Justification parameters of mechanized dryer unit

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Abstract. This article presents an analysis of the creation of a unit for drying stem agricultural crops and justification of its main parameters, which is aimed at growing large and high-quality products through this process. The purpose of creating such a unit and justification of its parameters was that during drying, products were dried unevenly, resulting in some parts of the product were dried more than necessary, and some areas rotted without complete drying. Therefore, the shape of the unit for drying products must be such that the product simultaneously dries. Based on theoretical and experimental studies on this criterion, was developed a nomogram, the shape and parameters of the dryer device were theoretically analyzed by using analytical dependencies

1. Introduction
For drying of green fodder and seed vegetable crops most widely used convection type dryers. Techniques of convective drying are very diverse and as material layer in the drying process can be divided into the stationary drying in a soft mode, a movable fluidized-bed and in suspension [1, 2, 3, 4]. The dryer with a fixed layer of material, is a periodic installation, easy to install and operate, this type includes rack, tray-channel, chamber, platform dryers and ventilated bunts and containers.

Due to the peculiarity of testes of vegetable crops as objects of drying, a relatively small number of methods can be considered for practical use. The impracticability of drying in a dormant or suspended state is due to extremely unsatisfactory working off of the heat carrier and poor mixing of the material. Therefore, for drying the testes of vegetable and forage crops, active ventilation in stacks is considered the most acceptable.

Air distribution systems for drying hay by active ventilation, with the exception of ventilation systems of tower hay stores, can be classified as follows: floor air distribution systems with the main channel side decks, air distribution systems with the main side and trapezoidal air distribution channels [5, 6, 7]. The first type of air distribution systems is currently most widely used in barn-type storage facilities. There are several modifications: with the main channel along the entire length of the side decking and with the main channel reaching to the middle of the decking. In addition, both of these systems can be equipped with removable plugs that reduce the resistance of the hay layer to blowing. All these air distribution systems have one significant advantage - a large transition surface area [8, 9, 10], which contributes to a more uniform distribution of air in the stack.
However, having undoubted advantages, air distribution systems with the main channel and side decks are not devoid of certain disadvantages. Made of lumber, they are short-lived, often in need of repair. Their production is difficult to establish in industrial enterprises and deliver complete unit to the farms. Air distribution systems with the main channel and side decks have a significant width, so they interfere with the operation of mechanisms when removing hay from the hay store. Such a system can be buried in the floor of a shed, but the high cost of such systems and the danger of flooding them with rain or melt water make such a design used not widely.

Air distribution systems with main and side channels of the UDS-300 type are the most acceptable. They can be manufactured in factories and delivered to consumers as a complete set. However, they are not particularly popular in farms. There are several reasons for this. The system is made of perforated sheet metal, and its mechanical strength is low. In addition, the main channel and side channels have insufficient cross-section, which leads to significant air pressure losses in the system itself. It is also very difficult to mechanize the unloading of material from a storage facility equipped with such systems.

Trapezoidal channels until recently were widely used only for drying hay in stacks. They are easy to manufacture, unpretentious in operation. They are made of various materials: boards, metal. Wooden channels are inexpensive, but after several years of operation they become completely unusable and need to be replaced with new ones, in addition, they make hay removal mechanization difficult by remain in the stack after drying. In this case, the falling grate is lowered on hinged racks and the channel easily exits the stack. The described channel is not widely used due to the bulkiness of the design; in addition, unscrewing the nuts that hold down the falling grilles in the working position is associated with a certain risk and does not comply with safety requirements.

2. Method

The distribution of air flow in the stack of dried material was studied by using a unit that has a removable means of mechanization, on which stalk crops are stacked in the form of a stack [11, 12, 13]. In the process of drying stem crops with high moisture content at the height of dried material in the stack occurs shrinkage resulting in the formation of breaks in stack. To eliminate breaks in stack and removable air distribution unit there is available a height adjustment mechanism. Therefore, the air flow speed at the exit from the stack is measured every 6 hours after the fan is turned on, during the drying process to the conditioned humidity of the material being dried. If there is a difference in the speed of air flow in the side and upper parts of the stack, the control mechanism is lowered to their alignment.

To measure of the air flow velocity at the exit from the stack the surface of the stack was conventionally divided using a measuring twine into squares of 0.80 m in size (Figure 1).

![Figure 1](image_url)

**Figure 1.** Diagram of measuring the air velocity at the exit of the stack: 1-conditional area of a stack; 2 - places of measurement; 3-air distribution channel
Air velocities were measured at the intersection points. For this purpose, a manual winged anemometer AGO-3 with a diameter of 350 mm was used. Measurements at each point were carried out five times with a 42-minute exposure, and then the arithmetic mean and root mean square value of the speed meter readings were determined, and the air velocity in the anemometer cage was determined by the calibration curve applied to the device. Based on the condition of continuity of the jet and the area of the lower base of the bell, the speed of air movement on the surface of the stack was determined.

