

Study on the main parameters of an air ionizer for fruit storage

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Abstract. This article reveals the results of studying various technological schemes of ionization of the fruit storage. The key factors influencing the quality of product processing are determined. The main requirements for ionizers for fruit storages and the mechanism of the ionized air blowing on the stored product are considered, and the operating modes of ionization of the ionizer for fruit storages are established.

1. Introduction

Corona-discharge electric ionizers are used in various technological processes. Positive results have been obtained with the use of electric ionizers in the technology of long-term storage of fruits and grapes [1, 2]. When applying electric ionizers in the technology of long-term storage of fruits and grapes, must be taken into account the requirements of technology for electrical equipment that undergoing long-term artificial cooling inside the room. Air ionizers must provide optimal values for the volume concentration of air ions, air ions must have the appropriate polarity and mobility, electrical processing modes must be stable, ions must be evenly distributed in the volume of the room, and cooling processes, ventilation and air ionization must be performed fully automatically without operator intervention. The air of the storage chamber is ionized in various ways and means [3]:

1. The air of the storage chamber is ionized by uniformly distributed corona-discharge ionizers in the form of antennas.
2. The air of the storage chamber is ionized by corona-discharge ionizers installed in the ventilation and cooling system of the fruit store.
3. The air of the storage chamber is ionized by individual corona discharge ionizers for individual stacks of the stored product.

Corona discharge electrodes can be in the form of a needle or thin filament, and come in a variety of shapes and configurations. For the industrial use of fruit storage air ionization technology is accepted first and second air ionization system. During the ionization of air by uniformly distributed coronary-function ionizers in the form of antennas, the system is simplified, hence, it makes it possible to obtain a sufficient degree of air ionization intensity. However, as the distance from the discharge electrodes increases, the volume concentration of ions decreases rapidly, and the uneven distribution of ions increases. Discharge electrodes, which located in a sufficiently close distance, interfere with the placement, sorting, inspection and transportation of the product. When air ionization occurs by corona-discharge ionizers installed in the ventilation and cooling system, the fruit storages cover a more uniform volume of air of ions, the ionizers enter the air ducts of the cooling and ventilation system and do not interfere with loading and unloading operations in the food storage system. The air ions are carried by the ventilation forces and with the dissipation of the density charge of the air ions, the ionic uniformity in the room is reached up to 85% at the same time.

There are certain requirements for Air ionizers: -not create noise during operation;

- not emit various electromagnetic radiation;
- not form harmful chemical compounds and should not pollute the air.

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Furthermore, the stored product has to be protected against light rays. The operation of the electric ionizer must be reliable and safe at low temperatures and high temperatures. The device needs to have a remote control system and consume a minimum amount of energy. In addition, the electric ionizer must be inexpensive and consumable during operation. Therefore, electrical ionizers for fruit storage must comply with the following requirements [4, 5, 6]:

- 1) to generate air ions of high concentration and mobility in conditions of high humidity and low temperatures;
- 2) to not create noise, various electromagnetic radiation, not form various harmful physical and chemical compounds, not pollute the air that adversely affects the stored product and maintenance personnel neither;
- 3) electric ionizers for fruit storage should hold a compact design, small dimensions, and weight, also be easy to install and operate, reliable in operation, and safe to maintain.
- 4) the operation of the electrical ionizer must not affect the microclimate and the gas composition of the fruit storage air. In particular, the air temperature is expected to be constant because the temperature change, even 1°C, can affect the quality of the stored product.

2. Research Methodology

The air was ionized by ionizers installed in the ventilation and cooling system of the fruit store for uniform ionization of the air environment and for efficient processing of the product during storage (Figure 1). At the same time, the ionizer is at a height and does not interfere with loading and unloading operations and does not pose a danger to the growth of service personnel. Air ions are transported by ventilation forces and space charge dissipation [7, 8].

