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APPLICATION OF ULTRAVIOLET LED SYSTEMS IN THE GRAIN PROCESSING AND COMPOUND FEED INDUSTRIES

Abstract

The materials of the article outline the features of the use of ultraviolet LED systems in industry, and propose a solution for their use in the grain processing and compound feed industry. Ultraviolet light (UV) is a well-researched and widely used means of decontamination and disinfection of surfaces, air, water, and food. Usually, far ultraviolet radiation (or ultraviolet C, UVC) with a wavelength of 254 nm is used, which corresponds to the peak absorption of wave energy by the DNA of a living cell. There is a mathematical mechanism for calculating the parameters of radiation in relation to its effect on microorganisms: a curve describing the microbial death depending on the increase in the radiation dose received by the bacteria and formulae for the relationship between the three main parameters (dose, radiation flux and exposure duration). Ultraviolet lamps (tubes) are commonly used, on the basis of which a large number of emitters have been developed for different needs. There are also emitters for grain and feed disinfection in use, but only outside of industrial production lines. Ultraviolet irradiation is not used directly on manufacturing lines so far. However, it can be used to reduce the microbial burden of a feed or food product prior to packaging the finished product. For this purpose, ultraviolet light-emitting diodes (LEDs) available on the world market today can be used. However, their use faces difficulties: ultraviolet LEDs emit wavelengths longer than lamps (at about 275 nm or more), which requires an increase in the duration of irradiation, which is undesirable for industrial processing of products directly on the line. However, the small size of the UVC LEDs will allow them to be installed in grain processing and feed mills inside equipment (magnetic separators, gravity feeders, etc.) with appropriate protection against damage by moving material. In addition, suspended emitters of any configuration can be placed above belt conveyors that move material at a certain speed. This approach will require certain measures to control the efficiency of irradiation (requires microbiological studies) and to protect personnel from the harmful effects of ultraviolet rays (means of personal and collective protection, measurement of radiation intensity).

Key words: ultraviolet irradiation, mathematical apparatus, LEDs, disinfection, compound feed.

Introduction

The problem of food disinfection to increase its safety and stability dates back to the discovery of the microbiological nature of foodborne diseases and of the products' deterioration to an unusable and dangerous state. Today, there are a number of ways to disinfect air, surfaces, water, and food raw materials and products in use in the food industry. There are chemical and physical methods, with physical methods mainly including heat treatment and ionizing radiation. For food raw materials and finished products, heat treatment is mainly used (for example, in canning). Feed raw materials and finished feeds are not subjected to special treatments at manufacturing facilities, although there are methods for their disinfection by ultraviolet irradiation on livestock farms. However, for a number of reasons, the use of ultraviolet disinfection directly at feed mills may be important.

The gastrointestinal tract of animals has been shown to possess a huge and diverse microbiome [1, 2], which is in close interaction with the host and significantly affects its health, which for domestic animals means productivity. This microbiome can be destroyed in the event of a strong interference of foreign microbiota, especially in young animals, whose organism is not yet fully formed and is unstable. In addition, there is evidence of high energy consumption for the immune response triggered by the intervention of foreign microbiota.

Ultraviolet radiation is a very promising and reliable method of disinfection due to a number of factors [3]:

– it does not change the flavor and organoleptic qualities of food and feed;

– it has high efficiency in compliance with the processing regimes;

– equipment for it is easy enough to install and maintain;

– it is economically feasible due to the low cost of equipment and electricity consumption;

– it has generally low harmfulness to humans and exposure of personnel is easily prevented.

Ultraviolet radiation is a portion of the electromagnetic wave spectrum between 190 and 380 nm, usually divided into three parts [3]:

– near, or ultraviolet A (UVA): 320-380 nm,

– middle, or ultraviolet B (UVB): 320-290 nm,

– far, or ultraviolet C (UVC): 290-190 nm.

Ultraviolet light is an effective disinfectant at a wavelength corresponding to the absorption peak on the DNA of living cells (250-265 nm) [4] with the formation of harmful compounds that lead to DNA destruction and cell death. In most cases, these compounds are pyrimidine, mostly thymine, dimers. The wavelength used is usually 254 nm [4].

Literary review

1. Application for grain and feed disinfection. The currently known devices are not part of production lines at manufactures and are used mainly on livestock farms, having low productivity.

