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K. Yeryganov, MSc student, *E-mail:* yeryganov.onaft@gmail.com
B. Iegorov, Doctor of Technical Sciences, Professor, *E-mail: bogdanegoroff58@gmail.com*,
ORCID: 0000-0001-7526-0315, Researcher ID: Q-1365-2015, Scopus Author ID: 56578802600
Department of Grain and Feed Technology
Odesa National University of Technology, 112, Kanatna Str., 65039, Odessa, Ukraine

USING ULTRAVIOLET IRRADIATION TO DISINFECT COMPOUND FEEDS

Annotation

Compound feeds are sources of not only nutrients required to maintain animals' vital activity, but also of a complex of microorganisms inhabiting them. This complex develops in them after the heat treatment of raw materials (extrusion, conditioning, expansion, etc.), which creates non-competitive conditions for the foreign microorganisms to enter (in particular, from non-grain and animal raw materials). At the same time, the animal's gastrointestinal tract contains its own complex microbiome, which in young animals (at the time of switching to pre-starter) is not yet fully formed and not very stable. It can be disturbed by foreign microbiota, which will lead to a decrease in productivity. In addition, the foreign microbiota requires an immune response from the body, which is a very energy-consuming process. Therefore, the disinfection of compound feed for young animals at the stage of production and in finished form is reasonable and important. The most promising method of disinfection today is ultraviolet irradiation, which is widely used for disinfection of surfaces, air and water. It is cheap, easy in mounting and maintenance and effective without disrupting any properties of the product or feed. For compound feeds, it is currently used only on livestock farms, and is not used on production lines. Therefore, the task of this study was to test the effectiveness of ultraviolet irradiation of a compound feed for further implementation in manufacture. Irradiation with a bactericidal lamp of a model feed mixture (60% crushed wheat, 30% sunflower oilcake, 10% wheat bran) was conducted. The numbers of MAFAnM (mesophilic aerobic and facultatively anaerobic microorganisms) declined from 1 million to 20 thousand cells per gram after 5 hours (300 minutes) of UVC exposition (254 nm wavelength). The diagram obtained coincides well with the reference diagram for a typical bacterial strain and shows that the use of ultraviolet irradiation is quite effective even without requiring a long-time exposition. Therefore, it can be used industrially to disinfect compound feeds and their raw materials.

Keywords: compound feed, ultraviolet irradiation, disinfection, microbiome, productivity

Introduction

In the modern world, the technology of manufacturing compound feeds for domestic animals has reached a significant development. The range of feed and raw materials used today to produce compound feeds for a wide range of animals (from cattle to invertebrates) includes dozens of items that are selected according to the needs of animals and to the required level of their productivity. Due to the fact the basic raw materials for feed (grain processing products, oilseed meals, fish and meat-bone meal, etc.) are a favorable environment for the development of spoilage microbiota or even pathogenic microorganisms, the issue of ensuring the sanitary quality of feed arises.

Modern standards establish that the feed should be safe for the animal, that is, must not contain harmful impurities and components, which include pathogenic microbiota and toxins released by it (for example, mycotoxins). However, the total background microbiota, consisting of aerobic and facultative anaerobic microorganisms (MAFAnM), can also have a negative impact on the health of the animal through competitive interference with the normal microbiota of the gastrointestinal tract (GIT) of the animal. The integrity of the normal microbiota is particularly important for young animals due to both the greater vulnerability of the animal at this age and the impact of negative pressures during this period on the further life and productivity of the animal [1]. In addition, foreign microorganisms provoke an immune response, which consumes metabolized energy derived from feed (energy expenditure can increase very significantly), and therefore, a high load on the immune system reduces feed efficiency and animal productivity [2].

It is known that the normal microbiota, which in young animals before weaning consists mainly of bifidobacteria and lactic acid bacteria [3], is an important factor in the protection of the host organism from the interference of foreign and pathogenic microbiota due to competition and helps the host to absorb nutrients from the feed (increases digestibility). However, with a high amount of background microbiota in the feed, the normal microbiota of the animal's gastrointestinal tract can be disrupted, and the animal's metabolic energy expenditure on the immune response will increase, which will lead to negative consequences for its health and productivity. In turn, the decrease in productivity leads to losses in livestock farming due to losses in body weight, milk yield and egg production (or egg quality), which can be significant.

As a result of heat treatment of grain raw materials (conditioning, extrusion, expansion, etc.), a non-competitive environment arises, which is quickly populated by foreign microorganisms, including potentially harmful ones.

