Development of a plant for electrostatic fumigation of grain crops in a perfled layer

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Abstract. Improving the processes of post-harvest processing of leguminous crops is an urgent task for enterprises of the agro-industrial complex. The issues of ensuring reliable protection of leguminous crops from the effects of pathogenic microflora, quarantine insect pests are of substantive interest for research. To date, fumigation is considered a common method of disinfecting products - the elimination of insect pests and pathogens by a gaseous or vaporous poison-ous chemist. The article describes the design features of the installation for carrying out the process of fumigation of leguminous crops with an ionized flow of an air-dispersed mixture, and also presents some dependences characterizing the course of the process of electrostatic fumigation of legumes in the device being developed. The use of the proposed design of the installation for electrostatic fumigation of leguminous crops in an overflowing layer will allow for a uniform and high-quality fumigation process.

1. Introduction

Phytosanitary treatment (fumigation) of seeds of leguminous crops before storing them is carried out in special apparatuses, in which the critical parameters reach the required level for the entire mass of products [1-4]. This treatment is carried out by the method of aerosol spraying of a gaseous (vaporous) toxic substance - a fumigant, which provides a highly effective effect on pests [5-10].

Often, fumigation of leguminous crops occurs already under conditions of silage and floor storage [8, 11]. Carrying out the process under such conditions does not fully ensure the distribution of the active components of the fumigant throughout the entire volume of the product [2, 9]. Only a portion of the seed located on the surface of the layer is exposed to aerosol spraying, while the seeds located in the depth do not experience effective interaction with the fumigant, due to a significant increase in the hydrodynamic resistance of the seed layer. To eliminate this disadvantage, it is proposed to carry out the process of fumigation of leguminous crops in a constant stirring mode using the effect of fumigant ionization. The use of this effect makes it possible to have an additional detrimental effect on patho-genic microflora, quarantine insect pests, and the use of a constant stirring regime ensures a uniform distribution of the fumigant and its penetration into the most difficult-to-reach areas, which guarantees significant treatment efficiency. [1, 3].

Purpose of study – development of an installation for the process of electrostatic fumigation of seeds of leguminous crops with an ionized flow of an aerodispersed mixture, which makes it possible to improve the quality of product processing.

2. Results of the study
In fig. 1 shows a model of a plant for electrostatic fumigation of leguminous crops in an overflowing bed. The model was generated in the environment of the Autodesk 3dsMax application package. In fig. 2 shows a schematic diagram of an installation for electrostatic fumigation of leguminous crops in an overflowing layer.

**Figure 1.** Plant model for electrostatic fumigation of leguminous crops in an overflow bed

**Figure 2.** Schematic diagram of a plant for electrostatic fumigation of leguminous crops in an overflowing layer

Installation for electrostatic fumigation of leguminous crops in an overflowing layer (Fig. 2) contains a fumigation chamber 1, a system for supplying an aerodispersed mixture, including a generator of an aerodispersed mixture 2, a rotary pump 3, a filter 4, a mixing chamber 5, an ionization chamber 6, a collector 8. The installation also has a device for removing the spent aerodispersed mixture 13, a condenser 9, a recirculating pump 10, as well as pipelines 22, 27, 28, 29.

In the working space of the generator of the aerodispersed mixture 2, there is a sheet 40 preheated by the thermoelement 39, to which the fumigant 36 is supplied from the hopper 34, while the dosage of the supply of a portion of the fumigant 36 occurs due to the rotating device 37. The generator of the aerodispersed mixture 2 is equipped with a thermostat 35. Visual control over the generation of the aerodispersed mixture is carried out through the viewing window 38.

A pipeline 27 is connected to the generator of the aerodispersed mixture 2, connected to the pump 3 and the filter 4, to which is adjoined by the pipeline 28, which connects it to the mixing chamber 5, connected to the inlet 30 of the ionization chamber 6, inside which the corona electrodes are located 7.

The outlet 31 of the ionization chamber 6 is connected to the collector 8, which in turn is connected to the fumigation chamber 1, made in the form of a drum.

The fumigation chamber 1 is equipped with channel nozzles 14, forming longitudinal channels 15, inside which there is a continuous transverse partition 16, dividing the fumigation chamber into two zones: an active fumigation zone (1) and a preliminary fumigation zone (2), while in the zone active fumigation, the inlet part of the channels 15 is located, and in the pre-fumigation zone, the outlet part,
which plays the role of a passive electrode. The fumigation chamber 1 is installed with the possibility of rotation by means of tires 17 and 18, support 19 and drive roller 20.

