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Surface irradiation of hatching eggs with nanosecond electron beam before incubation for stimulation

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***Abstract*—A new and promising method of radiation processing of egg products is the use of a nanosecond electron beam (NEB) generated at URT accelerators. A limitation of the radiation treatment for hatching eggs is the need to protect embryonic cells during irradiation. The effect of ionizing radiation (IR) on the embryo shows that irradiation, even in a small dose (from 50 cGy), can lead to stochastic effects affecting the future chick. There is an alternative concept without the threshold action of ionizing radiation (no-threshold model), which allows concluding that there is a positive effect of low doses (the effect of hormesis). When processing the incubated chicken eggs with small doses, the effect of hormesis can lead to an increase in the percentage of growth rate of chickens and chicken carcass weight. According to the results of our research, a decrease in the period of breeding by 30% and an increase in the average weight of the chicken carcass by 2% in the group irradiated on URT-0.5 was found.**

Keywords—food radiation processing, chicken eggs incubation, electrons, bremsstrahlung, dosimetry.

I. Introduction

Currently, the use of ionizing radiation (IP) is aimed at processing agricultural products to reduce contamination by microorganisms in order to increase shelf life at doses of 10-25 kGy. At the same time, food radiation processing and chicken eggs incubation is limited due to the reduction in the quality of food eggs when irradiated with doses of more than 3 kGy [1] and the sensitivity of embryos to the effects of IP [2] [3].

Chicken meat and eggs are considered the most common products in the world. According to statistics, Russian manufacturers produce more than 4 million tons of meat every month, and this number is growing annually. At the same time, poultry farms annually suffer losses due to diseases of birds. This requires the introduction of innovative technologies in the poultry industry to reduce losses.

Microbial infection of eggs is a well-known phenomenon and it has serious negative economic consequences for the poultry industry [4]. In industrialized countries, the number of food poisoning that was attended by various strains of Salmonella increased [5]. Inadequate disinfection of eggs leads to about 230,000 cases of foodborne illness each year [6]. The most common procedure for the inactivation of microorganisms on the surface of chicken eggs is disinfection with chemical agents such as formalin, ozone, etc. Treatment with IP is an attractive alternative to chemical disinfection for egg products [7].

A limitation of the radiation treatment for hatching eggs is the need to protect embryonic cells during irradiation. The most radiosensitive cells are the cells of rapidly regenerating tissues, as well as cells of embryos and fetuses. It is known [8], that the effect of IR in damaging doses (more than 1 Gy) has a negative effect on biological objects and can lead to radiation damage. The effect of IR on the embryo shows that irradiation, even in a small dose (from 50 cGy), can lead to stochastic effects affecting the future chick[9].

A new and promising method of radiation processing of egg products is the use of a NEB generated at URT accelerators [10].

This technology allows avoiding the irradiation of the egg contents by managing the distribution of the dose in depth of the processed product by changing the electron energy. At the same time, the inevitable presence of bremsstrahlung during the NEB processing needs the assessment of its negative impact on the development of the embryo and chicken.

By using this method, it will be possible to reduce the radiation commitment on embryonic cells of incubated eggs to a level of low doses and, therefore, minimize the negative effect of IR on the quality of products. [11]

Such effect can be equated to the influence of increased radiation background. Consequently, the products treated with NEB cannot be equated to those with the "Radura" sign, which will allow avoiding a preconceived attitude of the consumer because of radiophobia. There is an alternative concept without the threshold action of ionizing radiation, which allows concluding that there is a positive effect of low doses (the effect of hormesis). When processing the incubated chicken eggs with small doses, the effect of hormesis can lead to an increase in the percentage of hatching, growth rate of chickens and chicken carcass.

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Since the 1950s, a method of eggs irradiating with small doses has been investigated with the aim of increasing the hatchability egg production. Results of the first low dose research [12], [13], [14] showed that gamma irradiation of eggs with small doses of 1 to 3 cGy in the first days of incubation increased the hatchability and survival of chickens by an average of 2.6%, and the egg production by 7%. It is known that rodents after irradiation had a longer lifespan, normal fertility and a lower level of fetal mortality compared with control animals. Summarizing the data shows that low doses (up to 0.5 cGy / year) do not cause genetic damage in the progeny [15], [16]. Experiments [17] showed that irradiation of eggs with a dose of 3-5 cGy before incubation has caused an increase in the intensity of growth and development of chicken embryos, increase in hatchability of chickens and egg production.

