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PREVENTIVE TREATMENT OF DRYING CHAMBER WITH UV RADIATION AND OZONIZATION FOR PROTECTION AGAINST SPOILAGE OF RAW SMOKED SAUSAGES

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Abstract. *In this work, we present data on efficiency of UV irradiation and its combination with ozone treatment for disinfection of drying chambers of dry smoked sausages that are subject to molding during storage. Biocide effect was created using UV irradiator OBN-150 and ozonator-irradiator OZUF. A study of the total number of microorganisms and molds before and after inactivation was conducted with exposition times of 30, 60 and 90 minutes. Biocide effect was stronger with longer exposition times. Molds were more resistant to the effect of irradiators than bacteria. As a result of 90-minute irradiation with OZUF apparatus we achieved death of approximately 90% of microbiota and more than 80% of molds. Shelf-life of dry smoked sausage without molding increased.*

Keywords: *Protection, drying chamber, sausage, ozone, shelf-life, UV irradiation*

1. INTRODUCTION

In recent years growing urgency for meat industry is a topic of increasing microbiological effectiveness of controlling food products and efficiency of their antimicrobial protection. This is associated with the fact that in Russia and other countries a number of diseases emerge (salmonellosis, dysentery, toxicosis, etc.), which are associated with the consumption of meat products infected with various microorganisms [1, 2].

The epidemiological safety and quality of meat depends on factors such as the absence of infection of a slaughter animal, its maintenance conditions, transportation of meat, the technology of primary processing, as well as further processes of heat treatment and storage. If the storage conditions of meat and meat products are affected, then microbiological spoilage occurs in the form of rotting, mucus, mold, pigmentation, etc. On the surface of meat and meat products, putrefactive, lactic acid, butyric acid bacteria, micrococci, mold fungi, yeast and other microorganisms usually appear. These processes very often cause food poisoning [2, 3]. The list of microorganisms that cause damage is quite large. Gram-negative rods are known to be among the bacteria that cause spoilage, for example, *Pseudomonas*, as well as gram-positive spore-forming bacteria, such as *Bacillus*, *Clostridium*. In addition, there is a large group of bacteria from the family *Enterobacteriaceae*. This group is also used as an indicator of quality and nutritional risk. The surfaces of long-stored products are often colonized by mold fungi from the genera *Penicillium*, *Aspergillus*, *Cladosporium*, etc. [4, 5, 6,]. In order to extend the shelf life and prevent rapid spoilage of meat and meat products, highly efficient technologies are being created and various long-term storage methods based on the use of vacuum, modified gas atmosphere, preservatives of various nature, physical and chemical factors, etc. are used [7, 8]. Among all types of meat after the ban on importing pork into the Russian Federation since 2014, the share of consumption of poultry meat (chicken, turkey, goose, duck, guinea fowl) and their products has increased significantly. However, one of the significant problems of the poultry industry is to ensure the longest shelf-life for products of different product assortment. Thus, during storage, the stability of the properties of sausages containing chicken meat depends mainly on how dehydrated they are. Therefore, after smoking, sausages are dried. To preserve the qualities inherent in raw smoked sausage of a certain sort, the moisture content in the finished product is set at a level of 25-30%. Drying of smoked sausages is carried out at a temperature of 12 ° C and a relative humidity of 75%. Duration of drying is 25-90 days.

The purpose of our study was to assess the possible use of radiant energy using UV irradiators, as well as in combination with ozonation for disinfection of drying chambers for smoked sausages of long-term storage.

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2. Materials and methods

In our experiments, we used the drying chamber with a volume of 200 m³, equipped with OBN-150 UV irradiators with two sources of irradiation of 30 W each, mounted on the walls, or UV irradiators with OZUF 40 W ozonizers. OZUF ozonizer is a recirculator, which can disinfect air in the "stagnant zones" of the room. Its UV lamp is in a closed housing with a fan that drives the air around the lamp and disinfects it with UV rays and ozone. This eliminates the undesirable oxidation of fats on the sausage surface. The greatest bactericidal action against microorganisms has a spectrum of rays of 240-280 nm [9].

Drying chambers had air conditioners which regulated levels of temperature and humidity. The operation of air conditioners was additionally controlled by psychrometers and thermometers. Irradiation was carried out in the dark for 30, 60 and 90 minutes. Sausages for drying were placed in tiers in several rows, so as to ensure free air circulation between sausage loaves of the same size.

