Drying agent spreading in stack of drying material

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Abstract. This article analysis of drying agent's spreading in ventilated drying of stem type agricultural crops and vegetable seeds, through which it aims to produce more and more high-quality products. The similar drying was not observed in different parts of the crops in ventilated drying, some parts of the drying product were dried out but some parts not dried well. The aims of the paper study this process. Therefore, products must be placed in the dryer with the thickness to have each point dry at the same time. Based on the practical experience of this criterion, the determination of loading thickness in drying was carried out theoretical analysis by using analytical dependencies. Theoretical analysis and analytical dependencies allow determining dimensions of the stack, layer thickness

1. Introduction
Alfalfa is widely used as feed for animals, and preservation of fodder is an important problem. Drying of alfalfa one of the most important operations that effecting to quality of alfalfa hay. During the drying of alfalfa produces a lot of moisture. It is well known that at the moment most alfalfa hay is dried in fields, where the moisture content of the product is unevenly dried by intense sunlight. As a result, wet alfalfa dries quickly and even over dries out, which leads to loss of leaves, that leads to a decrease in the quality of feed it produces. Possible to dry the chopped alfalfa components, including stems, crushed stems, and crushed stems with attached leaves, and leaves. The leaves and uncrushed stems had the highest and lowest drying rates among the four components [1 – 3].

To drying process of stem type crops influence air velocity, size of the layer, and drying agent temperatures. Drying alfalfa for hay in a thin layer by forced convection shortened the drying time as compared with natural convection two and a half times [4]. A study evaluated dried alfalfa leaves for protein production and describes the functional properties of the proteins show dried alfalfa leaves contained 260 g kg⁻¹ dry basis crude protein, with albumins being the major fraction [5]. In literature, it is estimated that when the loss of leaves is about 20%, the nutritional value of alfalfa hay is reduced by about 30% [6 – 8].

Air-solar drying is drying in natural conditions, i.e. in the open air. Shade drying is carried out under a canopy. The climatic conditions of Uzbekistan allow widely use drying in open air and shade different agricultural crops and seeds of vegetables. Drying by active ventilation is carried out in a stack by blowing atmospheric and heated air through it. Drying of stem type agricultural products in open air can last from 8 to 21 days, depending on weather conditions, the initial moisture content of the material, and the length of the arrow.

In the existing method of drying onions seeds, the cut onion stems with umbels are carefully transported to a special paved area for drying and spread out in a layer of 10...15 sm. During
transportation some of the seeds are crumbled, even in the first days of harvesting, as a result, there are two types of losses: mechanical and biological. The first is caused by the decomposition of nutrients, the second by the impact of pitchforks when stirring stem agricultural products. In hot sunny weather on farms in Uzbekistan, such air-solar drying of agricultural stems on hot asphalt is undesirable, as it leads to overheating and reduce seed germination [9].

Drying of agricultural stem crops in open air has following disadvantages: duration of the drying process, the high labor intensity of unfolding, folding seed heads and stirring, need for large paved drying areas, the influence of direct sunlight on quality of seeds, lack of conditions for post-harvest maturation, low yield and loss of seeds, and others [9, 10].

In initial drying period, when the humidity of mass is high, process proceeds at maximum speed, a period of decreasing drying speed begins from the moment when the flow of moisture from the center of seed heads lags behind evaporation rate and areas are formed on the surface of seeds that are not sufficiently saturated with moisture. In the final part of the stage, seed drying speed drops to zero. The moisture content of seeds gradually decreases and reaches a constant equilibrium level. The obtained seeds by air-solar drying method showed that germination rate and germination energy are 85 and 84%, respectively, which does not meet norms for the high quality of seeds. Air-solar drying method, in addition to noted disadvantages, is very time-consuming, that is, periodically, every 2-3 hours; layer must be stirred with a pitchfork to prevent overheating itself [11, 12].

Shade drying of stem type agricultural crops and vegetable seeds is carried out under a canopy; density of unfolding is the same as when drying in the open air, operations performed are the same as when drying in the open air. The operations performed are the same as when drying in the open air. During the season, you can make two turns of drying. The main disadvantages of shadow drying are its complete dependence on weather conditions, great labor intensity when unfolding, folding, and especially when tilling, loss of seeds and their damage during tilling, high costs associated with the construction of sheds.

In recent years is improving the technology and design issues of drying plants for drying stem type agricultural products. From the analysis of published works possible to conclude that active ventilation reduces the drying time of stem agricultural crops and vegetable seeds and gives a good result in yields and seed quality. Analysis of research results on drying processes of stem type agricultural crops confirms that artificial drying allows you to get first-class seed material with a germination rate of up to 97% [13 – 16].

