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Research Article

Periblastic Sanitation of Poultry Meat and Offal with Nanosecond Electron Beam

[1]A. S. Krivonogova, [2]S.Yu. Sokovnin, [3]A. G. Isaeva,

[4]I. A. Shkuratova, [5]I. M. Donnik, [6]O. G. Loretts, [7]K. V. Moiseeva,

[8]N. B. Musikhina and [9]R. A. Vazirov

[1]Federal State Budgetary Educational Institution of Higher Education
"Ural State Agrarian University" (FSBEI HE Ural SAU), 42, K. Liebknechta St., Ekaterinburg
Federal State Budgetary Scientific Institution "Ural Federal Agrarian Scientific Research Centre,
Ural Branch of the Russian Academy of Sciences"
(FSBSI UrFASRC, UrB of RAS), 112 A, Belinskogo St., Ekaterinburg
[2]Federal State Budgetary Educational Institution of Higher Education
"Ural State Agrarian University" (FSBEI HE Ural SAU), 42, K. Liebknechta St., Ekaterinburg
Federal State Budgetary Scientific Institute of Electrophysics,
Ural Branch of Russian Academy of Science (FSBSI IEF UrB RAS), 106, Amundsena St., Ekaterinburg
[3]Federal State Budgetary Scientific Institution "Ural Federal Agrarian Scientific Research Centre,
Ural Branch of the Russian Academy of Sciences"
(FSBSI UrFASRC, UrB of RAS), 112 A, Belinskogo St., Ekaterinburg
[4]Federal State Budgetary Educational Institution of Higher Education"Ural State Agrarian University"
(FSBEI HE Ural SAU), 42, K. Liebknechta St., Ekaterinburg Federal State Budgetary Scientific Institution "Ural
Federal Agrarian Scientific Research Centre, Ural Branch of the Russian Academy of Sciences"
(FSBSI UrFASRC, UrB of RAS), 112 A, Belinskogo St., Ekaterinburg
[5-8]Federal State Budgetary Educational Institution of Higher Education"Ural State Agrarian University"
(FSBEI HE Ural SAU), 42, K. Liebknechta St., Ekaterinburg
[9]Federal State Budgetary Educational Institution of Higher Education"Ural State Agrarian University"
(FSBEI HE Ural SAU), 42, K. Liebknechta St., Ekaterinburg
Ural State Federal University (USFU), 19, Mira St., Ekaterinburg

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ABSTRACT:

We have done antibacterial sanitazation of the surface of chicken meat and offal in closed containers with nanosecond electron beam on accelerators type URT. We have conducted the research on the level of bacterial load of the surface of meat products, species composition and survival rate of microorganisms, and changing of their biochemical properties after the influence of accelerated electrons. Also, the article gives the results of experimental periblastic sanitation of the poultry meat products in containers made of various polymer materials. Comparative analysis of efficiency of methods of processing various types of products (broiler carcass, chicken fillet, prefabricated meat and offal) with accelerated electrons is given.

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Keywords: nanosecond electron beam, chicken meat, offal, antibacterial treatment, bacterial load.

1.INTRODUCTION

Electrophysical technologies are successfully implemented in processing of primary produce and products in some industries of food production [2]. The most widely-used methods are radiation sterilization and pasteurization of fish products, fruits, vegetables, cereals, juice, eggs, milk and seafood [3,4,11]. The use of those methods make it possible to solve a number of the following important issues: to prolong the expiry date of products; provide their biological safety and preserve valuable native components of protein, vitamin and lipid nature [5,6,13]. Nowadays industrial meat production uses traditional methods of sanitation of meat products, including thermal, physical or chemical influence. However, these methods have a number of unfavourable characteristics that limit their possibilities. Heating results in permanent denaturation of proteins and can not be used in production of refrigerated or frozen prefabricated meat and offal [8,9]. The use of chemical disinfectants does not always provide the expected level of antimicrobial treatment, so constant change of anti-infective agents is required. Besides, some pathogenic microorganisms are highly resistant to the influence of anti-infective agents, so contamination of solutions in chilling containers or cells results in bacterial semination of all the birds' carcasses at the given stage of processing. These microorganisms are of such types as Salmonella, Campylobacter, Listeria, Staphylococcus, Pseudomonas, that present danger of infection for a human [9,15].