This necessitates the development of methods for disinfection of feed for young animals, both at the production stage and in finished form. The modern method of non-thermal disinfection is ultraviolet radiation. It is widely used to disinfect water, surfaces and air, as well as recently - food products at

manufactures and feeds on livestock farms [4]. However, it is not currently used on manufacturing lines.

Literature review

The microbiota of raw materials and finished feeds is not the same in different types of raw materials and feeds of different composition. In addition, the microbial contamination of loose and pelleted feeds is also different. A wide study of the microbiota of mixed fodders and their raw materials is the dissertation work of V. V. Sokolov [5], which presents the results of a study of a wide range of raw materials and two types of mixed fodders. Table 1 describes the general microbiological characteristics of raw materials and finished feeds according to V. V. Sokolov.

The table shows that the highest level of contamination with bacteria is found in animal raw materials, and with micromycetes - in cereals, which is explained by the composition of these substrates, which promotes the development of the corresponding groups of microorganisms. In addition, a high level of contamination with coliforms (more than 57% of samples of non-cereal raw materials) and staphylococci (almost 50% of samples, S. aureus - 16% of samples) was observed, which indicates the risk of dangerous pathogenic strains entering the animal's body.

Table 1 – Levels of microbial contamination of raw materials and finished feeds according to V.V.Sokolov [5]

Substrate	Index value
Bacteria, contamination level, CFU/g	
Grain raw materials	270 thousand
Bran	371 thousand
Non-grain vegetable raw materials	965 thousand
Animal raw material	2,8 million
Premixes	757 thousand
Finished feeds	1,99 million
Fungi, contamination level, CFU/g	
Grain raw materials	44,2 thousand
Bran	5,0 thousand
Non-grain vegetable raw materials	7,0 thousand
Animal raw material	6,3 thousand
Premixes	1,2 thousand
Finished feeds	27,3 thousand
Coliforms, % of samples with presence	
Grain raw materials	35,0
Non-grain and animal raw materials	57,4
Finished feeds	70,8
Other sanitary indices	
Staphylococci (total), % of samples with presence	49,3
Staphylococcus aureus, % of samples with presence	16,0
Toxigenic fungi, % of all recovered cultures	29,4
Salmonellae, % of samples with presence	22,8
Enteropathogenic *E. coli*, % of samples with presence	5,1

This picture is complemented by a modern study of the microbiota of poultry feed [6], conducted by modern methods. Fig. 1 shows the indices of the number of microbial species in poultry feed.

These data coincide with the previous study on the highest microbial load in animal raw materials (blood and meat-bone meal, poultry fat) and significantly lower in grain.

There are various ways of processing grain and non-grain raw materials and finished feed, which in one way or another have a disinfecting effect. However, they have certain disadvantages.

To date, some methods of *chemical treatment* of feed have been proposed to improve its sanitary condition in order to prevent spoilage and increase safety for animals: ozonation on poultry farms [7] and the use of sodium formate [8], but ozonation is not used industrially, and the effect of sodium formate is not sufficiently studied.

Ultraviolet radiation can also be used to improve the quality of compound feed. Ultraviolet radiation is a part of the electromagnetic spectrum between 190 and 380 nm wavelength, traditionally divided into three main parts: near UV, or ultraviolet A (UVA) - 320-380 nm; middle UV, or ultraviolet B (UVB) - 320-290 nm; far UV, or ultraviolet C (UVC) - 290-190 nm. Ultraviolet is an effective means of disinfection at a wavelength that corresponds to the peak of absorption on the DNA of living cells (250-265 nm) [9] with the formation of harmful compounds in it, leading to DNA destruction and cell death.

When testing for UV or ionizing radtation efficiency, a diagram is usually built to show the process (Fig. 2). It shows the rate of death of a cell population during the radiation exposure, depending on the dose the cells receive.

Ultraviolet radiation requires a certain duration of the process, which reaches several hours in the case of complete destruction of the microbiota, but this is unacceptable in manufacture. However, it is possible to install LEDs (UVC-LED) inside the equipment (gravity flow pipes, magnetic separators) above the material flow or to mount a line for disinfection of the finished feed before packing.

Formulation of the problem.

The target of this study was to test the effect of UVC radiation on total viable count of bacteria in compound feeds, using a model feed mixture. The task was to determine the total viable count of bacteria in the model feed mixture before and after exposing it to UVC for certain time periods.

Materials and methods.

The aim of the study was to test the effectiveness of irradiation of the feed product with ultraviolet radiation.