For example, the device [5] allows for the treatment of feed only in portions with low productivity. The device [6] uses a top-down falling of the material to be treated between the UV tubes, which requires a complex installation and reduces the exposure time. Device [7] has a limited portion hopper with rotating blades and irradiation only from above. The device [8] has again a vertical loading with material falling between the lamps, which reduces processing time, and is limited to processing in portions only.

A line developed by Japanese scientists is close to in-line industrial decontamination [9]. It involves the cyclical rotation of the material between two belt conveyors, above which ultraviolet lamps are suspended at a minimum height (Fig. 1).

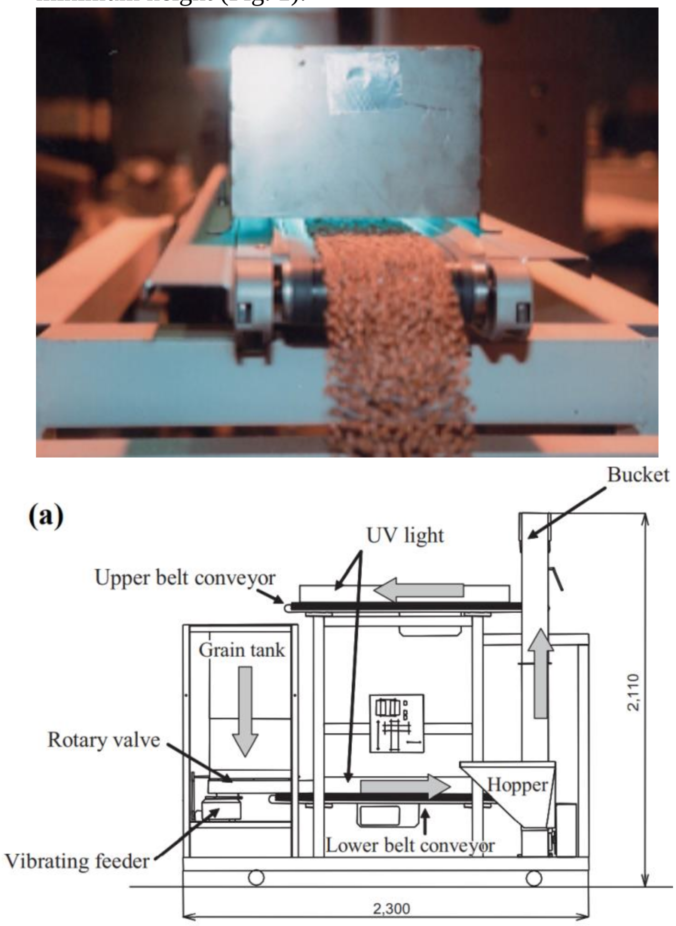

Fig. 1 - Machine from work [9], (a) - material flow diagram

The conveyors are located on different floors (storeys). The material is fed to the lower one, disinfected, and then taken up the bucket elevator to the upper one, disinfected in the opposite direction of movement, and then poured down to the lower conveyor again.

The distance between the material (grain) and the emitter was 2 cm, and the thickness of the material layer was 4 mm.

However, this setup has a problem. According to the authors, it took 6.3 hours for bacteria and 5.6 hours for fungi to destroy 90% of the grain microbiota. This duration is unacceptable for a plant of any production capacity. In addition, the productivity of this machinery is only 500 kg/hour.

2. The theory of ultraviolet disinfection

In radiobiological studies, the survival curve of the cells or organisms undergoing the experiment is usually plotted depending on the radiation dose, which is determined by the amount of energy received by the organism. Fig. 2 shows survival curves of three strains of E. coli: mutant deficient on DNA repair, wild type and proficient in DNA repair [10].

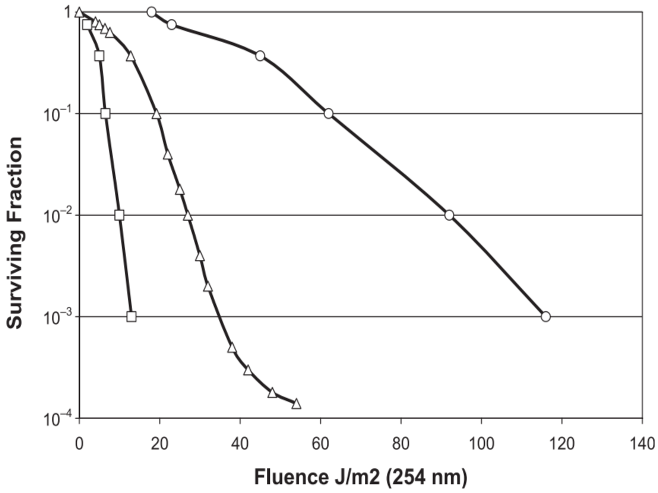

Fig. 2 - Bacterial survival curve of three *E. coli* strains by DNA repair: deficient mutant (squares), wild type (triangles) and proficient mutant (circles) [10]