Also, one more disadvantage of chemical methods of processing of primary produce in poultry industry can be generation of large amount of waste liquid, such as water contaminated with anti-infective agents, resistant microorganisms and others. Electrophysical methods of sanitation of primary produce and products of poultry industry make it possible to not only reduce bacterial load of the objects up to safe level without decrease of their quality, but are also resource-saving and ecologically safe. Damage of bacterial cell internal structures (DNA, membranes, ferments) causes high bactericidal activity of electron beam [7,9,10].

The method of food products and primary produce with impulses of accelerated electrons has proved to be efficient during processing of hatchery and market eggs, melange, milk, vegetables and fruits [14].

Bactericidal action of radiation treatment on Vibrio parahaemolyticus, Salmonella Enteritidis in seafood has been proved [11]. Its use in industrial poultry production for antimicrobial treatment of surface of chicken carcasses, refrigerated prefabricated meat, offal seems to be the promising one.

The disadvantages of radiation sterilization are high cost of industrial electron accelerators and high level of danger for the operating personnel. This danger can be significantly reduced by optimization of the source of radiation.

Besides, on the account of the proper choice of electron energy we should choose such a profile of the distribution of the absorbed dose inside the product that by radiation it can be possible to eliminate microorganisms on the surface (or in thin layers) without radiation of the whole product. It is of upmost importance, as it helps to significantly decrease negative effect of radiation on the product properties. In such a way, an internal part of food products is not or only insignificantly subject to radiation. Such an influence can be equal to the one of increased background radiation, so the products processed by NEB can not be equal to the ones processed with the mark of "Radura" that makes it possible to avoid consumers' prejudiced attitude and radiophobia.

Nanosecond electrons with energy of up to 0.5 MeV are the most suitable for this purpose. More effective bactericidal effect of nanosecond electron beam (NEB) has been stated [14], that can significantly reduce the absorbed dose, resulting in increase of the efficiency of the method by the same energy demands and expenses.

The specific feature of the NEB range is the presence of significantly greater amount of low-energy electrons, which appear during acceleration on the impulse fronts of

acceleration voltage. In case of this issue, this fact proves to be positive, as it provides the proper profile of distribution of the absorbed dose inside a product.

At present nanosecond electron accelerators of type URT [14] have been developed and produced, that makes it possible to significantly reduce both expenses on the source of radiation itself and radiological protection of personnel.

It is worth to note that it is possible form NEB of the exact required size, according to the size of the object subject to radiation, that eliminates energy consumption on beam expansion, as in case of DC beams or microsecond influence, and helps to avoid a number of issues regarding scanning. It is important that cathodes used for formation of NEB do not require some additional energy sources, as in case of DC beams (for heating or formation of plasma). Besides, they operate by low vacuum (~0,13Pa) and can resist even impact pressurization losses. That significantly reduces the expenses on the construction of accelerators of type URT and simplifies their use.

A doubtless advantage of an electron beam is the possibility to do the sanitation of already finished products in containers. Common usage of containers made of polymer materials results in demand on such methods of product processing that do not affect the properties of packaging [16]. Radiatoon with an electron beam meets the requirements, as used in doses necessary for sanitation and disinfection of food products, it does not have any great effect on packaging materials [2,6].

2. METHODS OF PERIBLASTIC ANTI-MICROBIAL TREATMENT OF POULTRY MEAT AND OFFAL WITH NANOSECOND ELECTRON BEAM

For treatment of chicken meat and by-products with accelerated electrons a pulse-periodic nanosecond accelerator URT-0,5 (electron energy up to 500 keV, impulse time 50 ns, frequency up to 200 Hz) [12]. The samples were prepacked products in containers: chicken fillet, drums, thighs, liver, hearts, and chicken carcasses. The packaging was containers made of expanded polystyrene (EP), airlight covering, outer polyolefin packaging of two types – stretch wrap (LLDPE), and BOPP-film; polyethylene (PE) bags. The samples were put on feeding table and passed through working space of the unit under the influence of width-uniform radiation with impulse electron beam. The range of absorbed doses was from 5.5kGy up to 86.5 kGy. Radiation control was done by a film dosimeter SO PD(F) R-5/50 type [1] in various points of the object influenced by radiation.