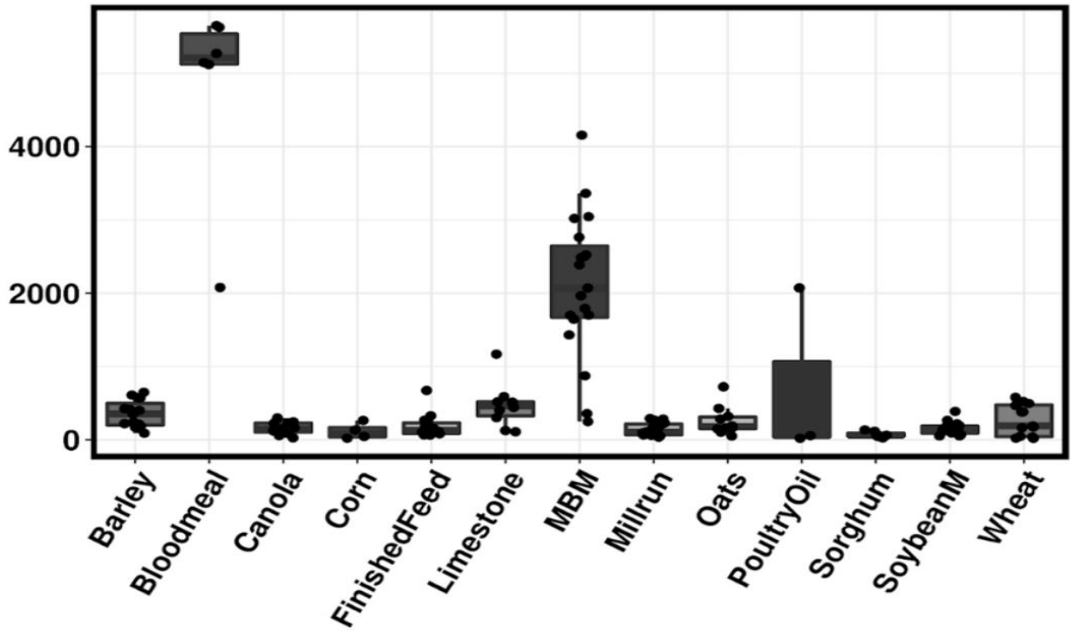


Fig. 1. Indices of the number of microbial species in poultry compound feeds and their raw materials according to metagenomic data obtained by [6]

To conduct this study, a model feed mixture was used, which was created according to the recipe: 60% wheat, 30% sunflower cake, 10% wheat bran. Wheat and oilcake were crushed to a particle size of 1-2 mm, then mixed with bran in the required proportions (% of weight). The resulting feed mixture was stored at room temperature in tightly closed containers (to prevent moisture content).

Microbiological studies were carried out according to the standard methodology for the study of grain and compound feed [10].

For the purpose of microbiological studies, weights of 1 g of the obtained feed mixture were taken, 11 weights in total.

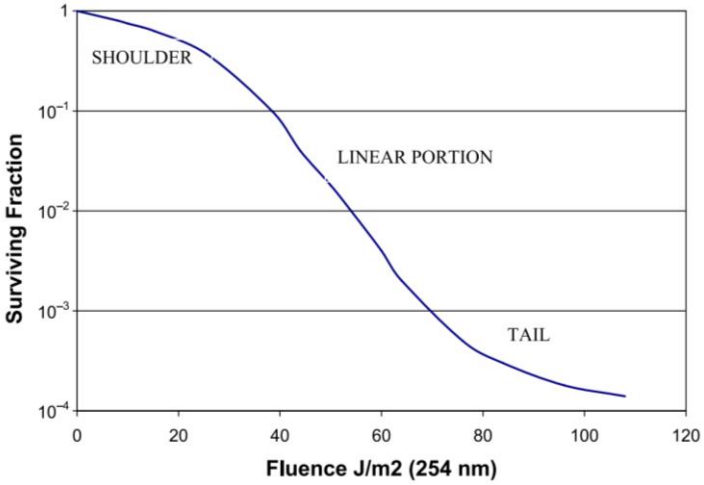


Fig. 2. Curve of bacterial death (average bacterial strain) depending on the UVC radiation dose (254 nm) [11]

One of the samples was immediately subjected to microbiological examination (control), the other 10 samples were laid out in a thin layer on sheets of paper under a UV lamp, covered with a tray to avoid settling of microorganisms from the air, and left until morning. For the study, a bactericidal table lamp Osram Germicidal Puritec HNS G15T8/OF was used, wavelength 254 nm, power 15 W.

