EurAsian Journal of BioSciences
Eurasia J Biosci 13, 625-631 (2019)

Method of fineness adjustment of shredded particles of stem fodder in open-type machines

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Abstract

As a result of theoretical studies, analytical expressions were obtained for determining the average length of shredded particles of stem fodder, depending on the distance between the faces of adjacent hammers, and also to determine the mass fraction of shredded particles with the required size depending on the number of encounters of rows of hammers with circulating mass in the grinding chamber, and depending on the number of rows of counter-hammers installed in the grinding chamber. The results of calculation showed that the average length of shredded particles corresponds to the distance between the faces of adjacent hammers. In order to verify the reliability of theoretical studies, experimental studies have been carried out at various rows of counter-hammers. The change in the mass part of fraction with a particle length of 30 mm, depending on the number of counter-hammer series, with sufficient accuracy (1.3-3.1%) coincided with a theoretical dependence, which confirms the reliability of the obtained analytical expressions. During the experiment, the required power was determined for the process of hay chopping (grasses with a moisture content of 17%). Nature of the change in the required power in the shredding process and values of the mass part of the required fraction are same, i.e. with an increase in the number of rows of counter-hammers to 2 rows, more intensive change occurs, and with a further increase in the number of rows of counter-hammers, the change in the above factors equally decreases, i.e. they have the same functional dependency. All of this speaks of sufficient reliability of theoretical research, and it can be argued that a method has been developed for adjusting the fineness of shredded stem fodder in open-type machines.

Keywords: fodder shredders, destruction probability, rows of counter-hammers, stem fodder, shredding fineness, mass fraction of shredded particles

Abilzhanuly T (2019) Method of fineness adjustment of shredded particles of stem fodder in open-type machines. Eurasia J Biosci 13: 625-631.

INTRODUCTION

Shredding stem fodder (hay, silage and haylage) is the main operation in the preparation of fodder mixtures for sheep and cattle. In previous studies, it was found that feeding cattle with chopped hay provides an increase in weight gain of 35%, compared with feeding cattle with not chopped hay (Walton 1986).

According to the zootechnical requirements, the sizes of shredded particles of stem fodder for sheep should be 20-30 mm, and for cattle – 30-50 mm. Particles of the specified size should be at least 80%, particles larger than 50 mm should be no more than 10%, and the number of particles split along the fibers should be 80-90% of the total mass (Kulakovsky et al. 1987).

From this it is clear that the shredders of stem fodder should ensure the fineness adjustment of shredded stem fodder. Currently, the quality of shredding green mass in shredders of forage combine harvesters is achieved by choosing the number and speed of working tools (Belov 2004, Chattopadhyay and Pandey 1999, El-Attar et al. 2013, Koprivica et al. 2012, Mahatale et al. 2015). However, in these machines dry hay is chopped coarsely and the quality of split stems is not enough, therefore, supplying the stem fodder shredders with a device providing adjustment of the length of shredded particles is a solution to the urgent problem of agriculture.

AIM OF THE STUDY

The aim of the study is to develop a theoretical basis for the fineness adjustment of shredded stem fodder in open-type machines and to verify the reliability of the obtained analytical expressions.

MATERIALS AND METHODS

In developing the theoretical basis for adjusting the fineness of shredded stem fodder, the probability theory method was applied, and in verifying the accuracy of the

Received: August 2018
Accepted: March 2019
Printed: May 2019

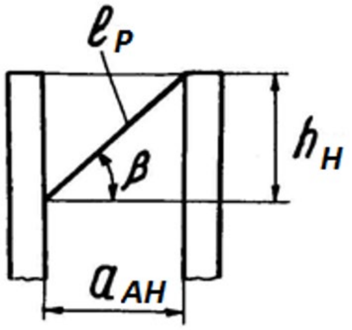


Fig. 1. Scheme of stems location in the plane of hammers blow

Table 1. The theoretical value of the average length of shredded particles, depending on the distance between the faces of adjacent hammers a_{AH}

a_{AH}, mm	20	30	40	90
l_{AS} by formula (2)	22.41	31.85	41.45	90.77

obtained analytical expressions, single-factor experimental studies were used.

