Theoretical Study of the Width and Height of the Feeding Window in Livestock Farming

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Abstract. The analysis of the technologies that grind, mix and distribute feed to livestock for livestock farms in the world today showed that the existing techniques are designed for livestock farms with a large production volume, so it is inconvenient to use them in small livestock farms. In addition, their metal capacity and energy consumption are high. For this reason, a device for distributing small-sized coarse feed was developed for small livestock farms.

According to the conducted studies, the uniform distribution of nutrients of the developed spreading device largely depends on the height and width of the device's discharge window. Therefore, in the article, the height and width of the discharge window of the feed distribution device were theoretically studied

Keywords: Spruce, mountain feed, corn, straw, alfalfa, bunker, height, width.

1 Introduction

In agricultural production, various structural and technological schemes are used for feed distribution in livestock farms. The most common technology for feeding cattle on farms is the distribution of feed by mobile distributors. The uniqueness of feed distribution processes in small livestock farms and farms requires the development of special solutions for their mechanization [1].

At present, in world practice, mixed feed distribution equipment, which combines the operations of moving feed, grinding and mixing, is widely introduced, which leads to a decrease in operational and other costs of feed preparation and distribution. With this in mind, research is being carried out on the development of food spreaders [2-4].

Thus, the existing technologies for the preparation and distribution of feed mixtures include the following technological equipment:

1) loader PE-0.8B - MTZ-80 tractor aggregated with feed spreader KTU-10A;

2) MTZ-80 tractor aggregated with self-loading vehicles [5].

The analysis of these technologies showed that the existing techniques are intended for large industrial livestock farms with a large production volume, so their use in small livestock farms and peasant (personal assistant) farms is not profitable or

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it is inconvenient to use them in every way. In addition, their metal capacity and energy capacity are large, their price is expensive, and it requires a lot of money to bring, install, use and organize technical service.

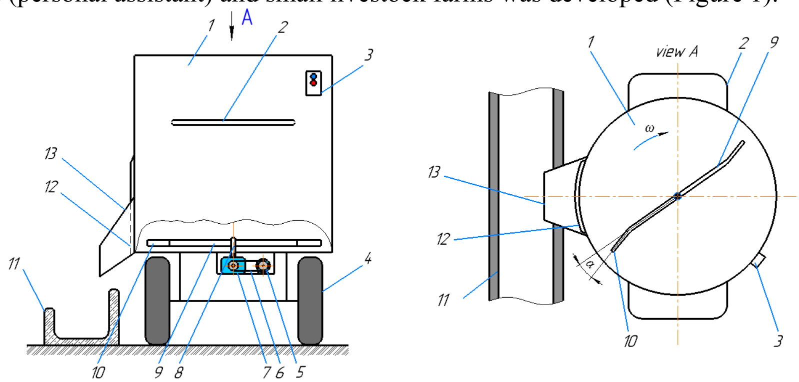
Therefore, there is a problem of improving and developing technology and technological tools for small family farms in order to reduce the energy consumption of technological processes. This situation requires the development of small feed distribution devices that satisfy farmers' (personal assistant) farms and family livestock farms in terms of productivity and energy consumption, and are not inferior to existing large-sized machines in terms of performance indicators [6].

Despite the fact that many studies have been conducted to improve the quality of coarse feed distribution, taking into account the above, additional theoretical and experimental studies have been conducted to justify the shape and parameters of the working parts of the distribution device, which will develop specific requirements and aspects of feed distribution to livestock.

According to the conducted studies, the spreader device that distributes the nutrients at the same rate depends to a large extent on the height and width of the device's discharge window. For this reason, in the article, the height and width of the discharge window of the feeding device were theoretically studied [7].

2 Materials and methods

Based on the design and technological workflow of coarse distribution devices, research conducted on their research, and the study of the structural structure of coarse, a compact version of a coarse distribution device with a light construction for farmers (personal assistant) and small livestock farms was developed (Figure 1).