The installation for electrostatic fumigation of leguminous crops in the overflowing layer includes a stationary loading device 11 passing through the end wall 12 of the fumigation chamber 1 with a device attached to it for withdrawing the spent aerodispersed mixture 13 adjacent to the longitudinal channels 15.

The fumigation chamber 1 is connected by means of a device for withdrawing the spent aerodispersed mixture 13 by a recirculating pipeline 22 with an inlet pipe 32 of a recirculating pump 10. By means of a recirculating pump 10, the spent aerodispersed mixture is sucked out of the fumigation chamber 1 and sent to the condenser 9, where it is separated from moisture, into as a result, it becomes possible to reuse it in the fumigation process. The outlet PA-tubes 33 of the condenser 9 by means of the pipeline 29 is connected to the mixing chamber 5.

The installation for electrostatic fumigation of leguminous crops in the overflowing layer is equipped with an unloading chamber 24, which includes a hatch 25 that connects it to the fumigation chamber 1. The unloading chamber 24 is adjacent to the fumigation chamber 1 using a special connecting device 26.

Along the entire length of the fumigation chamber 1 there is a perforated conical tube 23 made in a combination of ferromagnetic and non-ferromagnetic material, and part of the perforated conical tube 23 made of ferromagnetic material plays the role of a passive electrode. Separation of the perforated conical tube 23 into parts of ferromagnetic and non-ferromagnetic material is ensured by the installation of a solid transverse baffle 16. Due to the presence of the perforated conical tube 23, the usable volume of the fumigation chamber increases by approximately 15% due to a decrease in the volume occupied by air.

The collector 8 is stationary placed in the unloading chamber 24 and adjoins with one branch pipe to the ends of the channels 15, while the other extends into the perforated conical pipe 23, the length of this branch pipe being limited by the place where the solid transverse partition 16 is installed.

The product layer 21 in the fumigation chamber 1 is located on the surface of the channel nozzles 14.

Installation for electrostatic fumigation of leguminous crops in an overfilled bed works as follows.

A fumigant 36 from hopper 34 is poured into the working space of the generator of aero-dispersed mixture 2 on the sheet 40, adjusting its supply with a rotary device 37, after which thermoelement 39 is turned on and the fumigant is heated to the evaporation temperature and release of the aero-dispersed mixture. The temperature regime of the heating process of the fumigant 36 is set using the thermostat 35 connected to the thermoelement 39. The resulting aero-dispersed mixture is directed to the pipeline 27. Through the viewing window 38, visual control of the fumigant evaporation process is carried out.

From the generator 2, the aerodispersed mixture is sucked off by the rotary pump 3 and enters the filter 4, where it is cleaned, after which it passes the mixing chamber 5, then is pumped through the collector 8 into the fumigation chamber 1, heading before this into the ionization chamber 6, equipped with corona electrodes 7. In the ionization chamber 6, the aerodispersed mixture, passing through the gaps between the corona electrodes 7, is intensely ionized under the action of the electrostatic field.

The original product, subjected to the fumigation process, is directed through the stationary loading device 11 into the fumigation chamber 1 and is placed in a layer 21 on the surface of the channel nozzles 14 passing along the entire fumigation chamber 1.

When the drive roller 20 rotates (its drive is conventionally not shown), the fumigation chamber 1 rotates, the bands 17 and 18 of which interact with the drive 20 and support 19 rollers. Under the action of rotation of the fumigation chamber 1, the product, while mixing, moves from the end wall 12 to the unloading hatch 25 of the fumigation chamber 1, and then enters the unloading chamber 24, from which it is removed outside the installation.

The ionized aerodispersed mixture obtained in the ionization chamber 6 enters through the collector 8 into the inlet part of the channels 15 and through the longitudinal slotted holes between the chan-
nel nozzles 14 along their length it enters the product layer 21, and due to the effect of directional movement under the action of the electrostatic field intensively passes through it and exits through its upper surface. At the same time, through the manifold branch pipe 8 located inside the perforated conical pipe 23, an additional stream of ionized aero-dispersed mixture obtained in the ionization chamber 6 enters the free upper part of the fumigation chamber 1, passes through the layer of product 21 in the forward part of the fumigation chamber 1, located between the transverse partition 16 and the device for removing the spent aerodispersed mixture 13.