Quality control of treatment was done by means of collecting samples. The following microbiological research was done: determination of total bacterian count (TBC); identification of microorganisms and stating of their biochemical properties (ability to ferment Saccharum). Bacterial load of samples of meat and by-products during the period of three days of storage in closed containers by temperature of 0°…+2°C was evaluated.

3.RESEARCH ON BACTERIAL LOAD OF SAMPLES OF CHICKEN MEAT AND OFFAL IN VARIOUS TYPES OF PACKAGING, PROCESSED WITH ACCELERATED ELECTRONS

The analysis on bacterial load of the surface of samples of refrigerated chicken fillet, liver, hearts, drums, thighs, and chicken carcasses in various types of closed plastic packaging processed with NEB was done. After the control samples were taken and passed through working space of an accelerator, the total bacterian count in wash-offs from the surface of control samples was analyzed. The most effect was detected in case of processing of samples of chicken fillet with accelerated electrons. By the absorbed dose within the range of 6 - 9 kGy, the number of microorganisms on the surface of meat reduced twice; by 22 - 24 kGy it was 7-8 thousands CFU/g. By doses of 40 - 86 kGy all the surface of samples was germ-free (Figure 1).

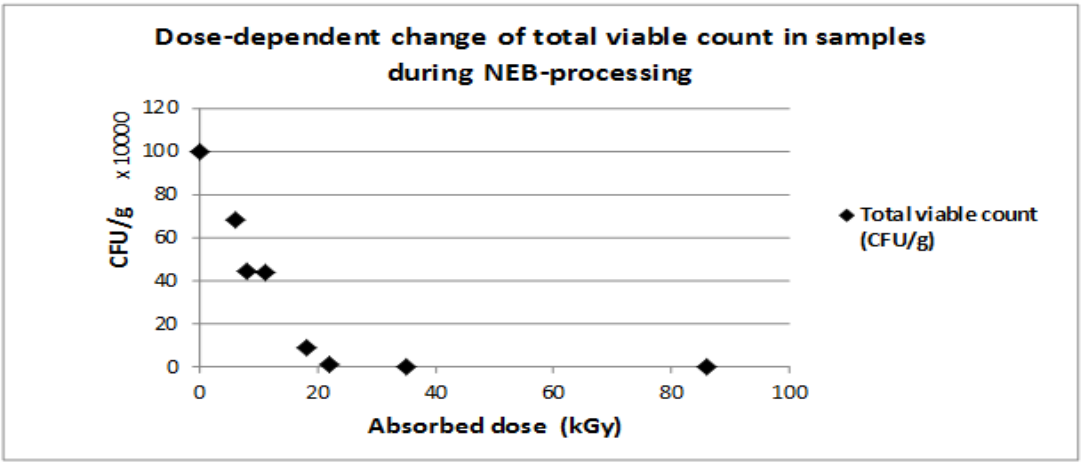

Figure 1 – Dose-dependent change of the total bacterian count in samples of chicken fillet processed with NEB

By processing of offal with accelerated electrons a number of specific features have been discovered. Thus, the microorganisms on the surface and in facial layer of chicken liver (up to 1,5 mm) have shown less resistance to the influence of accelerated electrons, than the microorganisms in samples of chicken fillet. The sterilization dose, by which no viable colony-forming units were found in samples, was within the range of 28 – 36 kGy.