The lamp was turned on the next day in the morning. Every 0.5 h for 5 hours (after 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 min) one sample was taken, which was immediately placed in vials with sterile water for rinsing. The contents of the vials were thoroughly shaken, then a series of 10-fold dilutions were made. At the initial stages of irradiation 4 dilutions (up to 1:100000) were made and inoculations taken from the last two, at the final stages after 180 min of irradiation - 3 dilutions (up to 1:10000) with inoculating from the last two. From each of these dilutions 1 ml was pour-plated on MPA in two replicates.

The cultures were incubated at +37°C for 24 h and the plates were checked. If necessary, they were left for another 24 h of incubation (mostly the cultures of the last irradiation intervals, since the incubation time was correspondingly shorter). After incubation, the colonies that grew were counted and the number of bacteria (mesophilic aerobic and facultative anaerobic microorganisms - MAFAnM) per 1 g of feed mixture was calculated by multiplying by the dilution factor.

Results and their discussion

According to the results obtained, a table (Table 2) was filled in and a diagram (Fig. 3) of changes in the level of microbial contamination of the material was drawn. This level was estimated in CFU (colony forming units) per 1 g.

The table and diagram show that the number of MAFAnM before irradiation (control) was at the level of 10^6 CFU/g, and during irradiation it gradually decreased.

It is noticeable that during the first 150 minutes the number of microorganisms decreased quite sharply, and then - much slower, which can be explained by the rather rapid death of non-spore-forming microbiota in the first hours of irradiation and the survival of spore

Table 2 – Changes in MAFAnM number (CFU/g) in the model feed mixture under action of UVC

Duration of exposition, min, and level of CFU/g										
0	30	60	90	120	150	180	210	240	270	300
$1 \cdot 10^6$	$7 \cdot 10^5$	$5 \cdot 10^5$	$3 \cdot 10^5$	$2 \cdot 10^5$	$1 \cdot 10^5$	$8 \cdot 10^4$	$7{,}5 \cdot 10^4$	$6 \cdot 10^4$	$4 \cdot 10^4$	$2 \cdot 10^4$

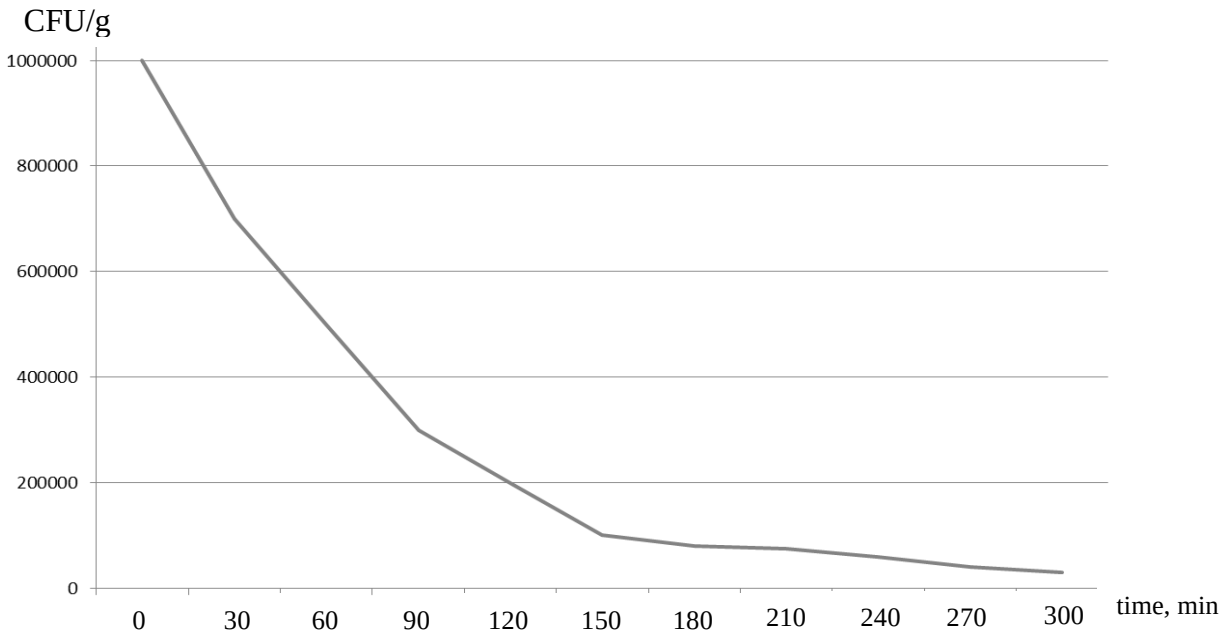
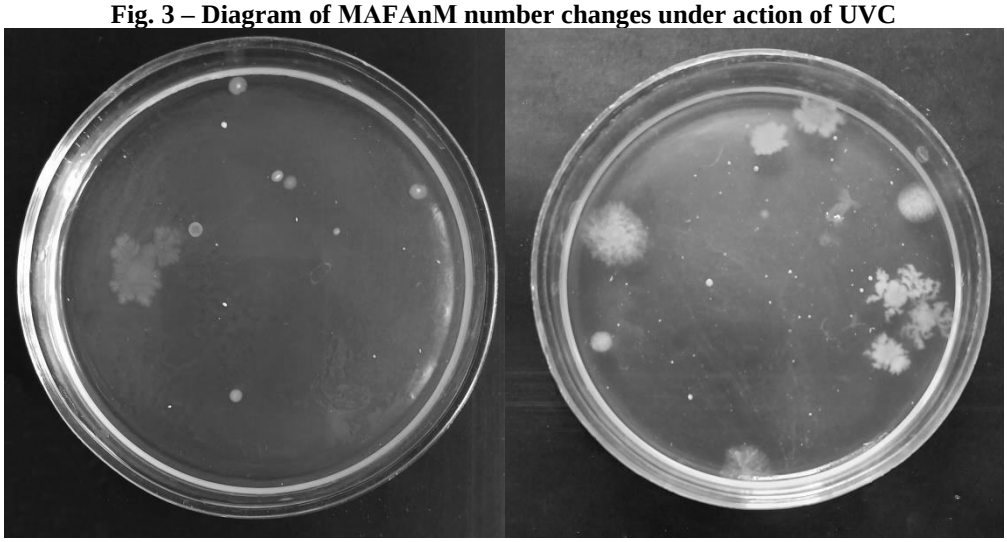