Due to the use of an electrostatic field, ionized components of the aero-dispersed mixture flow are deposited on the surface of the product, and due to the constant stirring mode, they are filtered through the product layer, which ensures their uniform distribution throughout the product layer. At the same time, when the fumigation chamber 1 rotates, the longitudinal channels 15 are adjacent to the collector nozzle 8 and the device for draining the spent aerodispersed mixture 13, located in such a way that the supply and discharge of the aerodispersed mixture occurs only through the channels located under the product layer 21.

The spent aero-dispersed mixture, which has passed through the product layer 21, is moved by pump 10 through the recirculating pipeline 22 to the condenser 9, where it is separated from moisture, and then sent to the mixing chamber 5 for its reuse in the fumigation process.[14]

In the course of constructing a mathematical model of the considered process of electrostatic fumigation of leguminous crops in the overflowing layer, the distribution of the linear current density along the length of the fumigation chamber was obtained [6]:

\[
dQ = \left( e_1 - e_2(x) \right) \cdot \omega \cdot 2\pi \cdot \left( R_{scp} - \frac{h}{2} \right) \cdot \frac{q}{4/3 \cdot \pi \cdot \eta^3 \cdot \rho_A} \cdot d\tau dx ,
\]

where \( R_{h} = R_{h}(\theta) \) - outer layer radius (Fig. 3);

\[
R_{n,cp} = \frac{1}{\pi} \int_{0}^{\pi} R_{n}(\theta) d\theta ,
\]

**Figure 3.** Arbitrary section in the installation

\( h = h(x) \) - seed bed height; \( c \) - mass volume concentration of ionized components in the flow (in the active fumigation zone and the pre-fumigation zone); \( \omega = \omega(x) \) - filtration rate of the aerodispersed mixture through the layer; \( q \) - average charge of ionized component; \( \eta \) - breakthrough ratio; \( \rho_A \) - density of the aerodispersed mixture [7].

The linear current density is defined by the expression:
\[ i = \frac{dQ}{d\tau dx}, \]  

(3)

From (1) we obtain:

- for active fumigation zone

\[ i_1(x) = \frac{3}{2} \cdot (c_1 - c_2(x)) \cdot \left( R_{aep} - \frac{h(x)}{2} \right) \cdot \frac{q \cdot \omega(x)}{\eta \cdot \rho_4}, \]  

(4)

- for pre-fumigation zone

\[ i_2(x) = \frac{3}{2} \cdot (c_{1b} - c_{2b}(x)) \cdot \left( R_{aep} - \frac{h(x)}{2} \right) \cdot \frac{q \cdot \omega(x)}{\eta \cdot \rho_4}. \]  

(5)

Below are graphs of various dependencies of the process of electrostatic fumigation of seeds of leguminous crops in an installation for electrostatic fumigation of leguminous crops in an overflowing layer.

![Figure 4](image1.png)  
**Figure 4.** Concentration dependence ionized parcles in aerodispersed mixture from the useful current in the ionization chamber

![Figure 5](image2.png)  
**Figure 5.** Dependency final concentration of ionized particles on seeds from useful current in the ionization chamber

3. Conclusions

1. The location inside the fumigation chamber of a conical perforated pipe allows the formation of channels of variable cross-section for the supply and removal of the aerodispersed mixture, as well as to increase the useful volume of the chamber by reducing the volume occupied by air.

2. The presence of a continuous transverse partition allows the chamber to be divided into two zones: an active fumigation zone and a pre-fumigation zone, which contributes to the uniform and high-quality conduct of the fumigation process.

3. The use of a collector for supplying an aerodispersed mixture allows sequentially implementing the processes of pre-fumigation and active fumigation, which ensures a decrease in the consumption of thermal energy.

4. The connection of the central nozzle of the collector with the ionization chamber, equipped with corona electrodes, allows for high-quality preparation of the aerodispersed mixture and intensifies the process of deposition of active ionized components on the product in an electrostatic field.

5. With an increase in the value of the supplied current into the ionization chamber, the concentration of ionized particles of the aerodispersed mixture on the seeds increases.

6. Installation of an additional bypass pipeline has a significant impact on the concentration distribution along the length of the fumigation chamber. At the place of its installation, there is a
sharp abrupt increase in the degree of deposition of ionized components of the aerodispersed mixture (fumigant) by 2 times.

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