The use of the NEB technology for sanitation of chicken hearts in containers was the least effective one. Influence with the absorbed dose within 10 kGy have not shown any statistically significant reduction of total bacterian count. By high absorbed dose (34 - 38 kGy) the semination level of the surface of chicken hearts stayed high enough (Figure 1). Supposedly, it was connected with presence of liquid in containers used for this kind of offal. The liquid containing microorganisms is inside hearts and not subject to the influence of NEB, because of insufficient penetrating power. Transfer of liquid during transportation of closed containers might have caused recontamination of germ-free surface of products.

Table 1 – Average total bacterian count (TBC) by processing of the samples of chicken offals with accelerated electrons with various absorbed doses

Samples	Absorbed dose of NEB (kGy)	TBC
Packaged refrigerated liver	0 (control)	$>10^6$
	11	$3{,}7*10^4$
	28	14
	36	0
	86	0
Packaged refrigerated chicken hearts	0 (control)	$7{,}75*10^5$
	8	$7{,}74*10^5$
	18	$6{,}8*10^5$
	22	$9{,}7*10^4$
	34	$2{,}23*10^4$
	38	$2{,}1*10^4$

During processing of refrigerated chicken carcasses, drums and thighs by the method of nanosecond electron beam the influence of packaging on the efficiency of periblastic sanitation was analyzed. It was detected that by the absorbed doses within the range of 2 - 4 kGy there is not any significant difference between the level of bacterial load in samples of carcasses in EP-containers, and the ones in polyethylene bags or BOPP-film. Thus, by the dose of 2 kGy the average TBC was $3*10^4$. By the absorbed dose of 5 kGy and more the advantage of the BOPP-film packaging was detected. For the samples in that type of packaging, the average TBC was 1,5-1,7 times less than for the samples in PE or EP packaging.

The NEB sanitation of chicken drums and thighs has not shown any difference in microbiological properties of the samples in the EP containers and polypropylene containers with the stretch-film.

4. EVALUATION OF RADIOSENSIBILITY OF SOME TYPES OF PATHOGENIC AND OPPORTUNSITIC PATHOGEN MICROORGANISMS OF PRE-FABRICATED MEAT PROCESSED WITH NEB

In the course of the microbiological research done on the samples, the following microorganisms were identified: Enterococcus faecium, Enterococcus faecalis, Proteus spp., Enterobacter spp., Pseudomonas aeruginosa, E.coli, Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus saprophyticus, Citrobacter, Candida spp., and Aspergillus spp. The most frequent ones were P. aeruginosa Ent. Faecium (found in over 20% samples) and S. epidermidis (found in over 10% samples). The analysis of the dynamics of viability of microorganisms on the surface of the NEB-processed chicken carcasses, meat and by-products has shown that P. aeruginosa, S. epidermidis and Ent. faecium were most resistant to high radiation doses. In some cases those microorganisms were found in the samples processed with NEB with the absorbed dose of 35- 40, and not found in 100% cases only in the samples with AD of 85 kGy. On the other hand, for example, E.coli was found mostly in the samples processed by NEB with low doses. Within the range of 8-12 kGy the frequency of strains reduced twice and within the range of 20-35 kGy there were only individual cases. In samples processed with the dose of over 35 kGy E.coli was not found.

Supression of the Citrobacter strains was discovered by the doses within the range of 1 – 35 kGy and by the doses of over 40 kGy that microorganism was not found. According to our data, the range of doses, within which the frequency of detection and activity of the Proteus strains reduced by 50-70% by the range of 10 – 25 kGy, whereas by the doses within the range of over 35 kGy no Proteus was found.