RESULTS AND DISCUSSION

In the process of circulation of fodder in the grinding chamber, any roughness of the deck delays long stems. If the rows of counter-hammers were established along the grinding chamber, they would contribute to the delay of long stems, as well as their complete destruction. In addition, when delayed by rows of counter-hammers, the stems are aligned in the plane of the front face of the counter-hammers and hammers, in this case, it is possible to consider the location of the stems only in the vertical plane, i.e. β (**Fig. 1**).

It can be seen from the figure that in this case the average size of shredded particles l_P does not depend on the initial length of stems, but depends on the distance between the faces of the adjacent hammers a_{AH} and the height of the loaded part of the hammer h_H.

The length of shredded particles depending on the angle is determined by the formula

$$l_P = \frac{a_{AH}}{cos\beta} \qquad (1)$$

In this case, the mathematical expectation of function from the angle β, i.e. the average size of shredded particles is determined by the formula:

$$l_{AS} = M\left[a_{AH}\left|\frac{1}{cos\beta}\right|\right] = \int_0^{\beta} a_{AH}\left|\frac{1}{cos\beta}\right| \frac{d\beta}{arctg\frac{h_H}{a_{AH}}} = \frac{a_{AH}}{arctg\frac{h_H}{a_{AH}}} \cdot \int_0^{\beta} \frac{d\beta}{cos\beta} =$$
$$= \frac{a_{AH}}{arctg\frac{h_H}{a_{AH}}} \cdot \int_0^{arctg\frac{h_H}{a_{AH}}} \frac{d\beta}{sin\left(\frac{\pi}{2}+\beta\right)} = \frac{a_{AH}}{arctg\frac{h_H}{a_{AH}}} \cdot ln\left|tg\left(\frac{\beta}{2}+\frac{\pi}{4}\right)\right|_0^{arctg\frac{h_H}{a_{AH}}} = \qquad (2)$$
$$= \frac{a_{AH}}{arctg\frac{h_H}{a_{AH}}} \cdot ln\left|tg\left(\frac{arctg\frac{h_H}{a_{AH}}}{2}+\frac{\pi}{4}\right)\right|$$

The results of the calculation by formula (2) are given in **Table 1**. From the table it can be seen that the average size of shredded particles in this case does not differ much from the distance between the faces of adjacent hammers.

From this it follows that by installing the rows of counter-hammers in the grinding chamber and changing the spacing of the hammers in the rows, it is possible to adjust the average length of shredded particles.

Thus, a method of fineness adjustment of shredded particles by the steps of placing the hammers in rows, i.e. a new method of fineness adjusting of shredded particles in shredders without lattices has been developed. It follows that the hypothesis was proved, which consists in the fact that the average length of shredded particles depends on the distance between the faces of adjacent hammers, i.e. from the step placement of hammers in the ranks. It is also proved that if the rows of counter-hammers are established in the grinding chamber, then the average size of shredded particles in size will approach the distance between the faces of adjacent hammers in a row.

However, the quality of shredded fodder is estimated by the mass part of the fractions having a certain average length. Therefore, a theoretical determination of the quality of shredded fodder is important.

In the process of work, the rows of hammers, passing through the receiving mouth of grinding chamber, separate a certain portion of fodder with a mass from the layer:

$$q = h_L \cdot C_{LP} \cdot L_C \cdot \rho_L \qquad (3)$$

where h_L –layer thickness, m;

C_{LP} –length of the loaded part of hammers, m;

L_C –grinding chamber length, m;

ρ_L –density of the layer entering the grinding chamber, kg/m^3.

This portion makes a circular motion in the chamber and, moving along the surface of the chamber and before exiting it, K_B encounters rows of rotor hammers. If take the radii of grinding chamber and the hammer rotor to be equal, then

$$K_E = \frac{\varphi \cdot K_R \cdot v_H}{360 \cdot v_L} \qquad (4)$$

where φ –the angle of coverage of the rotor grinding chamber, deg.;

K_R –the number of rows of hammers in the rotor, pcs;

v_H, v_L – peripheral speed of hammers and layer, m/s.

At each encounter of hammers with weight, a certain part of it is shredded. However, for effective shredding of fodder in open-type shredders, we propose to install rows of counter-hammers in the grinding chamber, which contribute to the inhibition of long stems and increase the efficiency of their destruction.