All of the above suggests that currently the most acceptable and promising method of drying stem agricultural products is active ventilation in stacks, but the question of whether to use drying of freshly harvested stem agricultural products requires theoretical and experimental testing in specific climatic conditions of the Republic of Uzbekistan.

2. Methods
Theoretical and applied research has been carried out to study the ventilated drying process of products. As a result of applied research, the effects, modes, and parameters of the product's drying time and quality were monitored and identified. Besides, for drying in the stack a method of determining the exit velocity of drying agent on the surface of the product was developed. It consists of following, where the surface of the stack is conventionally divided into 0.8 m squares and at the angles of the square is the determined velocity of drying agent [17]. On this basis, theoretical studies and analytical dependencies are established.

3. Results and discussion
In the drying of products in the stack by ventilation uniform distribution of the drying agent on layer greatly influence the energy [18 – 20].

When checking the spread of drying agent in the stack layer, the following is assumed:
- the drying agent spreads from the point in the middle the cross-section base;
- the density of product in a stack depends on their height;
- the density of the product in a stack depends on the velocity rate of the drying agent, and hence its specific consumption.

Studies have shown that the thickness of the layer at a height of stack up to 5 m can be summarized by following empirical formula:

\[ \rho = a + b \cdot h \]  

(1)

here: a and b are the coefficients characterizing drying material, \( a = 70.76 \text{ kg/m}^3 \); \( b = 14.83 \text{ kg/m}^4 \); \( h \) is the height of drying product, m.

Suppose the density of the stack is the same everywhere. In this case, its outer surface (due to the simultaneous drying conditions) is in the form of a semi-cylinder (fig 1), and the velocity of the drying agent is uniform in all directions starting from \( O_b \). On point \( O_b \) drying agent velocity set \( V_b \) and set with \( V_k \) in desired point \( K \) of the stack. Possibly to write by taking into account the same time drying condition:

\[ V_b = V_k + \Delta V \]  

(2)

here: \( V_b \) and \( V_k \) are the velocity of drying agent at the beginning and end of product layer, m/s; \( \Delta V \) is the difference in drying agent speeds, m/s.

![Figure 1. Schematic diagram of elemental drying agent movement in \( \alpha \) angle in stack](image)

The amount of outgoing drying agent from stack surface is equal to \( Q_k \) and the drying agent spreading from point \( O_b \) is equal to \( Q_b \).

\[ Q_k = Q_b \]  

(3)

If we know the surface area of the stack \( F_s \), \( Q_i \) is equal to

\[ Q_k = F_s \cdot V_k \]  

(4)

or if we take into account form of the stack

\[ Q_k = L_s \cdot l_k \cdot V_k \]  

(5)

here: \( L_s \) is the length of the stack, m; \( F_s \) is the surface of the stack, m²; \( Q \) is the amount of drying agent, m³; \( l_k \) is the length of the stack semicircle, m; \( l_k = \pi \cdot R_k \); \( R_k \) is the cross-sectional radius of the stack, m.

By taking formula (5) to formula (3), by equating the length of an air distribution channel to the stack length and through the changes we will have:

\[ V_k \cdot l_k = l_p \cdot V_p \]  

(6)

By considering the pore space in the stack the formula (6):
\[ V_k \cdot R_k = K_y \cdot V_b \cdot R_s \]  \hspace{1cm} (7)

here: \( l_b \) is the length of air distribution channels’ half-circle, m; \( R_k \) is the air distribution channel radius, m; \( K_y \) is the coefficient considering the porosity of stack in the direction of drying agent.

It is known that porosity affects the dispersion of the drying agent and is inversely proportional to the density. We assume that it is a linear relation:

\[ K_y = \frac{\rho_b}{\rho_k} \]  \hspace{1cm} (8)

here: \( \rho_b \) and \( \rho_k \) are the densities at the beginning and end of the drying agent, kg/m\(^3\).

Taking into account effect of change in density (1) and pore (8) formulas on drying agent dispersion, by obtaining \( R_k = h + R_s \) and slightly changing formula (7) possible to get following relation:

\[ V_k = \frac{[a + b \cdot (h - y)] \cdot R_b \cdot V_b}{(a + b \cdot h) \cdot (R_b + h)} \]  \hspace{1cm} (9)

here: \( y \) is the height of stack where measured density, m.

The main task is to find the value of layer thickness - \( h \) when \( V_k = \text{const.} \). Finding \( y \) in the formula above is the solution to this problem.

The form and dimensions of the stack and air distribution channel depend on the need to dry at the same time as described above.

Theoretical analysis, the developed three-layer drying technology, and mathematical model allow determining coordinates of all points on the stack surface.