To study the effect of UV irradiation on the ability to inactivate the microbiota of the chamber, raw smoked sausages were used, which have in its composition minced chicken. The determination of the total number of microorganisms and mold fungi in 1 m³ of the chamber was carried out after taking air samples using a sampling device (PU-1B) (Russia) and taking into account the grown colonies (CFU / m³) on Petri dishes with nutrient agar [10]. Samples through PU-1B were taken through conical nozzles with many tips and holes, under which Petri dishes were placed with meat-peptone agar. Jets of air from the nozzle containing the microbiota, falling on the surface of the nutrient medium, infected it. After 24 hours of incubation at 37 ° C, the grown bacteria were taken into account, and after 3-4 days – the mold fungi. Quantitative indices of the total number of microorganisms and mold fungi were calculated for 1 m³ of air [10]. Statistical data processing was performed using parametric criteria: arithmetic average (X), its error (m) and confidence interval fluctuations in arithmetic average value (I95) for reliability ($p \leq 0.05$).

3. Results

Experimental results after a 30-minute disinfection are presented in Table 1 and 2, in which indices of the total number of microorganisms (CFU / m³) and mold colonies are given.

Table 1. The results of the study of the bactericidal and fungicidal properties of the ultraviolet irradiator OBN-150 after treatment of the air in the drying chamber for 30 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m³ (CFU/ml)			
	Before treatment		After treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.67×10³	0.933×10³	2.00×10³	0.800×10³
2	2.53×10³	0.667×10³	1.73×10³	0.667×10³
3	2.40×10³	0.800×10³	1.87×10³	0.667×10³
4	2.53×10³	0.933×10³	2.00×10³	0.800×10³
5	2.27×10³	0.933×10³	2.00×10³	0.933×10³
6	2.40×10³	0.800×10³	1.87×10³	0.800×10³
7	2.40×10³	0.667×10³	1.73×10³	0.533×10³
8	2.67×10³	0.800×10³	1.73×10³	0.667×10³
9	2.53×10³	0.800×10³	1.87×10³	0.800×10³
10	2.27×10³	0.933×10³	2.00×10³	0.800×10³
X±m	(2.47 ± 0.043)×10³	(0.827 ± 0.031) ×10³	(1.88 ± 0.035)×10³	(0.747 ± 0.034)×10³
$X \pm I_{95}$	(2.47 ± 0.100)×10³	(0.827 ± 0.069) ×10³	(1.88 ± 0.078)×10³	(0.747 ± 0.076)×10³

Table 2. The results of the study of the bactericidal and fungicidal properties of the ultraviolet irradiator and ozonizer OZUF after treatment of the air in the drying chamber for 30 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m³ (CFU/ml)			
	before treatment		after treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.40×10³	0.933×10³	0.667×10³	0.533×10³
2	2.53×10³	0.667×10³	0.800×10³	0.400×10³
3	2.40×10³	0.800×10³	0.800×10³	0.533×10³
4	2.67×10³	0.800×10³	0.933×10³	0.400×10³
5	2.53×10³	0.933×10³	0.933×10³	0.533×10³
6	2.67×10³	0.933×10³	0.667×10³	0.667×10³
7	2.40×10³	0.667×10³	0.800×10³	0.400×10³
8	2.27×10³	0.800×10³	0.800×10³	0.533×10³
9	2.40×10³	0.800×10³	0.933×10³	0.533×10³
10	2.53×10³	0.667×10³	0.667×10³	0.667×10³
X±m	(2.48 ± 0.039)×10³	(0.800 ± 0.033) ×10³	(0.800 ± 0.033) ×10³	(0.520 ± 0.030) ×10³
$X \pm I_{95}$	(2.48 ±0.087)×10³	(0.800 ± 0.074) ×10³	(0.800 ± 0.074)×10³	(0.520 ± 0.067) ×10³