The number of shredded particles should depend on the number of counter-hammers interacting with rotating hammers, and the pitch of the hammers and counter-hammers in the rows.

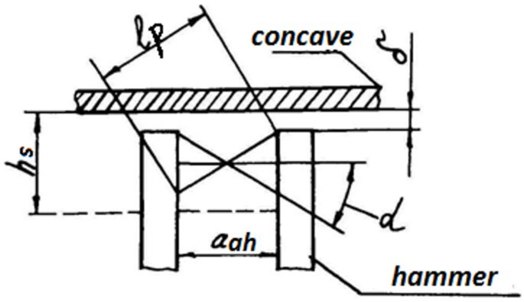


Fig. 2. Scheme of hitting stems of roughage under hammer blows in a vertical plane

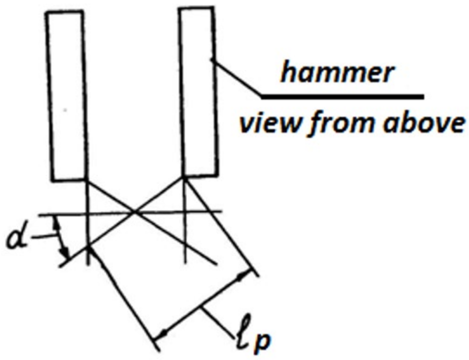


Fig. 3. Scheme of hitting stems of roughage under hammer blows in the horizontal plane

To test this hypothesis, consider the process of stem destruction of roughage in the grinding chamber. In this case, regardless of the number of rows of counter-hammers installed in the grinding chamber, a specific mass from the portion q should be shredded at $К_E$ encounters. Therefore, we first determine the probability of the content of shredded particles in a portion q without counter-hammers.

Since the stems in the chamber are not oriented in the same way, they do not all fall under blow, and also not all are destroyed. Considering that if the stems hit the hammer blows, the minimum size of shredded particles will be equal to the distance between the adjacent hammers, and taking into account the shredded particles with the maximum required size, you can determine the probability that the stems hit the hammers in the vertical plane (**Fig. 2**).

$$P_V = \frac{arccos\frac{a_{AH}}{l_P}}{90} \quad (5)$$

where a_{AH} – the distance between the faces of adjacent hammers, m;

l_P – maximum size of the required fraction, m

In order to consider the probability of the stems location in space, it is necessary to determine the probability of the stems hitting under the blows of hammers in the horizontal plane (**Fig. 3**).

From **Fig. 3** it can be seen that the probability of stems hitting under the blows of hammers in the horizontal plane is also determined by the formula (5).

Therefore, the probability of hitting the stems under the blows of hammers in space is determined by the formula:

$$P_S = \left(\frac{arccos\frac{a_{AH}}{l_P}}{90}\right)^2 \quad (6)$$

In addition, some stems located between the ends of hammers and the surface of grinding chamber in the gap δ, do not fall under the blows of hammers, so the probability of hitting the stems depending on the thickness of the layer h_L is determined by formula

$$P_h = \frac{h_L - \delta}{h_L} \quad (7)$$

It is known that the degree of destruction of materials depends on the speed of the working organs and the circulating layer. The probability of stems destruction that fell in shock, depending on the speed of hammer and layer:

$$P_D = \frac{v_H - v_L}{v_H} \quad (8)$$

The probability of destruction of all stems in the grinding chamber by one row of hammers (without counter-hammers) is determined by formula:

$$P_{sw} = P_n \cdot P_h \cdot P_P \quad (9)$$

The number of shredded particles in fractions of a unit at each encounter with rows of hammers is determined as follows:

1-encounter $P_{sw1} = P_{sw}$

2-encounter $P_{sw2} = (1 - P_{sw}) \cdot P_{sw} = P_{sw} - P_{sw}^2$

3-encounter

$$P_{sw3} = [1 - (P_{sw1} + P_{sw2})]P_{sw} = [1 - (P_{sw} + P_{sw} - P_{sw}^2)] =$$
$$= P_{sw} - P_{sw}^2 + P_{sw}^3 = P_{sw}2P_{sw}^2 + P_{sw}^3$$