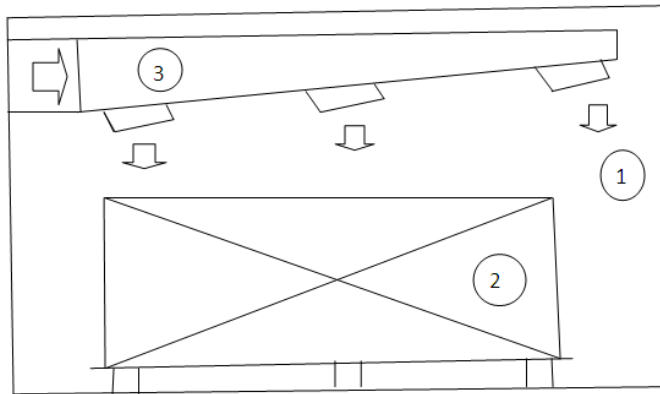


Fig. 1. Ionizers are installed in the ventilation and cooling system of the fruit storage: 1-storage room, 2-stacks with products, 3- air duct of the ventilation and cooling system with ionizers

Where air is ionized by ionizers installed in the fruit storage ventilation and cooling system, there may be two possible options. In the first variant, one ionizer with reasonable capacity is installed at the beginning of the air duct next to the fan. As a result, the ionization and cooling system will be compact.

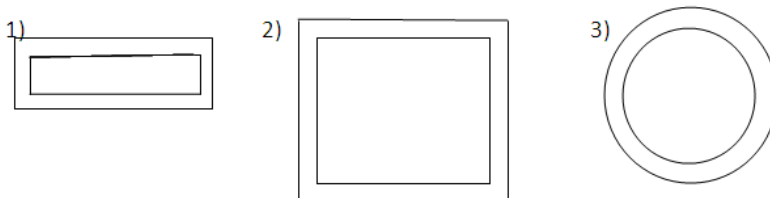


Fig. 2. The cross-sectional shape of the ventilation openings of the fruit storage duct: 1-quadrangular, 2-square, 3-round

Within the room, ionized air is blown by ventilation ducts. The ionization system will work safely and rationally. Only negatively charged air ions that are partly deposited on the inside surface of the duct are lost, the density of the ions may decrease significantly at the end of the duct. To avoid this process, the metal duct is disconnected from the ground

and connected to a multiple volt power supply. In this case, the potential for the energy source is determined by the volume concentration of the air ions.

In the second version, the ionizers have smaller dimensions and are mounted on the ventilation openings of the air duct, from where air is pumped into the room. Air duct vents can have various shapes: quadrilateral, square, round section (2-fig.). In our studies, we have manufactured ionizers of various configurations and installed them in the air vents of the fruit storage duct. [9].

The ionizer consists of a power source, a voltage regulator and instrumentation. The discharge electrodes are attached to a metal frame and at a certain distance from them there is a grounded electrode made of aluminum sheet with cutouts in the form of a circle, the points are located along the axial line of the circles. The distance between the discharge and ground electrodes is modified by replacing the textolite insulators in different thicknesses. The electrodes are easy to install and remove, resulting in a variety of options. The voltage on the electrodes is regulated at the input of the step-up transformer by an autotransformer. A step-up transformer increases the voltage from 220 V to 6000 V, then, using a multiplier, the voltage is multiplied up to 10,000 V [10, 11]. The onset of discharge and ion was also controlled by an oscilloscope.

When fruits are stored in an ionised environment, electromagnetic forces directly affect living biological objects without converting to another type of energy, so that the technological process requires low energy costs. The ionizers of such a system are energy-saving, the implementation of the technology is simple, cheaper and easy to use and maintain.

When ionising the air of large parts, in order to increase the efficiency of the treatment of the product, a uniform treatment of the stored product is required [12]. Here, the ions from the ioniser to the product pass through three characteristic areas: the ionization area, the dissipation field of the spatial charge and the coverage area of the fruit surface. In the ionization zone, water molecules are ionized under the action of the corona field with a high intensity and are carried out into the volume of the room by the action of the electric wind and ventilation. In this area, the momentum of ion movement will be highly volatile [13]. The intensity of ionization and the dynamics of ion scattering depend on the voltage of the discharge electrodes and the speed of air movement.

Ionization parameters are also determined by an analytical way. In this case, the primary data are the potential of the electrodes, the dimensions of the electrodes, and the length of the discharge gap. The parameters of the external discharge field are determined by the joint solution of the Differential Form of Gauss, the continuity of the current, and the dependences of the potential and field strength and current density and space charge density [14]. It is assumed that the potential of the discharge electrode is equal to the voltage of the discharge electrode, and the potential of the grounded electrode is zero:

$$\varphi_{p.э} = U_{p.э}; \quad \varphi_{cyэ} = 0. \tag{1}$$

The method of equivalent charges is often used in calculating the field of the electric field of point electrodes [15]. The discharge gap is formed between the tip and the ring, moreover, the tips are perpendicular to the plane of the rings. The length of the electrode L, the distance between the electrodes l_1 , the curvature of the surface of the tip r_3 .

