suspicion of consumers regarding the daily use of such foods in the diet.
It is uncertain to predict what the perspective of radiation in conservation is; to a large extent, this depends on the future policy of the FDA and similar organizations. It should be noted that traditional conservation methods are good and that their radiation does not represent competition.

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