Fig. 3 – Diagram of MAFAnM number changes under action of UVC



control, dilution 1:100000 300 min, dilution 1:1000

Fig. 4. Results of inoculations on Petri dishes

-forming species (bacilli), which are more resistant to irradiation (in the form of spores they withstood irradiation, Fig. 4).

The figure shows that the diversity of colonies at the beginning of irradiation is significantly higher than at the end. At the end of irradiation, almost all colonies belonged to spore-forming bacilli (genus *Bacillus*) by cultural characteristics.

During 5 hours of irradiation, the number of MAFAnM decreased from $1 \cdot 10^6$ to $2 \cdot 10^4$ CFU/g, which corresponds to the destruction of 98% of MAFAnM. Thus, the effectiveness of irradiation can be considered proven. However, it is known that compound feed should not be sterile, as its microbiota prevents the penetration of harmful or dangerous foreign microorganisms from the outside. Therefore, it can be assumed that at a given irradiation power, 2 hours (120 minutes) is enough to disinfect the feed (reaching a level of $2 \cdot 10^5$ CFU / g).

Conclusions

The study found that ultraviolet irradiation is effective for disinfection of the model feed mixture, which can be extrapolated to loose feeds, as well as pelleted feeds and feed granules of small granulometric composition (up to 5 mm). Provided that the radiation of the proper wavelength and power is used, the irradiation

process does not require a long time (no more than 2 hours), which makes it possible to apply it in production. When using higher radiation power, the process duration can be reduced, which will increase the productivity of the method.

Proposition: this method can be recommended for industrial use at compound feed manufactures to decrease the bacterial burden of the feed for young animals.