The stimulating effect of low doses is also observed on the productivity of adult laying hens. Irradiation of laying hens with a dose of 5 cGy increases egg production by 22%. [18]

A research [19] showed that the preincubation irradiation of eggs with a dose of 20 cGy reduces the incubation period and does not inhibit the development of embryos. Embryogenesis is inhibited during irradiation with a dose of 1 and 2 Gy. In other studies, the stimulating effect of doses up to 20 cGy is also noted.

In article [21], embryo irradiation on the 10th day of incubation with a dose of 20 cGy had a positive effect on their development and postembryonic growth of chickens: the incubation period was reduced by 1 day, the weight of chickens increased during the first month by an average of 12%. Irradiation of embryos on the 19th day of incubation had a negative effect on embryogenesis.

In addition to stimulating hatching, growth rate and egg production, studies were conducted to evaluate the effect of low doses of radiation on the immune system of broiler chickens. In article [22], stimulation of the immune system to Newcastle disease (a viral disease of birds) was detected. Irradiation was carried out before and on the 19th day of incubation with AD of 30 cGy. A 60Co with a dose rate of 2.4 cGy/s was used as a source.

At doses up to 50 cGy, stimulation of fertility, an increase in survival and growth rate in mammals, chickens and fish were noted, in plants - an acceleration of growth processes, more intensive branching, stimulation of the development of generative organs [10].

After irradiation of eggs before incubation with a dose of 50 cGy, the hatchability increased by 15%, and the duration of the incubation period did not change [23].

In accordance with the above data, it can be concluded that IR can be used to increase productivity in meat and egg poultry farming. However, determining the required dose value is a difficult task, since the stimulating effect, according to the literature, is contradictory, and depends on the type of radiation, dose rate, growth period of the embryo in which the irradiation takes place, and the functional state of the irradiated organism.

The process of eggs irradiation before laying in the incubator during the surface disinfection with NEB is the most promising. The optimal dose for pre-incubation radiation treatment of eggs is the dose in the range from 1 to 50 cGy. Thus, a new process can be easily integrated into an existing process chain.

Despite the existing contradictions and difficulties of implementation in the poultry industry, there are real opportunities for the introduction of radiation-biological technology into the practice of industrial poultry farming. To solve this problem, it is necessary to select the irradiation parameters, develop an appropriate processing method and conduct pilot tests at poultry farms.

The promising installations for the stimulation of hatching eggs are the accelerators of the URT type with an electron energy less than 1 MeV. These facilities are used to carry out the radiation surface disinfection of food and incubation chicken eggs [24].

Dosimetric monitoring showed [11] that in case of the surface radiation of chicken eggs with NEB (electron energy - 0.5 MeV, a dose - 5 kGy), the dose inside the egg yolk due to bremsstrahlung will not exceed 5 cGy. When processing hatching eggs, such a dose distribution will reduce the negative effects on embryo growth and hatching. To carry out a complete disinfection of the eggs surface in our work, we conducted irradiation of chicken eggs with a dose of 40 kGy. With this treatment, taking into account the bremsstrahlung, chicken embryos are exposed to a dose of 40 cGy, which is in the range of small doses leading to stimulation.

II. THE METHODOLOGY AND EXPERIMENT RESULTS

Experiments on the irradiation of chicken eggs with NEB were carried out at the accelerator URT-0.5. The accelerator operated at a charging voltage of 30 kV. On the feeding conveyor, plastic containers for 10 eggs were passed through the working space of the installation, irradiating with a uniform NEB width. [25]. Product control processing performed by film dosimeters CO AD (F) R-5/50 [26] on the egg surface.

To study the damaging radiation effect of the nanosecond electron beam on the tissues of hatching eggs and the embryo, ovoscopy and macroscopic analysis of the quality of hatching eggs was performed. Incubation was carried out according to the standard technology used in industrial poultry farming, the percentage of hatching eggs was counted, and the quality and health of young individuals were evaluated daily during the rearing period before slaughter time (37 days).

The biochemical, immunological and hematological parameters of the blood of broiler chickens were examined to identify possible metabolic and physiological disorders. After the slaughter of chickens from the experimental and control groups, their pathoanatomical research was carried out.

The chickens from eggs irradiated with the NEB showed higher activity in behavioral reactions than the chickens from the control group. No significant effect of stimulation or suppression of chickens was not detected after the NEB treatment of eggs with a dose in the yolk of 40 cGy.