As can be seen from the figure, in the wild strain at early stages of exposure a slow cell death is observed, which is explained by the manifestation of their certain resistance to radiation (certain physical protection of the nucleoid, repair of damaged DNA). This is followed by an exponential decrease in the number of living cells (repair mechanisms do not have time to repair the damage), and then another slowdown – due to the survival of cells that were protected in one way or another (for example, did not come under direct radiation immediately). Deficient strain shows a much faster decline in population, while the proficient strain declines much slower.

There is a formula for the relationship between dose and flux intensity [11]:

$$D = E_t \cdot I_R, \quad E_t = \frac{D}{I_R}, \quad I_R = \frac{D}{E_t}, \qquad (1)$$

where D is the radiation dose (J/m^2),
E_t is the exposure time (seconds),
I_R is the radiation flux (W/m^2).

The radiation flux for radiating devices is indicated by the manufacturer among the technical specifications of the device. The radiation dose obtained by formula (1) can be compared with the table values [12] (Table 1) or with the available graphs (see Fig. 2) to assess the radiation efficiency. Such calculations can allow to estimate the required number of emitters (given the radiation flux of one emitter of a certain model) and the time of irradiation by them.

Many of the species listed in Table 1 are quite common in feed raw materials and finished feed. For example, grain raw materials often contain bacteria of the genus Bacillus, animal raw materials also contain cocci and gram-negative rods, and contamination of raw materials and finished feeds with microscopic fungi (storage molds) from among those listed in Table 1 is not uncommon [13].

Table 1 – Values of the highest known D_{90} for some microorganisms according to [12].

Microorganism	Maximum known D_{90}, J/m^2
Bacteria	
Acinetobacter baumannii	33
Aeromonas hydrophila	16
Bacillus anthracis, spores	743
Bacillus cereus, spores	408
Bacillus megatherium, spores	273
Bacillus megatherium, vegetative cells	113
Bacillus subtilis, vegetative cells	25
Bacillus subtilis, spores	250
Bacillus thuringiensis, spores	2303
Burkholderia	58
Campylobacter jejuni	29
Citrobacter	46
Clostridium perfringens, vegetative cells	135
Clostridium tetani, vegetative cells	49
Corynebacterium diphtheriae	33
Enterobacter cloacae	64
Escherichia coli	81
Klebsiella pneumoniae	68
Legionella pneumophila	25
Listeria monocytogenes	181
Micrococcus (including *Sarcina*)	197
Mycobacterium in general	1047
Mycobacterium tuberculosis	77
Mycoplasma	6
Proteus mirabilis	8
Proteus vulgaris	30
Pseudomonas aeruginosa	172
Salmonella	295
Serratia marcescens	115
Shigella	18
Staphylococcus in general	161
Staphylococcus aureus	66
Streptococcus	468
Streptomyces	129
Vibrio	17
Yersinia	28
Fungi	
Aspergillus amstelodami, spores	700
Aspergillus flavus, spores	853
Aspergillus fumigatus, spores	2240
Aspergillus fumigatus, vegetative cells	560
Aspergillus niger, spores	4480
Aspergillus versicolor, spores	768
Botrytis cinerea, spores	250
Candida albicans, vegetative yeasts	750
Cladosporium, spores	4480
Fusarium, spores	560
Fusarium, vegetative cells	1120
Monilinia fructigena, spores	167
Mucor, spores	600
Penicillium, spores	2240
Rhizopus, spores	4480
Saccharomyces, vegetative yeasts	44
Ustilago zeae, spores	35
Ustilago zeae, vegetative cells	1120
Protozoa and other organisms	
Algae, green	1000
Cryptosporidia	50
Giardia lamblia, cysts	50
Prions	55618

3. Ultraviolet LEDs. Today, not only lamps are produced, but also LEDs that emit waves in the ultraviolet spectrum. A known manufacturer of ultraviolet light-emitting diodes (UV LEDs) is LuckyLight (China). Table 2 shows the characteristics of ultraviolet LEDs of this company according to its official website [14].