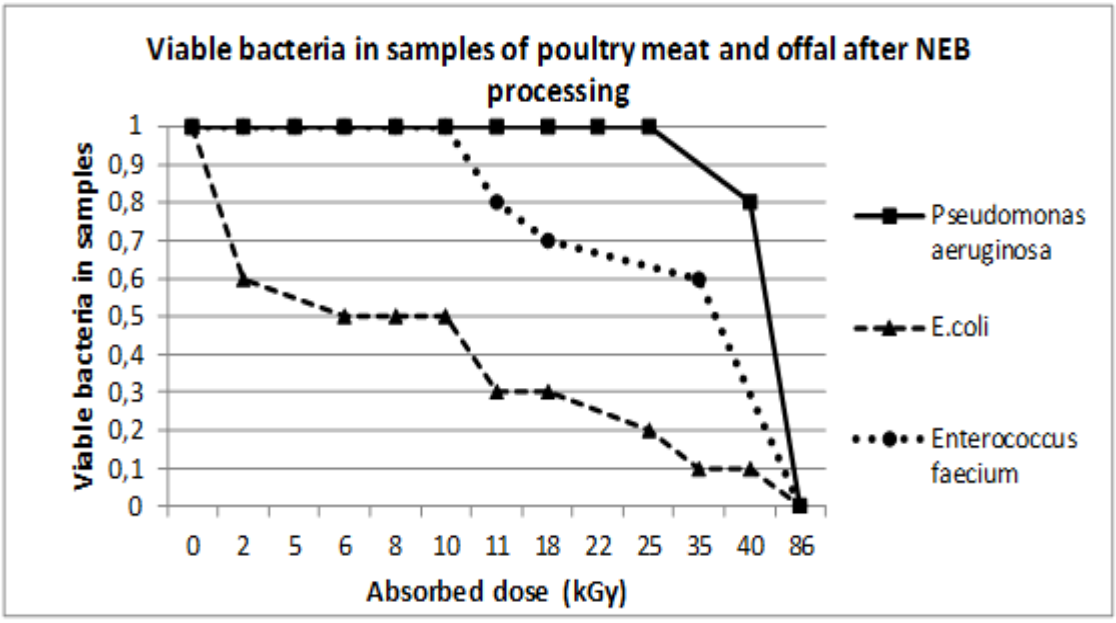

Figure 2 – Average bacteria viability by processing the samples of poultry meat and offal with nanosecond electron beam

Among staphylococcus the ones most resistant to high doses were the S.epidermidis strains. The significant suppression of viability of those microorganisms was stated only in the samples of meat and offal by the absorbed dose of over 40 kGy.

The least resistant ones was S. aureus, its activity by the absorbed doses within the range of 12-22 kGy reduced twice on average (Figure 3).

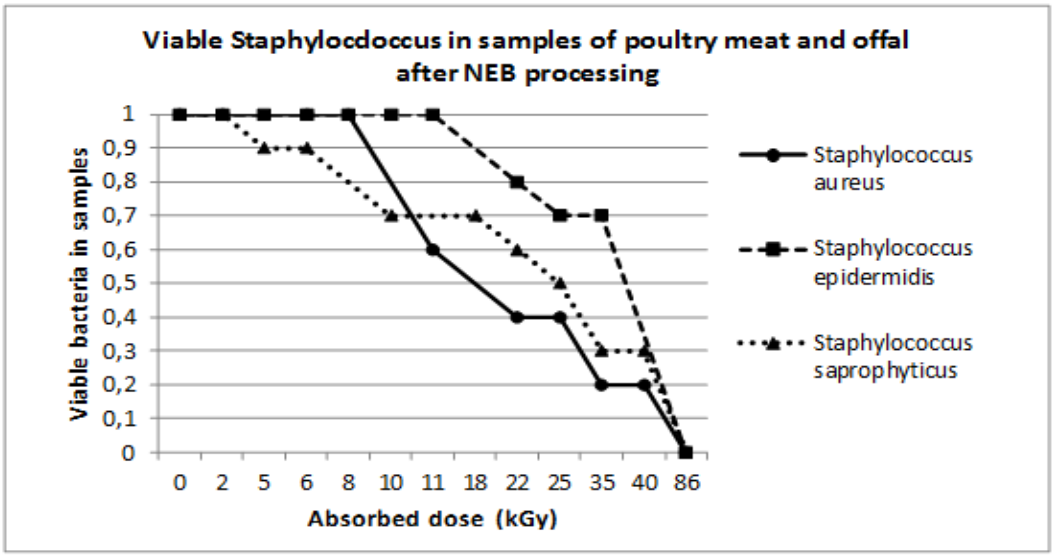

Figure 3 – Average Staphylococcus viability by processing the samples of poultry meat and offal with nanosecond electron beam

5. INFLUENCE OF NANOSECOND ELECTRON BEAM ON THE ABILITY OF MICROORGANISMS TO FERMENT SACCHARUM AND SPIRITS

The strains of microorganisms detected in control and experimental samples were researched, to state their ability to ferment Saccharum and spirits. Maltose, lactose, saccharose, glucose, sorbite, arabinose, dulcite, rhamnose, mannite, mannose, and xylose were used.