The potential distribution in the discharge gap is represented as the sum of the potentials of point charges (q) located along the tip and the potentials of linear charges located along the ring (τ) [15]. The potential equivalent of point charges has the following form:

$$\varphi = \frac{1}{4\pi\epsilon_0} \sum^n \frac{q_i}{\sqrt{(h+r_i-y)^2+x^2}} \tag{2}$$

Here: $\epsilon_0 = 8,85 \cdot 10^{-12}$ f/m – dielectric constant

q_i - the value of point charges

r_3 - radius of circles inscribed in the profile of the tip

h - distance from the tip of the point to the ring plane

x,y- coordinates of the target point of the electric field

Also, taking into account the expression in the final form, we can write the expression for the concentration of the space charge of the room in the following form:

$$n = \sum_{i=1}^n \frac{q_i}{4\pi e} [(h + R_i - y)^2 + x^2]^{-\frac{3}{2}} \tag{9}$$

Here: e- electron charge.

3. Results and Discussion

The density of the tip electrodes is one of the factors of air ionization intensity. The most efficient ionization regime is obtained at their density of 150–474 pieces/m² [16]. The length of the tip also depends on the distance between them. In turn, the distance between the needles depends on the length of the discharge gap. The density of the point electrodes is limited by the effect of mutual screening of the electric fields of the points. Besides, besides weakening the ionization intensity, a mutual screening of the electric fields of the tips, also affects the ionic flux in the volume.

At our university, Sh. Muzafarov dealt with the issues of determining the design parameters of point discharge electrodes and their arrangement. He used ionizers for air purification and for ozonation [17]. Accordingly, it has been proven that the electric corona charge effectively cleans the air from pollution, especially from fine dust. For this, in the research the various power sources were used: a positive and negative direct current source, a pulsed industrial, and an increased alternating current source, optimal parameters were determined for each case. Based on the results of the analysis, we studied the features of the technology for long-term storage of fruits, the processes occurring in the storage products, the sources of product losses, the effect of air ions on fruits, the optimal modes of air ionization, the main parameters of the corona-discharge ionizer that meet the requirements of the air ionization technology of fruit storages. The results of theoretical and experimental studies have been verified directly in production conditions.

The analytically obtained results $p \cdot 10^{-6} \text{ k/m}^3$, E, φ were verified experimentally, which are shown in Figure 3. Thus, at a voltage on the discharge electrodes of 2.8 - 6 kV, with a length of the discharge gap of 25-40 mm in the volume of the room, we obtain the density of the volume charge within 10^{-6} k/m^3 , and the volume concentration ions within 10^{14} ion/m^3 [18, 19].

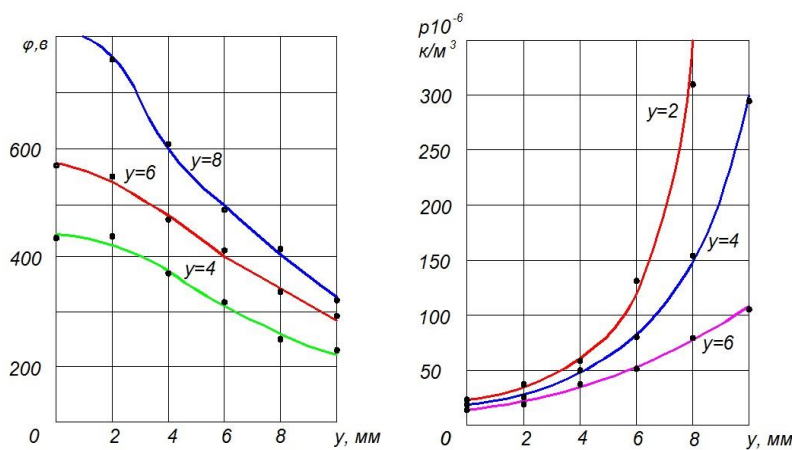


Fig. 3. Experimental distribution curves of the electric field potential of the corona discharge (φ) and space charge density (ρ) in the discharge gap

According to the research results, the optimal design parameters of the ionizer and their placement along the room were determined. If the ionizers are at a distance of 2–2.5 meters from each other and the ionization process is performed together with ventilation, the uniformity of the distribution of ions in the volume is within 85–87% [20]. In the ionization system, negatively charged air ions partially settling to the inner surface of the air duct are lost, as a result, the volume concentration of ions can significantly decrease at the end of the air duct. To prevent this process, the metal duct is disconnected from the ground and connected to a power source of several volts. In this case, the

potential of the air delivery pipe is determined by the value of the volume concentration of air ions. In the studies, the values of the air duct potential obtained as a result of the deposition of charged particles to the inner wall of the air duct were determined. The electrical circuit of the research is shown in Figure 4.