As follows from Table 1, prior to UV treatment with OBN-150, the number of mold colonies was (0.827 ± 0.069) × 10^3, which was 33% of the total number of microorganisms in 1 m^3 of air (2.47 ± .0.100) × 10^3. After treatment, this value was about 40% (0.747 ± 0.076) × 10^3, i.e. the amount of mold, which is more resistant to UV radiation, has slightly increased in relation to the remaining total number of microbes (1.88 ± 0.078) × 10^3. Disinfection for 30 minutes using the OBN-150 device reduced the total number of microorganisms by 1.3 times, and the amount of mold decreased 1.1 times. Under the effect of irradiation, about 24% of the number of all microorganisms and about 10% of mold fungi died (Table 7). With a similar conduct of air disinfection using an ozonizer-irradiator OZUF within 30 minutes revealed a decrease in the total number of microorganisms after exposure by 3.1 times. However, due to the fungicidal action after the combined inactivation of microorganisms by UV rays and ozone, the number of mold fungi decreased only 1.5 times. The amount of mold before treatment was in the association with the microbiota 32%, and after 65%, i.e. with a decrease in the population of all microorganisms, mold fungi dominated again. Therefore, after using the OZUF for 30 minutes, there was a higher total biocidal and a separate fungicidal effect (Table 7) in the air after treatment of the drying chambers (67.7% and 35%) than in the same time mode with the irradiator OBN -150 (23.9% and 9.7%) This difference in performance is statistically significant ($p < 0.05$). The data also indicate the statistical significance of differences in the viability of microorganisms and mold fungi before and after a 30-minute exposure (both using OBN-150 and OZUF) (Table 7). Comparison of the decline in the number of all microorganisms and mold fungi with a 60-minute air treatment in the drying chamber showed (Table 3) that for OBN-150 the disinfecting effect led to a decrease in the average number of all microorganisms by 3.2 times: (2.19 ± 0.096) × 10^3 compared to (0.693 ± 0.091) × 10^3, and the number of mold fungi by 1.2 times: (1.13 ± 0.105) × 10^3 compared to (0.920 ± 0.098) × 10^3.

Table 3. The results of the study of the bactericidal and fungicidal properties of the ultraviolet irradiator OBN-150 after treatment of the air in the drying chamber for 60 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m^3 (CFU/ml)			
	before treatment		after treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.27×10^3	1.20×10^3	0.533×10^3	0.667×10^3
2	2.13×10^3	0.933×10^3	0.533×10^3	0.800×10^3
3	2.13×10^3	1.07×10^3	0.667×10^3	0.800×10^3
4	2.40×10^3	0.933×10^3	0.667×10^3	0.933×10^3
5	2.13×10^3	0.933×10^3	0.800×10^3	1.07×10^3
6	2.00×10^3	1.33×10^3	0.800×10^3	1.07×10^3
7	2.00×10^3	1.20×10^3	0.933×10^3	0.933×10^3
8	2.40×10^3	1.33×10^3	0.800×10^3	0.800×10^3
9	2.27×10^3	1.20×10^3	0.667×10^3	1.07×10^3
10	2.13×10^3	1.20×10^3	0.533×10^3	1.07×10^3
X±m	(2.19 ± 0.043)×10^3	(1.13 ± 0.047) ×10^3	(0.693 ± 0.041)×10^3	(0.920 ± 0.044) ×10^3
X±I_{95}	(2.19 ± 0.096)×10^3	(1.13 ± 0.105) ×10^3	(0.693 ± 0.091) ×10^3	(0.920 ± 0.098) ×10^3

Table 4. The results of the study of the bactericidal and fungicidal properties of the ultraviolet irradiator and ozonizer OZUF after treatment of the air in the drying chamber for 60 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m^3 (CFU/ml)			
	before treatment		after treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.13×10^3	1.33×10^3	0.667×10^3	0.267×10^3
2	2.4×10^3	1.47×10^3	0.400×10^3	0.267×10^3
3	2.13×10^3	1.33×10^3	0.400×10^3	0.400×10^3
4	2.27×10^3	1.2×10^3	0.667×10^3	0.267×10^3
5	2.27×10^3	1.2×10^3	0.533×10^3	0.400×10^3
6	2.4×10^3	1.07×10^3	0.533×10^3	0.267×10^3
7	2.0×10^3	1.33×10^3	0.400×10^3	0.267×10^3
8	2.13×10^3	1.2×10^3	0.267×10^3	0.400×10^3
9	2.53×10^3	1.33×10^3	0.533×10^3	0.267×10^3
10	2.27×10^3	1.47×10^3	0.400×10^3	0.267×10^3
X±m	(2.25 ± 0.048) ×10^3	(1.29 ± 0.038) ×10^3	(0.480±0.039) ×10^3	(0.307 ± 0.019) ×10^3
X±I_{95}	(2.25 ± 0.107) ×10^3	(1.29 ± 0.085) ×10^3	(0.480±0.087) ×10^3	(0.307 ± 0.042) ×10^3