4-encounter

$$P_{sw4} = [1 - (P_{sw1} + P_{sw2} + P_{sw3})]P_{sw} =$$
$$[1 - (P_{sw} + P_{sw} - P_{sw}^2 + P_{sw} - 2P_{sw}^2 + P_{sw}^3)]P_{sw} =$$
$$= P_{sw} - P_{sw}^2 - P_{sw}^2 + P_{sw}^3 - P_{sw}^2 + 2P_{sw}^3 - P_{sw}^4 = P_{sw} - 3P_{sw}^2 + 3P_{sw}^3 - P_{sw}^4$$

Thus, it is possible to determine the number of shredded particles in fractions of a unit at $К_E$ –encounter:

$$P_{swKe} = P_{sw} - (К_E - 1) \cdot P_{sw}^2 + \frac{(К_E - 1) \cdot (К_E - 2) \ldots [(К_E - 1) - (п - 2)]}{(п - 1)!} \cdot P_{sw}^{п} + \ldots + P_{sw}^{Кe} \quad (10)$$

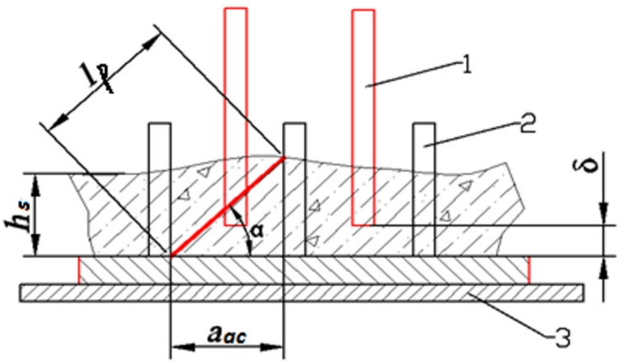
where $п = 1,2,3,\ldots,К_E$

Summarizing the calculated probabilities, we determine the probability P_{cw} of the content of shredded particles in the portion q at the K_E encounters (without counter-hammers):

$$P_{cw} = К_E P_{sw} - [К_E(К_E - 1)/1.2]P_{sw}^2 + [К_E(К_E - 1)(К_E - 2)/1.2.3]P_{sw}^3 -$$
$$-[К_E(К_E - 1)(К_E - 2)(К_E - 3)/1.2.3.4]P_{sw}^4 + \ldots +$$
$$+[К_E(К_E - 1)(К_E - 2) \ldots [К_E - (п - 1)/п!]]P_{sw}^{п} + \ldots +$$
$$+[К_E(К_E - 1)(К_E - 2) \ldots [К_E - (К_E - 1)/К_E!]]P_{sw}^{К_e} \quad (11)$$

It should be noted that if in formula (11) the degree of probability is even, then a minus sign is placed in front of this member, and if it is an odd degree, then a plus sign is put in front of the member.

Thus, an analytical expression was obtained for determining the amount of shredded particles in



1 – hammer, 2 – counter-hammer, 3 – concave

Fig. 4. Scheme of hitting stems of roughage under hammer blows while delaying them with the rows of counter-hammers

fractions of a unit (or percentage) when the shredder works without counter-hammers, and therefore the mass of shredded particles in portions *q* when the shredder works without counter-hammers is determined by formula:

$$q_{wh} = qP_{cw} \tag{12}$$

Now we determine the probability of shredded particles when the stems are delayed by rows of counter-hammers (**Fig. 4**).

The probability of delaying of the stems adjacent counter-hammers in the vertical plane, i.e. in a plane parallel to the radius of the grinding chamber is determined by formula:

$$\mathrm{P}_{VC} = \frac{arccos\frac{\mathrm{a}_{AC}}{l_P}}{90} \tag{13}$$

where a_{AC} – the distance between the faces of adjacent counter-hammers, m

It should be noted that the probability of delaying the stems with counter-hammers in the horizontal plane is also determined by formula (13). Therefore, the probability of delaying in the stems of counter-hammers in space is determined by formula:

$$\mathrm{P}_{PC} = \left(\frac{arccos\frac{\mathrm{a}_{AC}}{l_P}}{90}\right)^2 \tag{14}$$

Depending on the thickness of the layer P_H, the probability of stems hitting is also determined by the formula (7).

In this case, the probability of destruction of stems P_d = 1, as the stems, delaying with counter-hammers, lose their speed and at the same time, hitting under the blows of hammers, are destroyed.