The distributor of such LEDs (Fig. 3) in Ukraine is SMD Ukraine (Kyiv) [15]. The distributor also mounts

Fig. 3 - Some LEDs of the C3535DUVC series [14].

Table 2 - Characteristics of LEDs of C3535DUVC and C5050DUVC series

Model	Dimensions, l×w×h, mm	Electric power, W	Radiation flux, mW	Wavelength, nm
C3535DUVC-QBH-D1Y	3.40×3.40×3.05	0,50	15	275
C3535DUVC-QBH-DY	3.50×3.50×1.67	0,50	13	275
C3535DUVC-QB-DY	3.50×3.50×1.43	0,25	5	275
C3737DUVC-QBH-D	3.70×3.70×1.75	1,00	15	275
C3535DUVC-QB-D	3.50×3.50×1.36	0,25	4	275
C3535DUVC-QB-Q5-D	3.50×3.50×1.36	0,25	5	275+395
C3535DUVC-QBH-2C-D	3.50×3.50×1.60	1,00	16	275
C3535DUVC-QBH-1C-D	3.50×3.50×1.60	0,50	8	275
C5050DUVC-QBH-1C-D	5.00×5.00×1.70	2,45	50	275
C5050DUVC-QBH-2C-D	5.00×5.00×1.70	4,20	80	275

diodes on linear boards, the size of which is determined by the customer (depending on the required number of LEDs).

Linear boards (Fig. 4), on which diodes are arranged in a single row, are the most convenient for use in production. The number of diodes (and, accordingly, the length of the board) may vary depending on the equipment or irradiator on which they are mounted. It is possible to use round boards with radial rows of diodes.

Fig. 4 - Linear and round boards with diodes of C3535DUVC series (sketches-collages based on photos)

The number of diodes that can be placed depends on the size and configuration of the equipment or emitter, as well as on the configuration of the diode boards. Fig. 5 shows a diagram of the structure of the board (strip) from the manufacturer – LuckyLight. These parameters indicate that the boards or strips will take up very little space on the production line.

4. Application of theory and modeling to LEDs. LEDs have the same technical parameters as lamps, differing from them only in multiplicity: it is necessary to take into account the number of diodes that will give a sufficient disinfection result. This number can be calculated using formula (1). To do this, the D_{90} dose on which the calculation will be based must be known. Example: an average dose required to kill 90% of bacterial cells is 300 J/m2, and the exposure time is 2 hours, i. e. 7200 s:

$$I_R = \frac{D}{E_t} = \frac{300}{7200} = 0{,}041\ W/m^2$$

Radiation flux values are given by the manufacturer in mW, so we multiply this number by 1000 and express it as 41 mW/m^2. Dividing this figure by the flux from one LED (taking a LED with a radiation of 5 mW/m^2), we get:

$$41 \div 5 = 8{,}2$$

Thus, to kill 90% of bacteria for which the lethal dose is 300 J/m2, irradiation with 9 diodes for 2 hours is required. If the time is increased and/or more powerful diodes are used, the number of diodes can be reduced. Accordingly, the treatment duration can be reduced by increasing the number and/or power of LEDs.

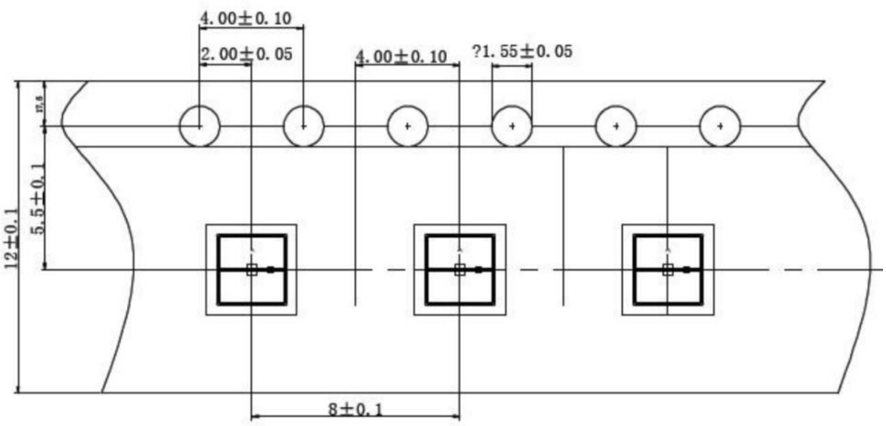

Fig. 5 - Diagram of a flexible tape with diodes by the manufacturer [14].