The death of all microorganisms was 68.4%, and mold fungi 18.6% (Table 7). It is probable that the irradiator had a greater inactivating effect not on fungi, but on bacterial representatives of the microbial association. However, in this association, the proportion of mold fungi before exposure to UV rays

for 60 minutes was 54%, and after treatment this value, as in a 30-minute period, increased (by 1.2 times) due to a higher resistance of mold to radiation compared to bacteria. These data indicate that this mode of UV irradiation of the sausage drying chamber cannot definitively prevent the molding of products.

It was of interest to disinfect the drying chamber with smoked sausages with the OZUF device for 60 minutes. As can be seen from Table 4, the total number of microorganisms, on average, decreased 4.7 times, and mold fungi 4.2 times. It should be noted that the share of mold fungi in the total number of microorganisms before the air treatment was 53%, and after disinfection 64%, i.e. the increase in the amount of mold in the remaining association of microorganisms is again associated with a greater mortality of bacteria that are sensitive to two biocidal factors (UV and ozone). Concentration of all microorganisms and separately mold fungi in 1 m^3 of air after a 60-minute disinfection turned out to be at a statistically equal level (78.7 and 76.2%, respectively).

Data comparing the effectiveness of factors detrimental to microorganisms from exposure to OBN-150 and OZUF in the air of the drying chamber for 60 minutes also statistically confirmed the effectiveness of the biocidal action of OZUF (Table 7).

In order to more intensively affect the microbes present in the drying chamber, a 90-minute treatment of the indoor air environment was carried out. As the data, obtained with the use of OBN-150, in Tables 5-7 shows, the death of the total number of microorganisms present in the air of the drying chamber increased from 23.7% to 75.7% with the increase in exposure from 30 to 90 minutes, and for mold fungi from 9.7 % to 56.3%.

Table 5. The results of the study of the bactericidal and fungicidal properties of the ultraviolet irradiator OBN-150 after treatment of the air in the drying chamber for 90 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m^3 (CFU/ml)			
	before treatment		after treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.80×10^3	1.20×10^3	0.667×10^3	0.533×10^3
2	2.67×10^3	1.20×10^3	0.667×10^3	0.533×10^3
3	2.80×10^3	1.07×10^3	0.800×10^3	0.667×10^3
4	2.53×10^3	1.33×10^3	0.533×10^3	0.533×10^3
5	2.53×10^3	1.20×10^3	0.800×10^3	0.400×10^3
6	2.67×10^3	1.07×10^3	0.667×10^3	0.533×10^3
7	2.80×10^3	1.07×10^3	0.533×10^3	0.400×10^3
8	2.40×10^3	1.20×10^3	0.533×10^3	0.400×10^3
9	2.53×10^3	1.33×10^3	0.667×10^3	0.667×10^3
10	2.53×10^3	1.20×10^3	0.533×10^3	0.533×10^3
X±m	(2.63±0.043) ×10^3	(1.19 ± 0.029) ×10^3	(0.640±0.032) ×10^3	(0.520 ± 0.030) ×10^3
X±I$_{95}$	(2.63±0.096) ×10^3	(1.19 ± 0.065) ×10^3	(0.640±0.071) ×10^3	(0.520 ± 0.067) ×10^3

Table 6. The results of the study of the fungicidal and bactericidal properties of the ultraviolet irradiator and ozonizer OZUF after treatment of the air in the drying chamber for 90 minutes