To determine the shrinkage of the layer of dried material in the drying process, a laboratory device was used to study the dynamics of drying. After laying the stalks of agricultural crops of a certain thickness, drying was carried out by active ventilation.

The shrinkage of stalk crops laid in a layer was determined 4 times a day, fixing their actual position in the drying chamber with a ruler with an absolute error of ±1 mm.

3. Results and Discussion

For the purpose of mechanization of stacking and unloading of stem crops stack, a means of mechanization has been developed [14, 15, 16]. Consider the scheme of the means of mechanization (Figure 2). The means of mechanization for drying contains walls 1, 2 which consist of two parts, pivotally connected to each other; one of them 1 forms an air supply box of a trapezoidal section, of different dimensions. At the end of them there is a hinge-connected screw mechanism 3 for sealing and breaking the stack, the other part of the wall 2 holds the dried material. The walls 1, 2 have retainers 4 positions of the angle of the locks, which are made of a hook-shaped form for fixing each other.

In addition, the means of mechanization has wheels 5 with a stop 6, installed at the junction of the movable part of the wall 1, 2.

Mechanization unit used in drying of stem agricultural crops is transferred from the initial position to the position of laying stem crops. To do this, the walls 2 are raised to a certain angle and in this position are fixed by the retainers 4 of the angle position. In the fixed position, it is loaded with loading means or directly from the trailer with the dried mass and a stack is formed.

At the end of formation of stack of stem crops, the stopper 6, wheels 5 are disconnected, and the movable side of the wall begins to mix into the stationary side of the wall. As a result of this and the gravity of stem crops, the walls 2, fall down. In this case, the mesh walls 1 begin to rise, since the walls 1 and 2 are fixed to each other by the holders 4 of the angle position, an air supply channel of a trapezoidal section is formed.

By moving the wheels 5 is possible to get different sizes of air supply trapezoidal channel. At the moment of releasing the wall 2, there are breaks in the middle of the stack, which are compacted by the
screw mechanism 3, as a result of this; the breaks in stack are eliminated. By formation of a trapezoidal air supply channel, a more uniform distribution and supply of drying agent in the layers of the material is provided. In addition, the trapezoidal section makes it possible to seal and eliminate breaks in the stack using the installed upper part of the screw mechanism. Then the fan is turned on in the installation. Atmospheric or heated air is pumped by a fan into the air supply channel and it passes through the layer of dried material, is saturated with moisture and is released into the atmosphere. After the layer is dried, before proceeding mechanized unloading with the help of unloading unit, the side mesh walls 1 and 2 are laid on a horizontal plane. To do this, necessary disconnect the holders 4 and move the right wall manually or by traction mechanisms, and the mechanization unit is transferred to the horizontal position.

The self-unloading mechanization unit used in drying contains walls with length $l_1$ and $l_2$ that are pivotally connected to each other. At the end of them there is a hinged screw mechanism with a length of $b_p$, for sealing and eliminating breaks in the stack. Figure 3 shows the design scheme of the stack for determining parameters of the self-unloading mechanization unit.

![Figure 3](image.png)

**Figure 3.** Calculation scheme of stem crop stack for determining the parameters of self-unloading mechanization unit in drying

The passed path $l_1$ and $l_2$ of the drying agent in the stack layers taking $l_1 - l_2 = \Delta l$, the angle $\gamma$ will be:

$$tg \gamma = \frac{h_x}{\Delta l}$$

(1)

where, $\gamma$ - is the wall mounting angle, deg; $h_x$ - height of the air distribution channel, m.

When justifying the parameters, we assume that density of stem crops stack at each point of cross-section is the same. Then to determine the gravity $G$ coordinate of stem crops, we use area $F$ of stack cross-section [17, 18, 19, 20]. From Figure 3 we have:

$$F_b = R^2 \theta / 2 - (R_b - l_2)^2 / 2$$

(2)
where, $l_2$ - the length of second wall, m; $F_b$ - cross-sectional area of the bunt, m; $\theta$ - angle between the walls, deg; $R_b$ - stack cross-section radius, m.

The height of the stack $h_o$ is determined from the following expression:

$$h_o = R_b - (R_b - l_2) \cdot \cos \left(\frac{\theta}{2}\right) \tag{3}$$

To perform self-unloading of gravity $G/2$, the stem crops in the stack pass through the support points $O_1$ and $O_2$. Based on this, the stack cross-section $F_b$ is divided into equal 4 parts:

$$F_b = 4 F, \tag{4}$$

A quarter of cross-section area of stack $F_1$ will be determined by following formula:

$$F_1 = \frac{R_b}{2} \left[ R_b - \left( R_b - l_2 \right) \cdot \cos \left( \frac{\theta}{2} \right) \right] \tag{5}$$

The distance $B$ between supports $O_1$ and $O_2$ is determined from the following expression:

$$B = 2 l_2 + b_p, \tag{6}$$

where, $b_p$ - is distance of the regulated zone, m.

