Radiation treatment of biological origin materials

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Abstract – The food products shelf life extending problem is considered. It is shown that these substances disinfecting least harmful way is treatment with γ- or β-ionizing radiation. The technical feasibility assessment of setting up such an impact was carried out using the grain silo example in stationary storage conditions.

Keywords – food products, storage periods, radiation exposure, γ-source, dose, silage, grain, technology.

Introduction

The food industry is dealing with the need problem for the prolonged storage of both agricultural and livestock products. The problem is the products spoilage due to the vital activity of microorganisms or insects in this environment and the biochemical processes flow. Damage to products also occurs when rodents and birds have access, but this problem is solved with relatively simple solutions. According to the UN analysis, "the food contamination problem by pests is a challenge for all mankind" [1]. In addition, the microorganisms vital activity in the environment of many plant origin materials occurs with the release of heat, which causes their self-heating up to the fires occurrence with the explosions possibility of gaseous decomposition products of the substance [2]. Insect colonies also cause the plant material self-heating, but not enough for the spontaneous combustion, however, it can help the microbiological spontaneous combustion development. A similar problem exists for the storage of intermediate food products – hay and compound feed, as well as for food waste and peat. These losses make up to 30% of the food market.

Currently, a significant number of ways to extend the food products storage have been developed. Some success in this direction is provided by strict storage conditions with reduced temperatures or humidity. Products disinfection is achieved by chemical treatment with fungicides, insecticides or complex action drugs. This technology disadvantage is the need to ensure a waiting time – a pause before further food use of up to 45 days, but the processing efficiency is about 50%.

As an alternative to traditional methods, technologies for the food products irradiation with the ionizing radiation are currently being actively developed, which increases the effectiveness of disinfection and disinfestation up to 100%, while simultaneously reducing the waiting time to the use possibility up to 1 day. Processing is carried out by acting on these products with a electrons beam or γ-quanta of ^{60}Co in conveyor systems. Doses of about 1.0 kGy cause the insects immediate death, but higher doses are required to inhibit the microorganisms vital activity. In the world, four main purposes of the radiation exposure to food products are used: 1) imported potentially dangerous products processing for safety against foreign infections; 2) products processing to extend their storage. 3) products processing for export; 4) the seed material irradiation to the increase germination.

Results and discussion

The international commission "FAO/WHO 1980" based on the 35 years data of testing established that the radiation exposure use in established optimal modes with doses up to 10 kGy is the preservation most harmless method. Doses of 3–4 kGy are sufficient to extend storage periods (radurization), doses of about 10 kGy cause the death of microorganisms most types; complete destruction of more resistant microorganisms (radopterization) requires doses of up to 50 kGy, which can be used for food waste landfills or peat. Doses greater than 10 kGy initiate the oxidation products formation, change in color and taste qualities, so they are not recommended for food processing. Such processing is carried out in accordance with the Interstate standard ISO 14470-2014 [3], which regulates irradiation processes using radionuclides 60Co, 137Cz, electron generators, X-ray sources. At the same time, food products do not become radioactive, because these sources do not have enough energy to interact with the atom nucleus (the neutron irradiation achieves this effect). Therefore, such food products are safe for consumption and do not change their organoleptic qualities. After this treatment, other influence methods (chemical, thermal, etc.) that change the composition and properties of the food products become unnecessary. Products after such processing are marked as "Radura-logo".

The conveyor systems disadvantage can be called limited throughput. Therefore, the radiation exposure possibility under stationary storage conditions is of interest. The problem here is the limited penetration depth of ionizing radiation and its influence weakening in material inner layers, which worsens the processing uniformity. For biological origin materials, the penetration depth depends on energies and type of the irradiation: for γ-quanta, about 1 m, and for an electron beam – several millimeters. The parameter "irradiation half attenuation depth " is also used. It is believed that for protection against γ-radiation, the insulating layer presence of a certain material with a thickness of at least ten periods of the half attenuation is necessary.

One of food products that requires the longest storage periods is grain. For this, steel silos with a height and diameter of up to 30 m are used, where the intensive ventilation, low temperatures and the chemical treatment are provided. Fresh grain has a moisture content of 25%, and it must be loaded into the silo with a moisture content of 13-14%. This is achieved by pre-blowing with hot air with a consumption of 7000 m^3/m^3 of grain. Unlike concrete silos, steel silos are unpleasant due to the condensate formation, but require a much smaller foundation.