Formula for calculating the number of LEDs:

$$N = \frac{D_{90}}{E_t \cdot F}$$

where D_{90} is the required radiation dose to destroy 90% of the population of a particular species of microorganism, J/m^2, a table value from the literature;

E_t is the irradiation time, s;

F is the radiation flux of one diode, W/m^2, specified in the manufacturer's technical characteristics of the diodes.

Table 3 - Number of LEDs to destroy 90% of the population of common microorganisms when using diodes of different power and different treatment duration

Microorganism	Max. D_{90}	LED number		
		5 mW/m^2, 7200 s	15 mW/m^2, 3600 s	50 mW/m^2, 1800 s
Acinetobacter	33	1	1	1
Aeromonas	16	1	1	1
Bacillus cereus, spores	408	12	8	5
Bacillus megatherium, spores	273	8	5	3
Bacillus subtilis, spores	250	7	5	3
Citrobacter	46	2	1	1
Clostridium perfringens, vegetative cells	135	4	3	2
Enterobacter cloacae	64	2	1	1
Escherichia coli	81	3	2	1
Klebsiella	68	3	1	1
Listeria monocytogenes	181	6	3	2
Micrococcus	197	6	4	2
Mycobacterium	1047	30	19	12
Proteus vulgaris	30	1	1	1
Pseudomonas aeruginosa	172	5	3	2
Salmonella	295	9	5	3
Serratia	209	6	4	2
Staphylococcus	161	5	3	2
Streptococcus	468	13	9	5
Aspergillus	4480	125	83	50
Candida albicans	750	21	14	8
Cladosporium	4480	125	83	50
Fusarium	1120	32	21	12
Mucor	600	17	11	7
Penicillium	2240	63	41	25
Rhizopus	3000	84	56	33
Non-pathogenic yeasts	100	3	2	1

If the radiation flux for diodes is specified in milliwatts (mW/m^2), then a multiplier of 1000 is added to the numerator:

$$N = \frac{D_{90} \cdot 1000}{E_t \cdot F}$$

Given the list of D_{90} doses (required to kill 90% of the bacterial population) covered in [12], it is possible to calculate the number of LEDs required for disinfection using the above methodology. Examples are given in Table 3.

It is possible to install LEDs that come with diffusing lenses or to add lenses to other LEDs (see Fig. 3, C3535DUVC-QBH-D1Y).

5. Application of LEDs in grain processing and feed production. There are three options for equipping production lines with lamp or LED ultraviolet emitters: directly on or in the equipment or as a separate unit as part of the production line.

Installation directly inside the equipment. The most efficient and convenient is the installation of linear boards in gravity pipes and magnetic separators and columns. In gravity pipes, boards with diodes can be installed on the inner wall along the pipe above the flow of material. The boards can be installed in one or more parallel rows; it is advisable to increase the number of rows in gravity pipes of large diameter (more than 300 mm). The radiation angle of 120° allows irradiating the entire area of the material moving along the pipe with one row of diodes at the top of the circle, but additional rows will increase the radiation effect, since the material moves at a quite high speed, reducing the duration of the radiation.

It is advisable to transform the upper part of the gravity pipe with the installed boards into a removable cover (possibly with seals to prevent dust emissions to the outside), through which access is obtained for maintenance of the installed diodes (replacement, repair).

1. Installation in magnetic separators and columns.

For magnetic separators, the method of installing LEDs depends on the model, design, and size of the separator.

For *separators with a bottom magnet*, the most convenient arrangement of the boards is on the inside of the top cover. Linear boards can be installed along the separator – two or three side by side at intervals.

For separators with a top-mounted magnet, it is possible to install line bpards only in front of the magnet and after it across the separator body. Due to the limited number of diodes, the decontamination may not be sufficient in this case.