1-hopper; 2-handle; 3-start button; 4-wheels;
5-electric motor; 6-belt drive; 7-worm reducer; 8-rotor; 9-blade; 10-blade tip;
11-trough and 12-13 discharge gate and trough;.

Fig 1. Coarse distribution device

The working process of the coarse feed distribution device is carried out as follows.

The fodder is loaded into the hopper 1 and, holding the handle 2, the feed spreader is moved by the wheels 4 and taken to the feed distribution place, and the mover 5 is started by the start button 3. At the same time, the movement is transmitted from the drive 5 to the worm gear reducer 7 through the belt drive 6. In turn, the worm reducer 7 transmits the movement to the rotor 8, reducing the number of revolutions several times. Blades 9 are installed on the shaft of the rotor 8, and at the same time, the shaft of the rotor 8 and the blades 9 rotate together. As a result of the rotation of the blades 9, the feed begins to move from the center of the hopper 1 towards the tip 10 of the blades. At the same time, the feed moves rapidly along the blades 9 to the slanted end of the blades 10 and starts to leave the discharge window 11. The feed coming out of the pouring window 11 comes to the manger through the pouring channel 12. The inclined position of the tip 10 of the shovels 9 improves the simultaneous pushing and ejection of feed by the shovels [8].

When distributing coarse feed, their required amount of spillage is regulated by the efficiency of the feed spreader shovels, their rotation speed and the ratio of the feed spreader movement speed. Similar relationships between rotation speed and feed distribution efficiency were experimentally confirmed in disc-type feed distribution devices [10].

3 Results

Now we determine the dimensions of the feeding window, that is, the width and height.

Inside the hopper, in front of the discharge window, there are two distinctive pieces of coarse feed, one of which (Figure 2, a) is a semi-ring-shaped "wall" attached to the discharge window, and the other (Figure 2, b) is a piece of feed pushed by the beveled tip of the shovel in the form of a "segment piece", which is a "wall" in front of the discharge window of the feed spreader. It comes and hits from time to time in order to destroy the nutrient layer formed as As a result, if the force of impact of the second piece on the first piece is sufficient, the feed will leave the window and pour into the manger and the process will be completed. Otherwise, the device will stop working.

In this case, the feed layer formed as a "wall" in front of the feed distributor's discharge gate has an outer width of b_{∂} equal to the width of the discharge gate, an inner width of b_u equal to the width of the inner surface of the "wall", a thickness of l_m equal to the width of the gap between the bucket and the bunker wall, a height of h_{δ} equal to the height of the discharge gate, and a second "segment"-shaped piece of the thickness of b_{κ} equals the thickness of the bucket, and a length of u_{κ} equals the length of the bucket (Figure 2).

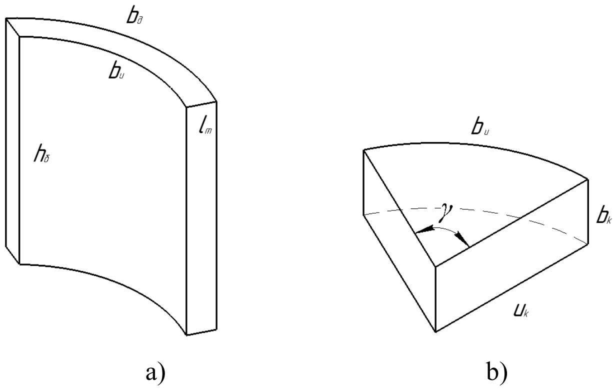


Fig. 2. Schematic diagram of coarse feed particles interacting as they exit the discharge window

The center angle of the "segment" piece being pushed out of the feed spreader by means of a shovel is found as follows:

$$\gamma = \frac{2b_\partial}{B_\kappa} \tag{1}$$

in which B_κ is the diameter of the hopper.

