Automated Energy-efficient System for Cleaning and Disinfection of Reusable Objects

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Abstract

The authors considered known systems of cleaning and disinfection of objects of repeated use. The shortcomings of specific installations were analyzed and identified, which are their complexity, energy consumption, and the use of harmful chemicals and solutions. The authors proposed a structural diagram of an automated energy-efficient system and developed an algorithm for its operation. The use of LED matrices of the infrared and ultraviolet ranges is proposed as elements of drying and disinfection. The use of a microcontroller ensures automated control of the movement of the cleaning object, turning on and off technological sources, and software setting of the processing (exposure) time. The use of fast-acting energy-saving disinfecting sources and software control allows to reduce the processing time and increase the energy efficiency of the system by 25-30%.

Keywords 1

Cleaning system, LED matrices, infrared drying, ultraviolet disinfection, energy efficiency.

1. Introduction

Automated cleaning and disinfection of containers and containers with residues of various organic and inorganic substances, bacteria, mold and fungi is widespread in agriculture (vegetables and horticulture), utilities, animal husbandry and other production areas. Usually, cleaning is carried out by using the combined action of pressurized water, liquid disinfectant solutions of chemicals, automated rubbing and drying, with the purpose of internal and external cleaning of bags, boxes, containers and other reusable objects. At the same time, significant material costs are spent, but the savings from the reuse of cleaning objects outweigh the costs, so such technology has found wide application. Disadvantages of such methods of cleaning and disinfection include the need for waste disposal and the possibility of environmental pollution.

It is extremely important to ensure the sanitary cleanliness of containers and containers for some vegetables and fruits for long-term storage of carrots, beets, cabbage, and especially winter varieties of apples. At the same time, big box plastic containers are used, which are indispensable in agriculture: when harvesting, when storing and processing vegetables and fruits. Ventilated walls and bottom ensure good air circulation, keeping vegetables and fruits fresh. Also, big box containers stack up to 12 pcs. in height, they are convenient to use as a bookmark for vegetables and fruits and are reusable items. But these advantages during repeated use can be realized only in hygienically clean containers [1].

In the process of designing ideal implants for tissue engineering, the graft-tissue contact area is a very important part that needs to be improved, since most of the interactions between grafts and surrounding tissues occur exactly in this zone.

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According to the data of the GADZ farm [2], losses of horticultural products during storage can reach 5-8% of the total volume laid down for crop storage for the entire storage period. The main causes of apple loss are bacteria and fungi that remain on reusable containers.

Therefore, carrying out preventive work on pre-treatment of containers, cleaning and disinfection contributes to reducing losses and increasing economic benefits in the process of storing horticultural products.

2. State of the problem

In work [3] described a tunnel installation for washing and cleaning various items and objects of reuse: racks, plastic boxes, wire cages for animals, garbage trays, and others. The installation consists of a transport platform, several technological chambers (sections) for pre-cleaning, washing, rinsing and drying operations. During these operations, water, steam, warm air for drying and waste products are introduced and removed from the respective chambers. The features of the considered installation include a tunnel structure, a transport platform, a conveyor line and the presence of separate functional technological chambers. The disadvantages of such an installation are complexity and multifunctionality, significant energy consumption and cost, which limits the possibility of its use only for significant volumes of processing facilities.

Simpler, similar European systems (installations) for internal and external cleaning and disinfection of containers with residual foreign substances are also known [4,5]. The installations have a similar structure and include a closed tunnel with a transport conveyor line and separate functional technological sections (chambers), where the outer surface of the container is treated with a foam-generated disinfectant solution and rinsed, then the inner surface is treated with a foam-generated solution and rinsed. After the processing, the clean container is fed to the outlet of the line for evacuation and use.

The disadvantages of the considered installations include the technical complexity of the cleaning and disinfection system, the need to use chemicals to treat the surface of the containers, the residues of which can be harmful for the long-term storage of food products (vegetables and fruits), and significant energy consumption.

Considering the shortcomings of the considered systems, the authors set their task to simplify the technological scheme of cleaning and disinfection, to exclude the use of harmful chemical solutions and elements, and to increase energy efficiency.

3. Description of the structural scheme and the principle of operation of the system

In order to fulfill the set tasks, based on the results of the research, the authors developed a functional scheme of the system for cleaning and disinfection of containers and small-sized containers and other objects of repeated use, as well as created an algorithm of work.

In fig. 1 presents a functional diagram of the developed system for cleaning and disinfection of containers and small-sized containers and other reusable items.

In Figure 1, the transport tunnel with the conveyor line is divided into 5 technological zones (sections): 1 – container supply zone; 2 – zone for cleaning containers with water (rinsing section); 3 – blowing and drying zone (infrared drying section); 4 – bactericidal disinfection zone (ultraviolet disinfection section); 5 – container exit zone.