For *vertical separators with a central magnet and for magnetic columns*, it is possible to mount the line boards vertically on the inner surface opposite the door with the magnet. In this case, the boards should be placed under the deflectors that deflect the material from the walls to the magnet: the deflectors will protect the diodes from damage by the falling material. It is also possible to install the boards next to the magnetic unit on the door.

Equipment in which the installation is to be performed. Prerequisites.

It is necessary to be able to lay electrical wiring from the installed boards to their power supply, which can be installed in another place from where it will be convenient to control the system. It is necessary to ensure an appropriate level of operational safety due to the presence of additional electrical equipment.

Sloped magnetic separators. Prerequisites include those mentioned above for gravity pipes, as well as:

– with the top magnet: sufficient space to install at least one line board near the magnetic unit on the separator lid or on the top wall;

– with the bottom magnet: the presence of a top cover for access to the inside for the installation and maintenance of boards; sufficient space on the top cover or on the wall outside it;

Vertical magnetic separators and magnetic columns. In columns of KM-50 type, the installation can be performed only on the rear wall opposite the door, because when installed on the door near the magnetic unit, the latter will block a significant part of the scattered flux from the diodes. In round columns (e.g., BMM series), it is also possible to mount the boards on the upper sloped surface above the magnetic unit. Prerequisites:

– sufficient clearance between the magnetic unit and the walls when the door is closed, as falling material can damage the diodes if the clearance is too small;

– the presence of deflectors on the wall that deflect material onto the magnetic unit; the boards should be installed under the deflectors to protect the diodes from damage by the material.

It is not recommended to install diodes in conical sub-hopper separators, such as U1-BMZ, because the material flow in them moves at high speed and touches all the walls, so there is a high probability of damage to the LEDs. It is not recommended to install high-power diodes (C5050 series) in tight conditions of small gaps of magnetic columns and vertical separators, as the closed space can adversely affect the operation of the diodes. In such conditions, it is safer to use diodes of lower power, and to use diodes of the C5050 series in gravity pipes of large diameters (300 mm and more).

Examples of suitable equipment are shown in Figure 6.

2. Machine for disinfection of finished feed

It is proposed to assemble the system in the room preceding the packaging. It is possible to install the diodes both on the inside of the casing of a closed conveyor and on a special emitter (for example, in the form of a metal frame with LED boards) suspended above an open belt conveyor.

The frame is supposed to be assembled from steel L-beams by welding. LED boards, 10-20 diodes each, are mounted at certain distances on transverse beams (depending on the size of the conveyor) or on longitudinal beams. The frame is suspended at a height of no more than 10-15 cm from the conveyor belt.

The finished feed is fed to the conveyor from hoppers through a flap that cuts off the flow at the required level of filling the conveyor belt (to a layer that allows effective disinfection - up to 2-3 mm, or in one granule or particle of crumble). After a certain required time of cyclical rotation of the material under irradiation (depending on the irradiation power and the initial number of microorganisms), the material is discharged to a bucket elevator, which lifts it up and feeds it either to the bins with disinfected feed or back to the bins with the original material (through the bypass valve on the feeders).

Fig. 6 - Examples of equipment (magnetic separators and columns), in which it is possible to install LED boards

Upon reaching the required level of disinfection (determined by the total processing time based on microbiological studies), the feed is discharged into irradiated material bins and then fed to the packaging line.

The level of microbial contamination of feed is not constant and strongly depends on the type and composition of the feed and the conditions and condition of the manufacture. Therefore, when implementing the disinfection scheme proposed in this paper, it is recommended to first conduct microbiological studies to establish the degree (depth) of disinfection required for a particular case. This degree is also regulated by the duration of irradiation.

6. Controlling the effectiveness of disinfection

The deterioration of LEDs due to wear over time leads to a decrease in the efficiency of material disinfection, so it is advisable to organize regular monitoring of disinfection efficiency.

The method of checking this indicator is microbiological analysis of samples taken before and after disinfection. The analysis should be performed in a microbiological laboratory, either at the manufacture itself if it has a laboratory or by an external laboratory on request. Control should be carried out according to standard microbiological methods for the analysis of feed and/or grain products or by modern methods (for example, indicator media or impedance analysis) provided for by the relevant standards for feed or grain products.

To control the efficiency of LEDs in gravity pipes and separators, two samples of material should be analyzed: the first one entering the separator or gravity pipe with diodes, and the second one after leaving them. To control the efficiency of the pre-packaging line, two samples (or two sets of samples) are also taken: from the hoppers before and after decontamination. In both cases, it is recommended to take several samples (at least 3), from which the average value is calculated. This will help to avoid erroneous assessment, when only one sample may show an inaccurate or false result.