The mass of the feed layer formed as a "wall" in front of the discharge window of the feed spreader can be calculated as follows:

$$m_\partial = \frac{\gamma}{2}\left(\left(\frac{B_\kappa}{2}\right)^2 - \left(\frac{B_\kappa}{2} - l_m\right)^2\right)h_б\rho \tag{2}$$

where ρ is the volumetric weight of coarse feed in the "wall".

Considering expression (1), expression (2) changes as follows:

$$m_\partial = \frac{b_\partial\left(B_\kappa - l_m\right)l_m h_б \rho}{B_\kappa} \tag{3}$$

We find the moment M_{qar} (Figure 3) against the breakdown of the feed layer, which is formed as a "wall" in front of the discharge window:

$$M_{qar} = F_{yc}\frac{l_m}{2}, \tag{4}$$

where F_{yc} is the weight of the feed column above the level of the shovel.

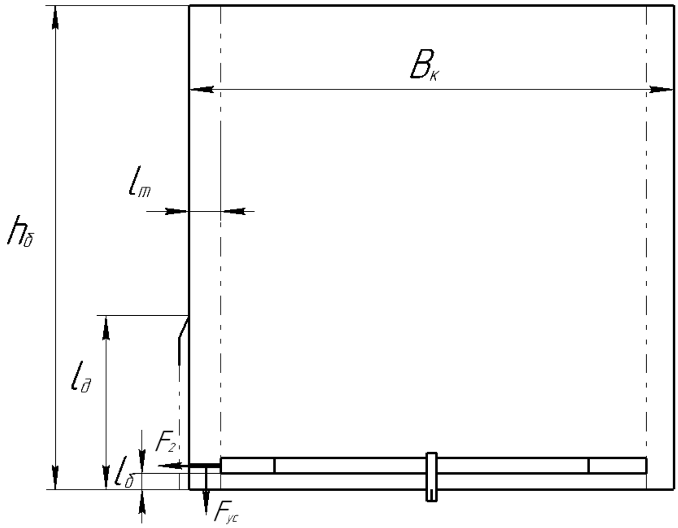


Fig 3. Scheme for calculating the moment against the spillage of coarse feed

$$F_{yc} = \frac{b_д(B_к - l_т)l_т(h_б - l_б)\rho g}{B_к} \text{ for being:}$$

$$M_{qar} = \frac{b_д(B_к - l_т)l_т^2(h_б - l_б)\rho g}{2B_к}, \quad (5)$$

where $l_б$ is the installation height of shovels relative to the bottom of the bunker; g - free fall acceleration.

Using the expressions $m\ddot{r} = m\omega^2 r - f(mk_m\omega r + 2m\omega\dot{r})$ and $\dot{r} = \sqrt{2(r - r_0)(C_1 z_1^2 + C_2 z_2^2)}$ and the fact that the mass of the elementary volume of feed is $m = \rho b_к \gamma (r - r_0)dr$, we find the force exerted by the second piece (Figure 2, b) pushed by the paddle on the first piece ("wall") in front of the spillway (Figure 2, a) as follows.

$$F_2 = \int_{r_0}^{u_к} \left[\rho(b_к\gamma(r - r_0)dr)(\omega^2 r - f(k_m\omega r + 2\omega\dot{r}))\right] =$$

$$= \rho b_к \gamma \int_{r_0}^{u_к} (r - r_0)\left[\omega^2 r - fk_m\omega r - 2f\omega\dot{r}\right]dr = \quad (6)$$

$$= \rho b_к \gamma \int_{r_0}^{u_к} (r - r_0)\left[\omega^2 r - fk_m\omega r - 2f\omega\sqrt{2(r - r_0)(C_1 z_1^2 + C_2 z_2^2)}\right]dr.$$