By solving formula (9), where stack height is \( h = 3.2 \text{ m} \) (the thickness of layers is \( h = 1.2 + 1 + 1 = 3.2 \)) on computer are obtained following values (see table 1):

| Thickness of layer, m | 0.6 | 1.2 | 1.7 | 2.2 | 2.7 | 3.2 |
|-----------------------|-----|-----|-----|-----|-----|-----|
| Amount of drying product, passed in one direction by one running meter, kg/m | 15.42 | 65.96 | 139.5 | 245.7 | 388.02 | 579.35 |

In table 2 is given the average value of \( l \) coordinates determined by the change of \( \alpha \) angle 0-90\(^0\) range.

| Angle,\(^0\) | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|--------------|---|----|----|----|----|----|----|----|----|
| Passed distance, m | 1.42 | 1.48 | 1.69 | 1.84 | 2.01 | 2.21 | 2.47 | 2.6 | 2.8 |

In figure 2 are presented in a graphical form calculation results. The curved line characterizes the rational form and dimensions of stacks cross-sectional surface.

In practice, the top of the stack is in semicircle form, while sides are at a certain angle with a straight line. But in practice, it is very difficult to provide the identified form.

The form identified above can be provided by changing the form of the air distribution channel. Assume that the stacks have a form that can be provided in practice. Here, where the air distribution points dry up the stacks at the same time, a form of air distribution channel is formed from those points (see figure 2).

The form of air distribution channel is determined by the formula (9), only here the problem is solved by moving in the opposite direction. It should also be taken into account that the height of the air distribution channel is \( h_k \), the height of the stacks \( h_b \) will be as follows:
Here: \( h_b \) is the height of the stack, m; \( h_k \) is the height of air distribution channels, m.

The width of the stack base \( B_b \) equal to or greater than the width of stack \( B \) from the term of simultaneous drying the width of air distribution is determined by the following dependency:

\[
B_k \geq B_b - B
\]

here: \( B_k, B_b \) are the stack and channel base widths, m; \( B \) is the largest width of the stack, m.

The form of air distribution channel is a semicircle, so:

\[
B_k = 2 \cdot R_k \cdot \sin \frac{\varphi}{2}
\]

from this

\[
R_k = \frac{B_k}{2 \cdot \sin \frac{\varphi}{2}}
\]

here: \( R_k \) is the radius of air distribution channel, m; \( \varphi \) is the sector angle, degree.

The cross-sectional surface of the air distribution channel is determined as follows:

\[
F_k = R_k^2 \cdot \frac{\varphi}{180} - \sin \frac{\varphi}{2}
\]

here: \( F_k \) is the air distribution channel cross-sectional surface, m\(^2\).

The cross-sectional surface of air distribution channel height from the formula (14), after some modifications, is equal to:

\[
h_k = \sqrt{\frac{2\pi}{\varphi \frac{\pi}{180} - \sin \frac{\varphi}{2}} - R_k \cos \frac{\varphi}{2}}
\]

The analytical dependence (15) allows finding the height of the air distribution channel by using the channel cross-sectional surface.

The dimensions of the stack layers provided in Table 3.

It is possible to determine dimensions of the stack, depending on the form of air distribution channel justified above. The last table is given a cross-sectional rational surface and coordinates of curve lines for each layer of the stack.

| Table 3. The coordinates of cross-sectional surface of each stack layer |
|---------------|---|---|---|---|---|---|---|---|---|---|
| Angle, degree | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 85 |
| X-axis, m:    |   |   |   |   |   |   |   |   |   |   |
| 1st layer     | 0.567 | 0.583 | 0.588 | 0.58 | 0.548 | 0.498 | 0.426 | 0.322 | 0.182 | 0.1 |
| 2nd layer     | 1.002 | 1.033 | 1.051 | 1.033 | 0.988 | 0.901 | 0.768 | 0.585 | 0.332 | 0.179 |
| 3rd layer     | 1.416 | 1.46 | 1.484 | 1.467 | 1.406 | 1.288 | 1.106 | 0.844 | 0.486 | 0.261 |
| Y-axis, m:    |   |   |   |   |   |   |   |   |   |   |
| 1st layer     | 0.02 | 0.103 | 0.214 | 0.335 | 0.46 | 0.593 | 0.738 | 0.884 | 1.034 | 1.098 |
| 2nd layer     | 0.035 | 0.182 | 0.382 | 0.597 | 0.829 | 1.073 | 1.329 | 1.607 | 1.881 | 2.04 |
| 3rd layer     | 0.049 | 0.257 | 0.54 | 0.847 | 1.18 | 1.535 | 1.915 | 2.32 | 2.755 | 2.986 |
Figure 2 shows the results of calculations in a graphical form. The curve shows the rational dimensions and form of stack’s cross-section.

4. Conclusion
The completed theoretical analysis of spreading drying agent among stack and analytical dependences allows determining form and parameters of ventilation channel and stack of product to be loaded into it from the point of view its simultaneous drying. The form and parameters of stack layers and drying agent were calculated by using obtained dependencies.

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