№ of the Petri dish	Numbers of colonies of microbes and molds in 1 m^3 (CFU/ml)			
	before treatment		after treatment	
	total microorganisms	of which molds	total microorganisms	of which molds
1	2.67×10^3	1.07×10^3	0.133×10^3	0.267×10^3
2	2.53×10^3	1.33×10^3	0.267×10^3	0.133×10^3
3	2.53×10^3	1.20×10^3	0.267×10^3	0.133×10^3
4	2.80×10^3	1.33×10^3	0.400×10^3	0.00
5	2.40×10^3	1.33×10^3	0.267×10^3	0.267×10^3
6	2.67×10^3	1.07×10^3	0.267×10^3	0.400×10^3
7	2.80×10^3	1.20×10^3	0.133×10^3	0.133×10^3
8	2.40×10^3	1.07×10^3	0.400×10^3	0.133×10^3
9	2.53×10^3	1.33×10^3	0.267×10^3	0.267×10^3
10	2.80×10^3	1.20×10^3	0.133×10^3	0.133×10^3
X±m	(2.61±0.047) ×10^3	(1.21 ± 0.034) ×10^3	(0.253 ± 0.030) ×10^3	(0.187 ± 0.031) ×10^3
X±I$_{95}$	(2.61±0.105) ×10^3	(1.21 ± 0.076) ×10^3	(0.253 ± 0.067) ×10^3	(0.187 ± 0.070) ×10^3

The combined irradiator-ozonizer OZUF turned out to be more effective. At the same time, the exposure provided an antibacterial effect with death from 67.7% to 90.3% and fungicidal effect – 35% to 84.5%. These were the highest rates of disinfection of air drying chambers for sausages, confirmed statistically ($p < 0.05$, Table 7).

It should be noted that additional studies of the organoleptic properties of smoked sausages did not change the specific properties of the product. Observations on the possibility of infection of raw smoked sausages for four months showed the effectiveness of such treatment.

Table 7. Comparative characteristics of bactericidal and fungicidal properties of UV irradiators OBN-150 and OZUF in a drying chamber

№	Irradiator	Numbers of colonies of microorganisms and molds in 1 m³ of air, $(X \pm I_{95}) \times 10^3$, CFU/m³				Significance of differences before and after treatment $\frac{p}{p}$	Effectiveness of irradiators, %		Significance of differences in effectiveness (p)	
		before treatment		after treatment						
		total microorganisms	molds	total microorganisms	molds		total microorganisms	molds	total microorganisms	molds
	Treatment of the air for 30 min									
1	OBN-150	2.47±0.100 (2.37 – 2.57)	0.827± 0.069 (0.758 – 0.896)	1.88±0.078 (1.802 – 1.958)	0.747±0.076 (0.671 – 0.823)	$\frac{< 0.05}{> 0.05}$	23.9	9.7	p1-5 <0.05	p1-5 <0.05
2	OZUF	2.48±0.087 (2.393 – 2.567	0.800± 0.074 0.726 - 0.874)	0.800±0.074 (0.726 - 0.874)	0.520±0.067 (0.453 – 0.587)	$\frac{< 0.05}{< 0.05}$	67.7	35	p2-6 <0.05	p2-6 <0.05
		>0.05	>0.05	>0.05	<0.05					
	Treatment of the air for 60 min									
3	OBN-150	2.19±0.096 (2.094 – 2.286)	1.13±0.105 (1.025 – 1.235)	0.693±0.091 (0.602 -0.784)	0.920± 0.098 (0.822 – 1.018)	$\frac{< 0.05}{\leq 0.05}$	68.4	18.6	p3-5 >0.05	p3-5 <0.05
4	OZUF	2.25±0.107 (2.143 – 2.357)	1.29±0.085 (1.205 – 1.375)	0.480±0.087 (0.393 – 0.567)	0.307± 0.042 (0.265 – 0.349)	$\frac{< 0.05}{< 0.05}$	78.7	76.2	p4-6 ≤0.05	p4-6 <0.05
		>0.05	>0.05	<0.05	<0.05					
	Treatment of the air for 90 min									
5	OBN-150	2.63±0.096 (2.534 – 2.726)	1.19 ± 0.065 (1.125 – 1.255)	0.640±0.071 (0.569 – 0.711)	0.520± 0.067 (0.453 – 0.587)	$\frac{< 0.05}{< 0.05}$	75.7	56.3	p5-6 <0.05	p5-6 <0.05
6	OZUF	2.61±0.105 (2.505 – 2.715)	1.21±0.076 (1.134 – 1.286)	0.253±0.067 (0.186 – 0.320)	0.187±0.070 (0.117 – 0.257)	$\frac{< 0.05}{< 0.05}$	90.3	84.5	-	-
		>0.05	>0.05	<0.05	<0.05					

5. Conclusion

The data indicate the process of disinfection of the chambers for drying raw smoked sausages must be a combined action of UV rays and ozonation, with exposure times of at least 90 minutes.

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