The criterion for evaluating the effectiveness is the ratio of microbiota in the material before and after disinfection.

In case of doubtful or unsatisfactory efficiency assessment, the equipment should be checked for interruptions in electrical contacts, dust on the LEDs, and damage to them. If such problems are detected, they should be eliminated (by cleaning diodes, replacing individual diodes, adjusting contacts) and the sample should be reanalyzed after disinfection. On the pre-packaging line, also the speed of the conveyor and the degree of its loading must be checked and samples analyzed again. If the unsatisfactory assessment reoccurs, the above actions should be supplemented by replacing all old (i.e., long-used) diodes with new ones, checking the preceding lines (e.g., dosing and mixing, making crumbles after granulation, etc.) for the presence of a source of contamination by foreign microorganisms that is excessive for the effective operation of the pre-packaging line.

The frequency of control depends on the production capacity requiring the operation of the disinfection equipment: the higher the production capacity, the more frequent the control should be.

7. Labor protection of personnel, protection against the harmful effects of ultraviolet radiation. The proposed technological innovations involve far ultraviolet radiation (UVC), i.e., with a wavelength of 190 to 290 nm. Although UV radiation is considered non-ionizing under normal conditions, it can have an impact on human health. The stimulation of vitamin D formation from its precursor in the skin under the influence of UV irradiation is well known. However, prolonged exposure to UVC can have a negative impact. According to the WHO, ultraviolet light with prolonged exposure can cause a number of diseases [16, 17].

Therefore, the need to protect personnel working on the maintenance of the pre-packaging disinfection line becomes obvious. This protection can be both individual and collective, and consists of standard measures when working with sources of harmful radiation.

Individual protection involves wearing protective goggles or a face shield made of UV-screening material (Fig. 7) and avoiding exposed areas of the body that would be constantly exposed to radiation (wearing gloves, closed work clothes).

Collective protection may include the installation of transparent (so that the line can be observed) screens around the pre-packaging disinfection line. They can surround the line completely, but be movable to allow access for personnel to maintain the line. The screens should have a stable base to prevent falling and a lightweight metal frame around the edges (Fig. 7). Depending on the height of the diode installation, the screens can be raised above the floor on small stands. The material of the screens must effectively screen UV, but be transparent and easy to clean with a damp cloth or even to wash (during a sanitary shutdown of the plant's lines). Plexiglass sheets of 3 mm thickness meet these properties well.

Fig. 7 - Examples of a face shield and goggles for UVC protection and possible configurations of screens of different heights

Warning signs can be used to alert people to the possible danger of exposure. In addition to the standard radiation hazard sign, some countries use a hazard sign specifically for ultraviolet radiation. Such signs (with or without text) can be placed on the entrance door of the pre-packaging room, its walls and screens around the line. It is also possible to use a standard light radiation hazard sign and a warning about the need to wear a face shield (Fig. 8).

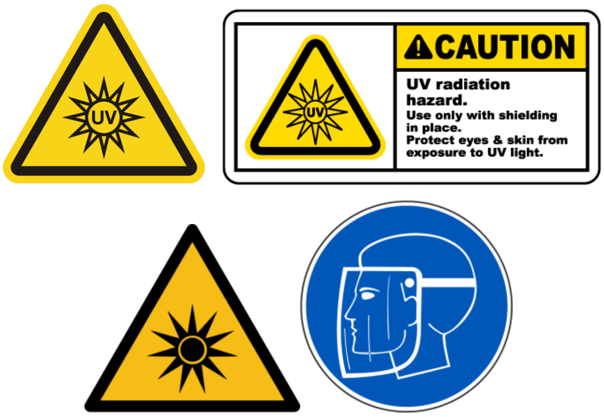

Fig. 8 - From left to right: UV warning signs, standard light radiation hazard sign and an example of the warning sign about the need to wear protective shields

When servicing or repairing diode systems, all diodes must be switched off. If it is necessary to service the pre-packaging line without shutting it down completely, the diodes must also be turned off. The switches should be located in a place accessible to personnel.