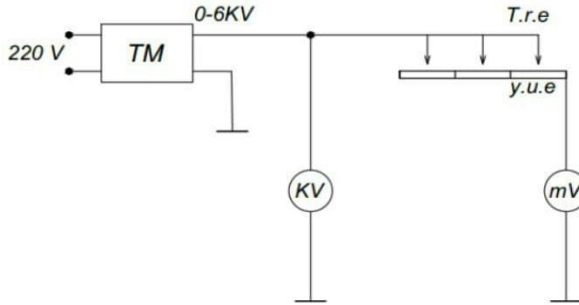


Fig. 4. Electric circuit of studies to determine the potential of the fruit storage duct during air ionization

Directly proportional dependence of these parameters is obtained. When the volume concentration of air ions changed from 10^{11} ions/ m^3 to 10^{14} ions/ m^3 , the potential value changed from 1 to 5.5 V. To prevent loss of ions in the inner walls of the duct, the duct was disconnected from the ground and turned on the power supply with a voltage of 1-5 V. The results of the research are presented in Figure 5

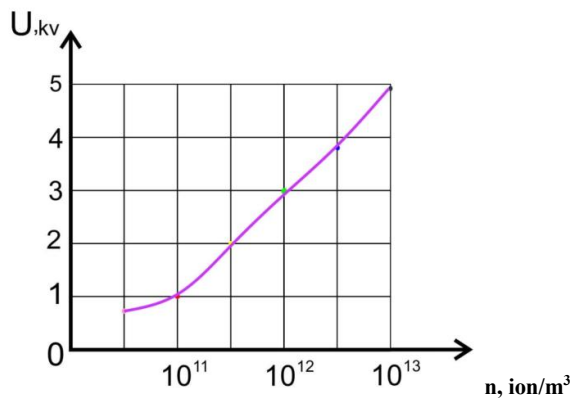


Fig. 5. The dependence of the potential of ventilation ducts as a result of the deposition of air ions on the volume concentration of air ions moving through the ventilation duct

Thus, when air is ionized with a volume concentration of 10^{12} ions/ m^3 , the air duct potential should be within 3–5 V. The results obtained are the basis for the development of indoor air ionizers.

4. Conclusions

- The most effective fruit storage ion system is obtained when ionizers are installed in the fruit storage cooling and ventilation system. At the same time, the technology is at the ceiling and does not interfere with the loading and unloading operations of the storage room.
- In this case, the ionizer and the ventilation and cooling system will be in one set, a compact microclimate system is formed. The air ions are pumped through the ventilation ducts and during this, the ions are partly deposited into the walls of the air duct and discharged. As a result, the volume concentration of air ions may decrease. To prevent this process, a power source with a voltage of several volts can be connected to the duct. In this case, the potential of the power source is determined by the volume concentration of air ions.
- The regime parameters of air ionization depend on the design parameters of the ionizer and the features of the power source. In the analytical and experimental determination of the parameters of the electric field of the corona

discharge and the ionization of air in the volume, the errors in the results do not exceed 3÷5%. When the volume charge density in the outer zone is 10^{-6} K /,M³ the volume concentration of ions is within 10^{14} ion/M³.

d) Ionized air in an enclosed space, moving from the ionizer to the surface of the processed product, passes through three characteristic zones: the ionization zone, the dissipation of the volume charge in the volume, and the zone of product surface coverage with an ion layer. The parameters of these zones differ sharply from each other and require separate consideration. In the technological process of ionization, air ions are affected by the electric field strength of the corona discharge, the own weight of the ionized particle, the electric field strength of the space charge, the resistance force of the medium and the electric field strength of the ionic layer of the product surface.

e) Thus, when air is ionized with a volume concentration of 1012 ions/m³, the air duct potential should be within 3–5 V. The results obtained are the basis for the development of indoor air ionizers.

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