If we replace $r = r_0 + l$ in expression (6), we get the following changes:

$$F_2 = \rho b_\kappa \gamma \int_0^{u_\kappa - r_0} l\left[(r_0 + l)(\omega^2 - fk_m\omega) - 2f\omega\sqrt{2l\left(C_1 z_1{}^2 + C_2 z_2{}^2\right)}\right]dl =$$

$$= \rho b_\kappa \gamma\left[(\omega^2 - fk_m\omega)\left(\frac{r_0(u_\kappa - r_0)^2}{2} + \frac{(u_\kappa - r_0)^3}{3}\right) - \right.$$

$$\left. - 2f\omega\sqrt{2\left(C_1 z_1{}^2 + C_2 z_2{}^2\right)} \cdot \frac{2(u_\kappa - r_0)^{\frac{5}{2}}}{5}\right] =$$

$$= \rho b_\kappa \gamma\omega(u_\kappa - r_0)^2\left[(\omega - fk_m)\left(\frac{r_0}{2} + \frac{(u_\kappa - r_0)}{3}\right) - \frac{4f\sqrt{2(u_\kappa - r_0)\left(C_1 z_1{}^2 + C_2 z_2{}^2\right)}}{5}\right]. \tag{7}$$

The moment of force affecting the breaking of the feed "wall" by the second piece pushed by the shovel (Fig. 3) is determined as follows

$$M_{buz} = F_2 l_\partial \tag{8}$$

where l_∂ is the height of the spillway.

Another feature that causes the feed in the bunker to spill onto the ground is the fact that, in addition to having the properties of a partially solid body, this feed also has a fluidity, which is determined by its natural inclination angle.

We find the work done as a result of the fluidity of the feed, which is located opposite the discharge window.

The fluidity of the feed causes it to move from ABCD to AEHD (Figure 4), i.e., the rectangle EBCF becomes a triangle FHD.

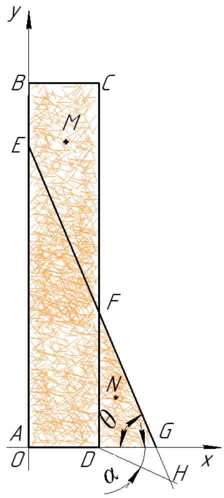


Fig. 4. Calculate the work done by the fluidity of the feed

Given that $AB = l_\partial$ and $AD = l_m$, we find the equations of straight lines EH and DH in the *xOy* coordinate system, and the center of gravity and areas of the rectangles EBCF and FHD.

$$EH: \quad y = AE + tg(\pi - \theta)x$$

or

$$EH: \quad y = AE - tg\theta \cdot x \tag{9}$$

$$DH: \quad y = tg(\pi - \alpha)(x - AD)$$

or

$$DH: \quad y = -tg\alpha(x - l_m) \tag{10}$$

$$S_{EBCF} = \frac{BE + CF}{2} \cdot AD = \frac{(l_\partial - AE) + (l_\partial - (AE - tg\theta \cdot l_m))}{2} \cdot l_m$$

or

$$S_{EBCF} = \frac{2(l_\partial - AE) + tg\theta \cdot l_m}{2} \cdot l_m \tag{11}$$

We make a system of equations for the coordinates of the point H:

$$\begin{cases} y = AE - tg\theta \cdot x \\ y = -tg\alpha(x - l_m) \end{cases} \tag{12}$$

from this

$$x_H = \frac{AE - l_m \cdot tg\alpha}{tg\theta - tg\alpha}; \quad y_H = \frac{l_m tg\theta - AE}{tg\theta - tg\alpha} \cdot tg\alpha \tag{13}$$

$$S_{FHD} = \frac{\left(AE - tg\theta \cdot l_m\right) \cdot \left(\dfrac{AE - l_m \cdot tg\alpha}{tg\theta - tg\alpha} - l_m \right)}{2} \tag{14}$$

$$S_{FHD} = \frac{\left(AE - tg\theta \cdot l_m\right)^2}{2\left(tg\theta - tg\alpha\right)} \tag{15}$$