Each of the sections is equipped with sensors that ensure the control of the passage of the object of processing to enable the corresponding technological operation: 6 sensor of the presence of containers in the supply zone; 7 - sensor for the presence of containers in the cleaning zone; 8 - sensor for the presence of containers in the drying zone; 9 - sensor for the presence of containers in the decontamination zone; 10 - a sensor for the presence of a container in the container exit zone. Management and automation of cleaning and disinfection processes is carried out using: microcontroller -11; control panel – 12 and control unit of executive elements – 13. Executive elements of the automated system include: 14 – engine; 15 – conveyor belt; 16 – water supply nozzles; 17 – infrared heaters (infrared matrix for complete drying of containers, located in all planes); 18 – ultraviolet irradiator (LED matrix for bactericidal disinfection of containers, located in all planes).

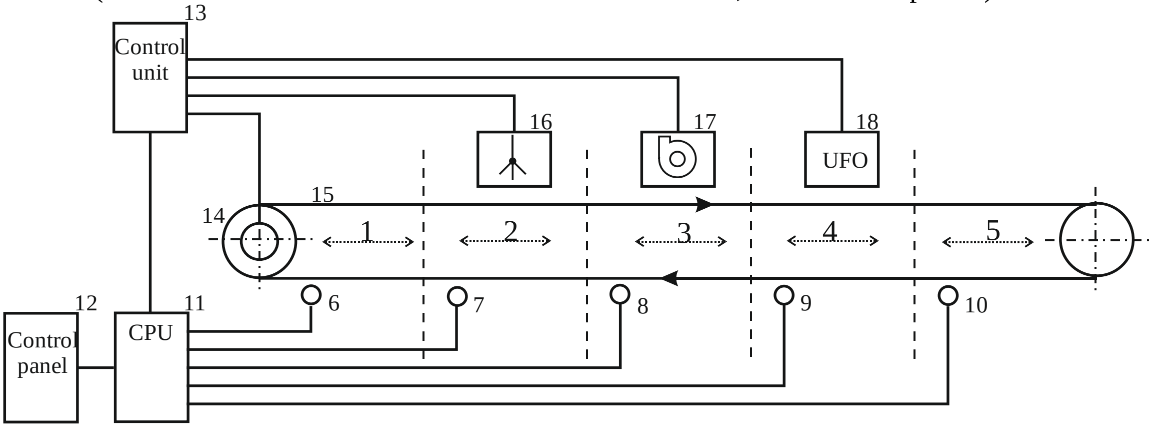

Figure 1: Functional diagram of the automated system.

Fig. 2 shows the algorithm that describes the technological process of cleaning and disinfection of objects of repeated use. As an example, the process of processing containers and small-sized containers for storage of gardening products.

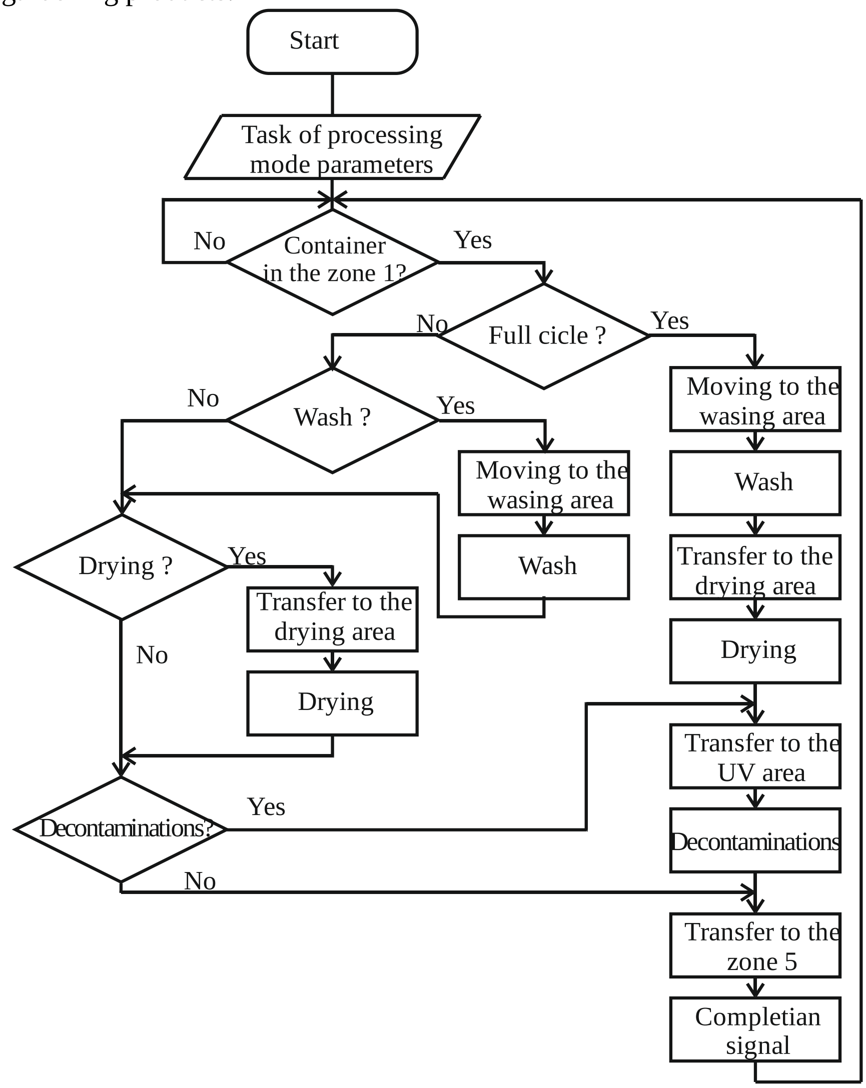

Figure 2: Algorithm of operation of the automated system in the container processing mode.