Substituting the formula (6) in (5) and (5) in (4) we get:

$$F_b = \left( 2l_1 + b_p \right) \left[ R_b - \left( R_b \cos \left( \frac{\theta}{2} \right) + l_2 \cos \left( \frac{\theta}{2} \right) \right) \right] \tag{7}$$

from here the length of the first wall $l_1$ will be:

$$l_1 = \frac{F_b}{2 \left[ R_b - \left( R_b - l_2 \right) \cdot \cos \left( \frac{\theta}{2} \right) \right]} \tag{8}$$

where, $l_1$ - is the length of the first wall, m.

Justification of constructive parameters in designing of mechanization unit in drying: the length of the air distribution box $L_k$, and the bunt $L_b$, depends on other parameters of stack. Possible to find out these relations.

We assume that the length of air distribution channel $L_k$ is related with the length of stack $L_b$ by the following relation:

$$L_b = L_k + 2 l_1 \tag{9}$$

where, $l_1$ - is the path of drying agent along the X-axis, m.

Moreover, the length of air distribution box should not exceed 18 m [21], and drying agent moving speed in terms of uniform distribution of drying agent in the layers of stack should be 4...5 m/s [22].

The volume of stem crops stack can be determined by the following expression:

$$W_b = F_b \cdot L_b \tag{10}$$

where, $F_b$ - is the stack cross-section area without taking into account air distribution channel, m.

Taking into account the formula (10), mass of stack in calculation of absolutely dry state will be:

$$M_b = F_b \cdot L_b \cdot \rho \tag{11}$$

where, $\rho$ - is density of stem crops stack in calculation of absolutely dry state, t/m$^3$.

The hourly consumption of drying agent for drying stem crops will be:

$$Q_b = M_b \cdot Q \tag{12}$$

where $Q$ - is specific consumption of drying agent, m$^3$/t h.

Or formula (12) can be written differently:
Substituting the formula (11) in (12) and (12) in (13) through some mathematical transformations we get:

\[ Q_b = F_k \cdot (4 \quad 5) \cdot 3600 \]  \hspace{1cm} (13)

Substituting the formula (9) in (14) through some transformations we get:

\[ F_k = \frac{F_b \cdot L_b \cdot \rho \cdot Q}{(4 \quad 5) \cdot 3,6 \cdot 10^3} \]  \hspace{1cm} (14)

Substituting the formula (9) in (14) through some transformations we get:

\[ L_k = \frac{F_k \cdot (4 \quad 5) \cdot 3,6 \cdot 10^3}{F_b \cdot Q \cdot \rho} - 2l_1' \]  \hspace{1cm} (15)

As we can see, the length of air distribution channel is directly related to other technological and design parameters of the stack.

Based on this, we can conclude that almost all parameters of mechanization unit in drying stem crops are dependent on each other. For approximate calculations of constructive and technological parameters of mechanization unit used in drying stem crops, was developed a nomogram (Figure 4).

**Figure 4.** Nomogram for calculation of constructive and technological parameters of mechanization unit used in drying: \( Q_M \) – daily supply of stem crops in the calculation of standard moisture, t; \( Q_b \) – specific supply of the drying agent, m³/h \cdot t; \( V \) – moving speed of drying agent in the channel, m/s; \( F_k \) – air channel sectional area, m²; \( F_b \) – cross-sectional area of stack, m²; \( L_k \) – is the length of air channel, m; \( l_1' \) – distance traveled, by drying agent in layers of the stack, m; \( L_b \) – length of the stack, m

In the first quarter (I) of the nomogram, is given family of curves that allows determining the amount of drying agent for drying stalks of agricultural crops per stack at different specific consumption of drying agent and depending on daily \( Q_M \) supply mass in the calculation of conditioned moisture. The cross-section area of the air distribution channel \( F_k \) can be determined in the second quarter (II) by the speed of drying agent in air distribution channel and amount of drying agent for drying stem crops per stack. In third (III) quarter of the nomogram depending on the stack cross-section area \( F_b \), possible to get the length of air distribution channel \( L_k \). In the fourth quarter (IV) of nomogram depending on the length of air distribution channel \( L_k \), possible to determine the length of stack \( L_b \).

Using this nomogram, possible to solve the inverse problem, depending on the length of stack and air distribution channel, possible to determine the necessary amount of mass coming to drying in the calculation of conditioning and basic parameters of mechanization unit used in drying stem crops.
4. Conclusions
The mathematical model has been developed that describes the path of drying agent, which characterizes its uniform distribution over the layers of dried material, which allows to justify the shape of stack and mechanization unit for stem crops. Analytical dependencies are obtained that determine the rational parameters of stack and mechanization unit for drying stem crops. The parameters of the stack and the developed movable and self-unloading mechanization unit used in drying stem crops are determined by the proposed nomogram developed as a result of theoretical and experimental study, depending on the required productivity.

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