We determine the value of *AE* from $S_{EBCF} = S_{FHD}$:

$$\frac{2\left(l_\partial - AE\right) + tg\theta \cdot l_m}{2} \cdot l_m = \frac{\left(AE - tg\theta \cdot l_m\right)^2}{2\left(tg\theta - tg\alpha\right)} \tag{16}$$

We enter the character:

$$z = AE - tg\theta \cdot l_m . \tag{17}$$

Then:

$$\left(tg\theta - tg\alpha\right)\left(2l_\partial - tg\theta \cdot l_m - 2z\right)l_m = z^2 \tag{18}$$

$$z^2 + 2\left(tg\theta - tg\alpha\right)l_m z - \left(tg\theta - tg\alpha\right)\left(2l_\partial - tg\theta \cdot l_m\right)l_m = 0 \tag{19}$$

We select only the positive root of the quadratic equation:

$$z = -\left(tg\theta - tg\alpha\right)l_m + \sqrt{\left(\left(tg\theta - tg\alpha\right)l_m\right)^2 + \left(tg\theta - tg\alpha\right)\left(2l_\partial - tg\theta \cdot l_m\right)l_m} \tag{20}$$

$$AE = z + tg\theta \cdot l_m . \tag{21}$$

$$AE = l_m tg\alpha + \sqrt{\left(\left(tg\theta - tg\alpha\right)l_m\right)^2 + \left(tg\theta - tg\alpha\right)\left(2l_\partial - tg\theta \cdot l_m\right)l_m} \tag{22}$$

Let's find the center of gravity of the rectangle EBCF:

$$x_M = \frac{x_E + x_B + x_C + x_F}{4} = \frac{0 + 0 + l_m + l_m}{4} = \frac{l_m}{2}; \tag{23}$$

$$y_M = \frac{y_E + y_B + y_C + y_F}{4} = \frac{AE + l_\partial + l_\partial + AE - tg\theta \cdot l_m}{4} \tag{24}$$

We find the centroid of the triangles FHD:

$$x_N = \frac{x_F + x_H + x_D}{3} = \frac{l_m + \frac{AE - l_m \cdot tg\alpha}{tg\theta - tg\alpha} + l_m}{3} = \frac{AE + 2l_m \cdot tg\theta - 3l_m \cdot tg\alpha}{3(tg\theta - tg\alpha)}$$

(25)

$$y_N = \frac{y_F + y_H + y_D}{3} = \frac{AE - l_m \cdot tg\alpha + \frac{l_m tg\theta - AE}{tg\theta - tg\alpha} \cdot tg\alpha + 0}{3} = \frac{AE \cdot tg\theta + l_m \cdot tg^2\alpha - 2AE \cdot tg\alpha}{3(tg\theta - tg\alpha)} \tag{26}$$

Taking into account the above quantities, we determine the work done by the fluidity of the feed located in front of the discharge window as follows

$$A_{oquv} = S_{FHD} b_{\partial} \rho g (y_M - y_N) + S_{FHD} b_{\partial} \rho g f_{ilash} (x_N - x_M) \tag{27}$$

where f_{ilash} is the internal coefficient of feed.

We determine the height of the drain window from the following condition:

$$M_{qar} < M_{buz} + A_{oquv} \tag{28}$$

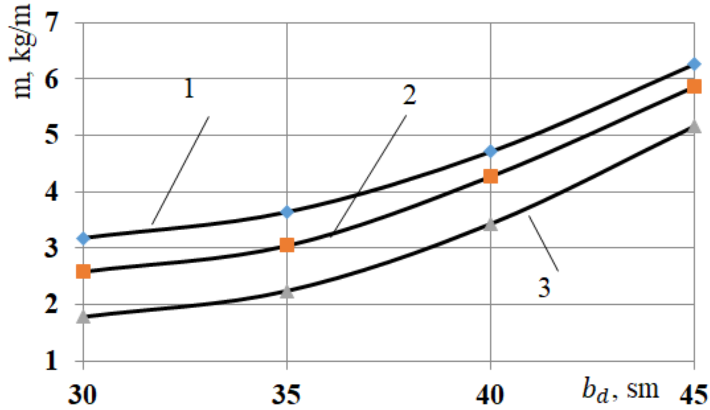
Ushbu tengsizlikni analitik ko‘rinishda yechish mushkul, shuning uchun uni sonli usulda yechamiz.