The algorithm provides a full processing cycle (right branch of Fig. 2) and a shortened container processing cycle (left branch), when some operations are not advisable. The automated system works as follows. Depending on the type of container, its size and level of contamination, the control panel sets the initial technological requirements for the impact parameters for each processing section and enters them into the computer.

The dirty container enters from the entrance zone 1 to the cleaning zone of section 2, where the presence of the container is detected by the sensor 6. The control unit 13 turns on and off for the programmed time the nozzles of high pressure water supply, under the action of which the container is rinsed. After rinsing, the container is fed to the blowing and drying zone 3 (infrared drying section).

The sensor 8 detects the presence of containers in the section, the conveyor belt 15 stops and the containers are blown and dried. An infrared LED matrix - IR LED, with a wavelength of 940 nm and a power of 10 W [6] is used as a source of thermal radiation. As a microcontroller, it is advisable to use the Arduino platform and a simple available version of the LilyPad USB or Mega 2560 boards with a clock frequency of 8 or 16 MHz [7].

An important point is the process of decontamination of the container, for which it is fed to zone 4. After the container is fixed by the sensor 9, the control unit 13 includes the process of bactericidal disinfection of the container for a specified time. Depending on the types of bacteria and fungi and their sensitivity to UV radiation, the term of disinfection can have different duration and intensity, and the bactericidal effect can reach up to 90-95% [8]. At the same time, the bactericidal flow, which provides disinfection of the surface of the container, can be calculated using the formula:

$$P_B = P_\Sigma K_E \, , \tag{1}$$

where P_Σ - total flow of the UV source; K_E - the efficiency factor of the UV source, which can be in the range of 0,2…0,8.

The authors paid special attention to the development of the UV of the fourth section. Usually, bactericidal energy-intensive mercury lamps of ultraviolet action are used to provide typical facilities for water disinfection in swimming pools, various premises, medical instruments, etc. The power of these lamps can range from 50 W to 1000 W with a luminous flux of 1800 lm, the number of sources depending on the size of the radiation decontamination objects is 4-6 pcs. Stopping at the minimum number of mercury lamps (option 4 pcs), we get a luminous flux of 7200 Lm and energy consumption of 200 W. To reduce energy consumption, the authors suggested replacing mercury lamps with ultraviolet light emitting diodes (UVDs), for example, of the GNL-8003VC type, with a power of 600 mW and a luminous flux of 42 Lm. To ensure the indicated luminous flux and technological conditions, the number of light emitting diodes is 180 pcs. From the point of view of uniform irradiation, LED containers are grouped by 30 pieces and placed in the form of six matrices, the design of which is presented in [9].

From the ratio of powers Φ_p and luminous fluxes of radiation in a typical emitting part based on mercury ultraviolet radiation source to LED, we determine the required amount of LED in the matrix:

$$N=\Phi_p/\Phi_{UVDs}, \tag{2}$$

Based on the calculations, to ensure the total required luminous flux of 7200 Lm, from 80 LEDs are required, depending on their power and optical characteristics. From the point of view of uniform irradiation of the container, it is necessary to use LED with a size of 5…8 mm, for this we calculate the number of such LED taking into account their optical radiation power.

For evaluation, we will take a GNL-8003VC type UV LED with a diameter of 8 mm, power 600 mW, luminous flux of 42 Lm and a radiation angle of 22 degrees [10]. About 180 LED are needed to ensure technological conditions. Thus, the cost of electricity consumption is reduced from 200 W to 108 W.

Thus, the use of an LED ultraviolet matrix reduces electricity consumption by 54%, the durability of radiation sources will ensure stable operation 4 times longer. In addition, the LED matrix does not contain mercury, as mercury sources of radiation and thus provides the necessary conditions for labor protection and environmental protection.

After decontamination in the UV zone, the container is fed to the output section 6 and the conveyor belt is stopped. Therefore, at the exit of the conveyor belt, we receive a completely clean container without fungi and bacteria for further sale in trade or economic needs.

4. Conclusions

1. The use of modern electronic devices allows to reduce the consumption of electrical energy by 30-40% due to:

a) reduction of direct electricity consumption;

b) time optimization of the processing technological process;

c) fast-acting mode of readiness for the operation of electronic devices after switching on and the possibility of switching off, reducing the exposure of the processing cycle,

2. Software management of the process of preparing subjects for re-examination the use and application of modern electronic devices ensures complete automation of the technological cycle of cleaning and disinfection and significantly reduces their processing time.

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