8. Personnel training. Before launching the proposed innovations, the personnel who will operate the diode equipment and the pre-packaging line should be informed about the hazards of UVC exposure and appropriate safety measures. A safety manual for working with UVC sources should be available.

9. Measuring the level of ultraviolet radiation. To ensure reliable protection of personnel from the harmful effects of ultraviolet radiation, it is necessary to monitor the level of ultraviolet radiation in the rooms. For this purpose, it is advisable to use special radiometers (Fig. 9). Monitoring should be carried out daily: this will allow not only to detect an increase in the level of radiation dangerous for personnel, but also its decrease, which indicates a decrease in the efficiency of the line (failure of diodes, their wear, etc.).

Fig. 9 - Radiometers for measuring the intensity of light and ultraviolet radiation intensity

If LED boards are installed in the casing of a closed conveyor and inside a magnetic separator, the protection of personnel from UV exposure will be guaranteed, except for the need to access the casing or separator to maintain or repair equipment or replace worn diodes (for the separator, also to clean the magnetic unit from trapped particles). In this case, it is advisable to install safety switches that automatically turn off the radiation when the door or cover of the casing is opened [18].

Conclusions

Ultraviolet radiation is an effective means of disinfecting food and feed, which is already used today for disinfection of food and feed outside of manufactures. For feed production facilities, the use of UV disinfection is recommended for the production of pre-starter and starter feeds, which are produced and consumed in small amounts. UV disinfection has a mathematical apparatus for calculating the necessary parameters and equipment and the possibility of applying it directly in the manufacturing process. It is advisable to use LEDs instead of lamps because they are inexpensive, easy to maintain, and easy to use in production. There are reliable and inexpensive ways to monitor the effectiveness of disinfection and protect personnel from the harmful effects of ultraviolet rays.

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ЗАСТОСУВАННЯ УЛЬТРАФІОЛЕТОВИХ СВІТЛОДІОДНИХ СИСТЕМ У ЗЕРНОПЕРЕРОБНІЙ ТА КОМБІКОРМОВІЙ ПРОМИСЛОВОСТІ

Анотація

В матеріалах статті викладені особливості застосування ультрафіолетових світлодіодних систем у промисловості, запропоновано рішення їх використання у зернопереробній та комбікормовій промисловості. Ультрафіолет є добре дослідженим і вживаним засобом знезараження та дезінфекції поверхонь, повітря, води та харчових продуктів. Зазвичай застосовується ультрафіолетове випромінювання дальнього спектру (UVC) з довжиною хвилі 254 нм, що відповідає піку поглинання хвильової енергії ДНК живої клітини. Існує математичний механізм розрахунків параметрів випромінювання відносно його впливу на мікроорганізми: крива загибелі мікроорганізмів залежно від наростання отриманої дози випромінювання та формули взаємозв'язку трьох основних параметрів (доза, потік випромінювання та тривалість опромінення). Зазвичай використовують ультрафіолетові лампи (трубки), на основі яких розроблено велику кількість випромінювачів для різних потреб. Існують і випромінювачі для знезараження зерна та комбікормів, але лише поза виробничими лініями. Безпосередньо на виробничих лініях ультрафіолетове опромінення не застосовується. Однак за його допомогою можливо знизити мікробне навантаження комбікорму або харчового продукту до затарювання або фасування готового продукту. Для цієї мети можна використовувати ультрафіолетові світлодіоди, наявні сьогодні на світовому ринку. Однак їхнє використання стикається з труднощами: світлодіоди випромінюють хвилі більшої довжини, ніж лампи (275 нм), що потребує збільшення тривалості опромінення, небажаного для промислової обробки продуктів безпосередньо на лінії. Однак малий розмір світлодіодів дозволить встановлювати їх на зернопереробних та комбікормових виробництвах всередині обладнання (магнітних сепараторів, самопливів та ін.) з відповідним захистом від пошкодження матеріалом, що рухається. Крім цього, підвісні опромінювачі будь-якої конфігурації можна розміщувати над стрічковими транспортерами, що рухають матеріал з певною швидкістю. Такий підхід потребуватиме певних заходів щодо контролю ефективності опромінення (мікробіологічні дослідження) та захисту персоналу від шкідливого впливу ультрафіолетових променів (індивідуальний та колективний захист, вимірювання інтенсивності випромінювання).

Ключові слова: ультрафіолетове випромінювання, математичний апарат, світлодіоди, знезараження, комбікорми.

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