If $b_{\partial} = 0{,}4m$; $B_{\kappa} = 1m$; $l_m = 0{,}08m$; $h_{б} = 1m$; $l_{б} = 0{,}02m$; $\rho = 80kg/m^3$; $g = 9{,}8m/s^2$; $f = 0{,}3$; $n_p = 50r/\min$; $k_m = 0{,}5s^{-1}$; $r_0 = 0{,}03m$; $b_{\kappa} = 0{,}01m$; $u_{\kappa} = 0{,}42m$; $\alpha = 35^0$; $\theta = 55^0$; $f_{ilash} = 0{,}6$ the following condition must be met for the height of the drain window: $l_{\partial} > 0{,}296m$.

4 Conclusion

Based on the conducted theoretical studies, experimental work was also carried out. According to the initial requirements, the feed distribution device should distribute 2-5 kg of dry coarse feed along the front of the feeding troughs and corridors in the one-way distribution of feed.

According to the above theoretical and preliminary requirements, we first conducted experiments to study the width of the pouring window in this part, the width of the pouring window was changed from 30 cm to 45 cm in 5 cm intervals, and the height of the pouring window was changed from 20 cm to 35 cm. The experimental conclusions obtained are presented in (Figures 5, 6).

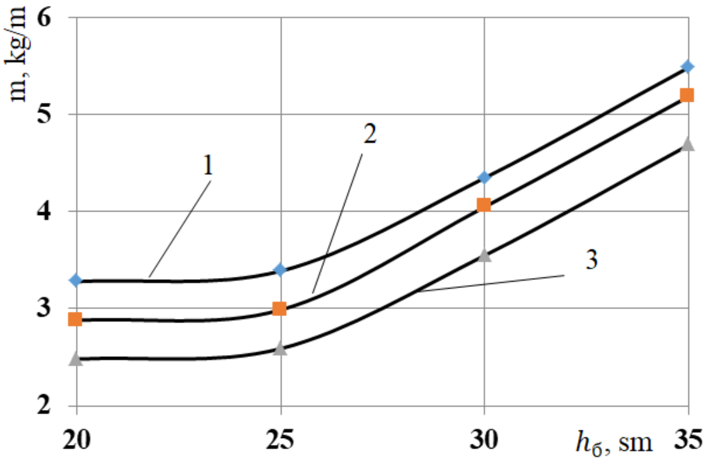


1) corn 2) clover 3) straw

Fig. 5. Coarse feed depending on the width of the chute change in the amount of distribution

According to the results of the obtained experiments, the quality of distribution of coarse feed at the level of the specified requirements was determined when the width of the discharge window of the distributor device is 40 cm. In this case, the amount of feed spillage was 4.71 kg/m in corn, 4.27 kg/m in alfalfa and 3.43 kg/m in straw, which was found to satisfy the initial requirements (Figures 5, 6).

Based on the research, the height of the pouring window was changed from 20 cm to 35 cm when the width of the pouring window was 40 cm.



1) corn 2) clover 3) straw

Fig. 6. Coarse feed depending on the height of the discharge window change in the amount of distribution

According to the obtained experimental results, the required quality of pouring ground corn, clover and straw was determined when the height of the pouring window was 30 cm. It was found that the amount of distributed mass is 4.35 kg/m in corn, 4.05 kg/m in clover, and 3.55 kg/m in straw, from 3 kg to 5 kg per daily single ration, which is at the level of the specified requirements [9]. Similar studies indicate that granulometric composition and particle mass significantly influence uniformity of feed distribution [11].

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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