Therefore, the probability of destruction of stems when they are delayed by one row of counter-hammers is determined by

$$\mathrm{P}_S = \mathrm{P}_{PC}\mathrm{P}_h \tag{15}$$

The mass of shredded particles in a portion by mass q_{K_C}, when each row of counter-hammers is delayed, changes as follows:

$$q_1 = (q - qP_{cw})\mathrm{P}_S = qP_S - qP_{cw}P_S$$

$$\begin{aligned}
&q_2 = [q - (q_{wc} + q_1)]P_S = [q - (q_{cw}P + qP_S - qP_{cw}P_S)]P_S = \\
&= qP_S - qP_{cw}P_S - qP_S^2 + qP_{cw}P_S^2. \\
&\cdot q_3 = [q - (q_{wc} + q_1 + q_2)]P_S = \\
&= q - [(qP_{cw} + qP_S - qP_{cw}P_S + qP_S - qP_{cw}P_S - qP_S^2 + qP_{cw}P_S^2)]P_S = \\
&= qP_S - qP_{cw}P_S - qP_S^2 + qP_{cw}P_S^2 - qP_S^2 + qP_{cw}P_S^2 + qP_S^3 - qP_{cw}P_S^3 = \\
&= qP_S - qP_{cw}P_S - 2qP_S^2 + 2qP_{cw}\mathrm{P}_S^2 + qP_S^3 - qP_{cw}P_S^3 \\
&q_4 = [q - (q_{wc} + q_1 + q_2 + q_3)]P_S = qP_S - qP_{cw}P_S - 3qP_S^2 + 3qP_{cw}P_S^2 + \\
&+3qP_S^3 - 3qP_{cw}P_S^3 - qP_S^4 + qP_{cw}P_S^4 \\
&q_{C_C} = qP_S - qP_{cw}P_S - (K_C - 1)qP_S^2 + (K_C + 1)qP_{cw}P_S^2 + \ldots + \\
&+ \frac{(K_C - 1)(K_C - 2)\ldots[K_C - 1 - (n - 2)]}{(n - 1)!} \cdot qP_{cw}P_S^{\text{п}} + \ldots + qP_S^{Kc} + qP_{cw}P_S^{Kc}
\end{aligned} \tag{16}$$

where $\text{п} = 1,2,3,\ldots,K_C$

In formula (17) the expression in curly brackets represents the probability P_{CC} of content of shredded particles in the portion *q* when the stems are delayed by K_C rows of counter-hammers:

$$\begin{aligned}
&q_S = q\left\{K_CP_S - K_CP_{cw}P_S - \frac{K_C(K_C - 1)}{1 \cdot 2}P_S^2 + \frac{K_C(K_C - 1)}{1 \cdot 2}P_{cw}P_S^2 + \right. \\
&+ \ldots + \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C - (n - 1)]}{n!}P_S^{\text{п}} + \\
&+ \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C - (n - 1)]}{n!}P_{cw}P_S^{\text{п}} + \ldots + \\
&+ \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C(K_C - 1)]}{K_C!}P_S^{\text{К}c} + \\
&\left. + \frac{\text{К}_C(\text{К}_C - 1)(\text{К}_C - 2)\ldots[\text{К}_C(\text{К}_C - 1)]}{\text{К}_C!}\mathrm{P}_{cw}\mathrm{P}_S^{\text{К}c}\right\}.
\end{aligned} \tag{17}$$

In formula (17) the expression in curly brackets represents the probability P_{CC} of content of shredded particles in the portion *q* when the stems are delayed by K_C rows of counter-hammers:

$$\begin{aligned}
&P_{CC} = K_CP_S - K_CP_{cw}P_S - \frac{K_C(K_C - 1)}{1 \cdot 2}P_S^2 + \\
&+ \frac{K_C(K_C - 1)}{1 \cdot 2}P_{cw}P_S^2 + \ldots + \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C - (n - 1)]}{n!}P_S^{\text{п}} + \\
&+ \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C - (n - 1)]}{n!}P_{cw}P_S^{\text{п}} + \ldots + \\
&+ \frac{K_C(K_C - 1)(K_C - 2)\ldots[K_C - (K_C - 1)]}{K_K!}P_S^{\text{К}c} + \\
&+ \frac{K_C(K_C - 1)(K_C2)\ldots[K_C - (K_C - 1)]}{K_C!}P_{cw}P_S^{\text{К}c}.
\end{aligned} \tag{18}$$

As in formula (11) in expression (18), it is also necessary to pay attention to the fact that if the total degree P_{cw} of each member P_S is even, then a minus sign is put in front of it, if the above degree is odd, then the sign a plus.