Analysis of biochemical activity of microorganisms has shown the pronounced dose-dependent effect among the Enterococcus faecium strains detected in the samples of chicken fillet. By the absorbed dose of over 22,7 kGy that microorganism lost its ability to ferment lactose, dulcite and rhamnose. Also, less intensivity of fermentation of maltose, saccharose, sorbite, arabinose, mannose, and xylose was stated. In the samples, the surface of which was processed with nanosecond electron beam with the absorbed dose of over 34 kGy Enterococcus faecium was not found.

The Staphylococcus epidermidis strains by the absorbed dose of over 18 kGy lost their ability to ferment dulcite, and by the dose of over 34 kGy there was no growth. The experimental samples of the Enterobacter spp., Pseudomonas aeruginosa, Staphylococcus aureus, and E.coli strains have not shown any suppression of biochemical functions, as compared with the control ones.

6. RESULTS

Processing of poultry meat, chicken carcasses and offal with nanosecond electron beam allows to reduce bacterial load of products directly in their closed packaging. The research done have shown dose-dependent dynamics of microflora suppression on the surface of chicken carcasses, poultry meat and offal influenced by accelerated electrons. The range of absorbed doses by which bacterial load reduces twice, as well as the range of sterilization dose for sanitation of various kinds of poultry meat production have been determined. Thus, by processing chicken fillet, and chicken drums, thighs and carcasses the number of microorganisms on the surface was 7-8 thousands CFU/g by 22-24 kGy, whereas the influence with the dose of 40 - 86 kGy provided elimination of microorganisms not only on the surface but 1-1.5 mm deep. This fact acquires most importance by sanitation of chicken carcasses with the patterned surface that is not smooth. Processing chicken liver with accelerated electrons have shown low range of sterilization doses, that is 28 – 36 kGy.

Various forms of packaging (expanded polystyrene, polypropylene, polyethylene, or BOPP-film) do not have any significant effect on the efficiency of NEB sanitation of poultry meat.

The microorganisms detected in control and experimental samples, belong to the typical opportunistic pathogen and pathogenic microflora and are mostly presented by Enterococcus faecium, Pseudomonas aeruginosa, E.coli, Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus saprophyticus, and Candida. The most resistant ones to NEB are Ent.faecium, P. aeruginosa and S. epidermidis, and the least resistant one is E.coli.

The influence of NEB sanitation on biochemical properties of the Enterococcus faecium strains on the meat surface was also stated. Thus, by the dose of over 22 kGy that microorganism stopped fermentation of lactose, dulcite and rhamnose. S. epidermidis by the dose within the range of 22-35 kGy lost its ability to ferment dulcite.

7.CONCLUSION

Implementation of the NEB technology for periblastic sanitation of packaged poultry meat and offal is considered to be promising for industrial poultry production. Dose-dependent dynamics of suppression of growth of typical pathogenic and opportunistic pathogen microorganisms proves the possibility of effective disinfection of the product surface. Therefore, that fact does not only result in increasing safety of products, but also allows to prolong the expiry date of refrigerated poultry meat and offal, that is especially important for large retail chains selling this kind of products. The doubtless advantage of the technology of NEB sanitation is the possibility to process packaged products, that eliminates the case of meat recontamination with microorganisms. To achieve the maximum effect of anti-microbial processing, it is necessary to make a proper choice of technological regimes of influence, effective dose, electron energy and frequency of an electron beam, taking into account the type of products.

9. CONFLICT OF INTEREST

The authors confirm that the data presented here have no conflict of interest.

CREDITS

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