TABLE I. INDICATORS OF BROILER CHICKENS AFTER THE TREATMENT WITH 40 CGR BREMSSTRAHLUNG FROM NEB

Parameter	Control group	Experimental group (40 cGy)
Average carcass weight, g	1280	almost 2% 1305
Average weight of pectoral muscles, g	383	almost 2% 390
Mass and ratio of red and white meat, g (%)	815 (49)	3 % 840 (47)
Hemoglobin concentration (median), g/l	51 (49,5)	56 (54,5)
The number of red blood cells: mod (median), 10^{12}/l	2,94 (2,7)	3,4 (3,24)

Macroscopic analysis of hatching eggs showed that the indicators of protein, yolk and egg shell of the control and experimental groups are very similar in values: for example, the average protein diameter of the eggs of the experimental and control groups was within 79.2 - 80.8 mm, height - 7.6 mm, the protein index - 0.1%, the diameter of the yolk was varied in the range of 43.5-44.5 mm, the yolk index - 0.4%. The mass of the shell was 7.4 g, the shell thickness was 0.32 mm, the elastic deformation was 22.5 μm in the control lot, and the analogous values in the experimental lot were 7.5 g, 0.33 mm and 22.0 μm, respectively. The ovoscopic evaluation of eggs resulted in slight differences in the structure of the shell: there were more eggs with a large number of points and sticks on the shell in the experimental group (80% of the total number) than in the control group (53%). Other parameters like protein structure yolk air chamber, the presence of pathological inclusions had no statistically significant difference.

In the first series of experiments, the percentage of hatching eggs irradiated with NEB was 64%, in the control group - 64%. A pathoanatomical study of chickens who had not hatched or died during the first time showed that the natural faults of incubation caused the fading and death of the chicks. In the second series of experiments, the percentage of hatching in the experimental group was 96%, in the control group - 94%. No morphological signs of radiation damage to the embryos or its effects were found. Thus, it was established that the percentage of chickens in the experimental and control groups had no statistically significant differences. It should be noted that in the experimental group the period of chickens breeding was on average less than in the control group (16-18 hours and 22-24 hours), respectively. This effect may be associated with the effect of radiation hormesis. Reducing the period of eggs breeding is very important for industrial poultry.

III. DISCUSSION OF THE MEASUREMENT RESULTS

The study of the immunological and hematological parameters of the blood of chickens revealed that in the samples irradiated with NEB, the indicators of red blood slightly exceed those of the control (Table 1). The results obtained show that the hemoglobin and erythrocyte values in the blood of experimental samples are at the upper limit of the norm, while in the test group it is slightly below the threshold.

It is worth noting the significant difference in the demonstration of hormesis effects in chickens under irradiation during incubation. This may be due to the difference in biological efficiency of bremsstrahlung and electron beam. In addition, the URT accelerator creates a high dose rate of about10 cGy / s inside the yolk.

The obtained results allow us to conclude that there is no occurrence of radiation-induced complications of the embryo development or diseases of chickens. Moreover, the small doses of bremsstrahlung had a favorable effect on the rate of hatching, which is of great importance in the industrial poultry farming.

However, the differences between eggs and chickens from the experimental and control groups cannot be determined only by the action of bremsstrahlung - the key difference is the reduction of inflammation in chickens and the low level of disease of the experimental samples.

Based on the results obtained, it can be assumed that chronic inflammatory processes in the control group are caused by contamination of pathogenic microorganisms on the shell surface. In the tested samples, surface disinfection by NEB with dose of 40 kGy led to the complete elimination of pathogenic and conditionally pathogenic microorganisms.

A pathoanatomical study of broiler chickens revealed the signs of chronic inflammatory process in 86% of chickens in a group of hatching eggs that were not irradiated. At the same time, in the samples subjected to NEB treatment only one chicken was found with similar changes in the internal organs, which is 4% of all samples.

IV. CONCLUSION

High and rapidly growing demand for poultry products requires the introduction of innovative technologies to improve safety and efficiency in the poultry industry. Some estimates show that radiation surface disinfection at URT-type accelerators leads to significant economic efficiency.

The experiments show that NEB irradiated chicken eggs do not fall under the type of product that requires marking with a “Radura” sign.

It is important to note that the introduction of the small doses stimulation method in the agricultural industry requires additional in-depth studies of the increase in fertility or biomass of animals from the point of view of favorability and utility for the consumer.

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