Taking into account the rather complex technology of extending grain storage periods in silos, the possibility assessment of the implementing grain treatment with γ-radiation in the silo itself was carried out. It is assumed that for the appropriate treatment, a certain number of γ-radiation sources should be located along the silo perimeter on lifts to enable treatment by each source along the silo height [4].

To establish the such processing technological parameters, an assessment of the γ-radiation half attenuation depth in the grain was made, based on its bulk density and known relevant data for concrete (6.1 cm), steel (2.5 cm), lead (1.8 cm) and soil (9.1 cm). Such an estimate does not take into account that plant material consists of lighter atoms than other considered substances. This dependence was approximated by a power function: $h_{0,5}=18\rho^{-0,95}$, cm. Then, for a grain with a high bulk density of 0.84 g/cm³, the expected γ-radiation half-attenuation layer is 21 cm, and 10 attenuation periods will create a grain layer about 2 m thick. That is, the container with grain, which is irradiated and, at the same time, used as an absorbing layer, cannot be less than 2 m in the diameter. If the grain or flour has a lower density, the half attenuation layer and the storage container minimum diameter will increase. Then, along this container perimeter, it is necessary to place such the irradiators number that for a dose near the wall of 9 kGy from one irradiator, the dose in the center was at least 3 kGy, taking into account the irradiation beams overlap. Then, for such an effect, it is necessary to install 11 radiation sources. But already for a diameter of 4 m, it is necessary to install 352 irradiators around the container perimeter, which becomes not technological.

It is possible to reduce the irradiators number by placing internal lifts with the circular irradiation from each source. Then, to ensure the specified radiation regime, the distance between the sources should be no more than 1.2 m, but the distance to the outer wall should be 2 m so that the grain, by its mass, provides a safe radiation level of to the outside. Then it will be necessary to place additional sources along the container perimeter to increase the radiation doses in the middle layer. Under such conditions, 21 irradiators (1 internal) will be enough to irradiate a container with a diameter of 4 m. Similar geometric problems must be solved for silos of larger diameters. Although the internal irradiators arrangement greatly simplifies the exposure system, it remains cumbersome. Nevertheless, such an idea can be implemented and deserves attention.

It is possible to use the grain processing mode during its filling into the silo with the radiation directed to the filled surface, which rises in the level. To increase the processing uniformity, you can use γ-radiation scatterers and place them opposite the radiation sources as a wall element. If the energy of γ-quanta is increased from 5 to 20 MeV, the half attenuation depth will increase from 0.2 to 0.6 m. Then the distance between the emitters can be increased from 1.2 m to 3.6 m, and 10 radiation attenuation periods will correspond to a grain layer of 6 m. Then the silo minimum diameter with external irradiators will be 6 m, and with the addition of one internal – 12 m. But at the same time, again, there will be zones with insufficient radiation doses. A solution may be to increase the metal silo wall thickness from 4 mm to 100 mm, so that the powerful internal source can be brought closer to the wall. But this will critically increase the construction weight. Then it is possible to place in silo zones, which are closer to the wall, lower power ionizing radiation sources.

For radiation treatment of non-food plant materials accumulations (food waste or peat) in order to prevent the microbiological self-ignition, it is necessary to scan the accumulation with the ionizing radiation, which is directed vertically into the soil. If you ensure the radiation dose accumulation on the material accumulation surface in the amount of 50 kGy, then with the radiation source energy of 20 MeV, the microorganisms vital activity will be suppressed in a layer 2.5 m deep for materials with a density close to the considered grain. Such processing can be carried out by a radiation mobile source using various systems.

Conclusion

The conducted studies showed the theoretical possibility of extending the storage period or preventing self-ignition for food products in stationary conditions at storage sites by treatment means with the ionizing radiation. For this, it is necessary to accumulate doses of 3–9 kGy in food products, and 4–50 kGy in non-food plant materials. If silos are equipped with radiation sources, they must be placed around the perimeter on lifts. The silo minimum size is determined by 10 radiation half attenuation periods by the given grain. In significant size silos, similar lifts must be placed inside as well, but those of them that will be closer to walls must have less γ-quanta energy.

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