Thus, the total probability of the content of shredded particles in the grinding chamber without counter-hammers, and also taking into account the counter-hammers P_{CS} is determined by formula:

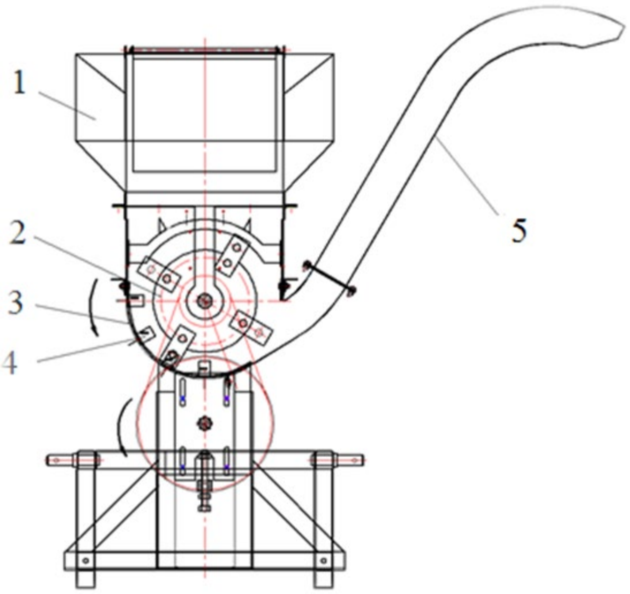
$$\begin{aligned}
\mathrm{P}_{CS} &= \mathrm{P}_{cw} + \mathrm{P}_{WH} \\
&or \\
F &= 100 \cdot \mathrm{P}_{CS}
\end{aligned} \tag{19}$$

where *F* – mass part of the required fraction, %.

To determine the effect of the number of rows of counter-hammers and the step of their installation in rows, as well as the ways to adjust the size of shredded particles, we use the formulas obtained (11, 18, and 19).

To test the reliability of the analytical expressions obtained, experimental studies were carried out on the DU-11 universal crusher (**Fig. 5**).

Crusher DU-11 is produced from the drive of an electric motor with a power of 11 kW or from the tractor PTO (Abilzhanuly et al. 2017). Here, in the grinding chamber, rows of counter-hammers are established, which provide adjustment of the fineness of shredded



1 - bunker; 5 - hammer rotor; 3 - concave; 4 - a number of counter-hammers; 5 - deflector

Fig. 5. Scheme of the universal crusher DU-11

stem particles. The spacing of the hammers and counter-hammers is 25 mm and the distance between the walls of adjacent hammers is 20 mm. At the same time, it is possible to install four rows of counter-hammers in the grinding chamber. The linear speed at the ends of the hammers is 60 m/s.

In previous studies, it was found that when the shredded mass circulates in the grinding chamber, the layer thickness is 20 mm, and the gap between the ends of the hammers and the chamber surface is 6 mm, and the speed of the circulating mass is equal to the speed of the air flow created in the grinding chamber, and the layer velocity is determined by formula (Abilzhanov 1979):

$$v_l = 0{,}35 v_m \tag{20}$$

The analytical expressions obtained determine the mass fraction of shredded particles, i.e. it is possible to theoretically determine the quality of shredded stem fodder when they are shredded in open-type machines.

According to the zootechnical requirements for sheep, the average size of shredded particles should be 20-30 mm, and for cattle – 30-50 mm, therefore, to calculate, the required size of shredded particles will be considered equal to 30 mm, i.e. l_P = 30 mm.

Taking into account the required size of shredder stem fodder, the probabilities of stems hitting under the hammer blows in the space P_S were determined, as well as the probability of destruction of stems depending on the speed of the hammers and the layer, and they have the following values: P_S = 0.39; P_h = 0.7; P_d = 0.65; P_{wc} = 0.177.