REFERENCES

1. Lytvyn V.P., Oliynyk L.V., Korniyenko L.YE., Yarchuk B.M. Faktorni khvoroby sil′s′kohospodars′kykh tvaryn / Monohrafiya. Bila Tserkva: 2002. 303 s.
2. Robert L. Lochmiller, Charlotte Deerenberg. Trade-offs in evolutionary immunology: just what is the cost of immunity? // Copenhagen: OIKOS. – 2000, 88:1. P. 87-98.
3. Raphaële Gresse, Frédérique Chaucheyras Durand, Lysiane Dunière, Stéphanie Blanquet-Diot, Evelyne Forano. Microbiota composition and functional profiling throughout the gastrointestinal tract of commercial weaning piglets // MDPI: Microorganisms. 2019, 7, 343.
4. Klyevakin R.V. Modul′na ustanovka dlya obrobky sypkykh zernovykh produktiv ul′trafioletovym vyprominyuvannyam / Patent na vynakhid №UA124149C2. – Ukrayins′kyy instytut intelektual′noyi vlasnosti, 2021.
5. Sokolov V.V. Veterynarno-sanytarnoe sostoyanye syr′ya, kombykormov, kombykormovykh predpryyatyy y razrabotka meropryyatyy po eho uluchshenyyu / Dyssertatsyya na soyskanye nauchnoy stepeny doktora veterynarnykh nauk. 2002. 534 s.
6. Sarah Haberecht, Yadav S. Bajagai, Robert J. Moore et al. Poultry feeds carry diverse microbial communities that infuence chicken intestinal microbiota colonisation and maturation // AMB Express, 2020. v. 10, n. 143.
7. Antonenko P.P., Pushkar T.D., Kotets H.I., Rud V.O. et al. Sanitary-hygienic treatment of fodder for chickens with ozone-air mixture // Theoretical and Applied Veterinary Medicine: 2019. v. 7, i. 3.
8. EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP), Vasileios Bampidis, Giovanna Azimonti, Maria de Lourdes Bastos et. al. Efficacy of sodium formate as a technological feed additive (hygiene condition enhancer) for all animal species // EFSA Journal: 2019. 17(3).
9. Marin Sapunar, Wolfgang Domcke and Nađa Došlić. UV absorption spectra of DNA bases in the 350–190 nm range: assignment and state specific analysis of solvation effects // PCCP: 2019. issue 41.
10. Kapreľyants L. V., Pylypenko L. V., Yehorova A. V. ta in. Mikrobiolohich kharchovykh vyrobnytstv / Pidruchnyk – Kherson: OLDI-PLYUS, 2016. S. 119-124.

К.В. Єриганов, магістр, *E-mail:* yeryganov.onaft@gmail.com
Б.В. Єгоров, д-р техн. наук, професор, *E-mail: bogdanegoroff58@gmail.com*
Кафедра технології зерна і комбікормів
Одеський національний технологічний університет, 112, Канатна, Одеса, Україна, 65039

ЗАСТОСУВАННЯ УЛЬТРАФІОЛЕТОВОГО ОПРОМІНЕННЯ ДЛЯ ЗНЕЗАРАЖЕННЯ КОМБІКОРМІВ

Анотація.

Комбікорми є джерелом не лише поживних речовин, необхідних для підтримки життєдіяльності тваринного організму, але й комплексу мікроорганізмів, що в них мешкає. Цей комплекс розвивається в них після термічної обробки сировини (екструдування, кондиціонування, експандування та ін.), яка створює неконкурентні умови для заселення стронніми мікроорганізмами (зокрема, з незернової та тваринної сировини). В той же час, шлунково-кишковий тракт тварини містить власний складний мікробіом, який у молодняка (на момент переводу на передстартер та стартер) ще не повністю сформований та не дуже стабільний. Він може бути порушений сторонньою мікробіотою, що призведе до зниження продуктивності. Крім того, стороння мікробіота вимагає від організму іммунної відповіді, що є дуже енергозатратним процесом. Отже, знезараження комбікормів для молодняка на етапі виробництва та в готовому вигляді є доцільним та важливим. Найперспективнішим на сьогодні способом знезараження є ультрафіолетове опромінення, яке широко використовується для знезараження або стерилізації поверхонь, повітря та води. Цей метод дешевий, легкий у монтажі та обслуговуванні та ефективний без порушень властивостей продукту чи корму. Для комбікормів УФ застосовується на сьогодні лише на тваринницьких господарствах, а на виробничих лініях не задіяне. Тому завданням данного дослідження була перевірка ефективності ультрафіолетового опромінення комбікормів для впровадження на виробництві. Булло проведене опромінення бактерицидною лампою модельної кормосуміші (60% пшениці подрібненої, 30% макухи соняшникової, 10% висівок пшеничних). Кількість МАФАнМ (мезофільних аеробних та факультативно анаеробних мікроорганізмів) знизилась з 1 млн до 20 тис клітин в 1 г за 5 год (300 хв) опромінення (254 нм). Отриманий графік добре співпадає з порівняльним графіком для типового штаму та показує, що застосування ультрафіолетового опромінення є цілком ефективним, навіть не вимагаючи тривалої експозиції. Отже, воно може бути застососване на виробництві для знезараження комбікормів та їхньої сировини.

Ключові слова: комбікорм, ультрафіолетове опромінення, знезараження, мікробіом, продуктивність

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