In process of shredding stem fodder on the crusher DU-11, the fodder enters the grinding chamber from above and the angle of coverage of the chamber, in which process of shredding stem fodder occurs, reaches 300°, the number of rows of hammers is 2.0 and K_E = 5 i.e. before leaving the grinding chamber, the incoming mass is hit 5 times by hammer blows. Calculations based on the obtained analytical expressions showed that P_{cw} = 0.622, i.e. when operating the shredder without counter-hammers, out of the entire shredded mass, 62.2% should have a length of shredded particles up to 30 mm. Further, the probability of the content of shredded particles was calculated depending on the number of rows of counter-hammers P_{WC}, as well as the values of the total probability P_{CS}.

1 - belt conveyor; 2 - universal crusher DU-11; 3 - electric power quality analyzer AKE-824

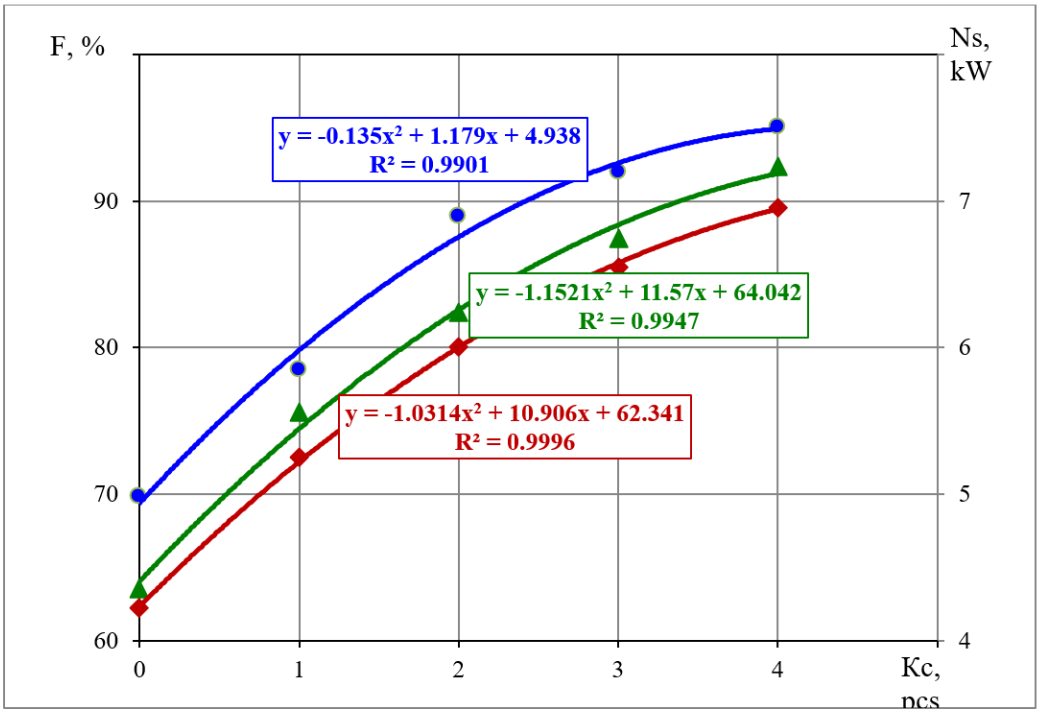
Fig. 6. Experimental unit, consisting of a crusher DU-11 and a three-meter belt conveyor

To compare the obtained calculated values of the mass part of fraction with an average size of 30 mm, experimental studies were conducted on DU-11 crusher with installation of a different number of rows of counter-hammers, with a spacing of 25 m in rows, and the distance between the faces of complex hammers and counter-hammers was 20 mm.

In the experiment, grass hay with a moisture content of 17% was fed to the DU-11 crusher billet through a belt conveyor, and the mass feed was equal to Q = 1800 kg/h, the required power was recorded by the AKE-824 power quality analyzer (**Fig. 6**).

During the experiment, the number of rows of counter-hammers was changed with a spacing of 25 mm within 0-4 pcs. After each experiment, carried out with a certain number of rows of counter-hammers, samples were taken from shredded mass to determine the mass part of fraction with a size of up to 30 mm. The results of experimental studies are presented in **Fig. 7**.

From **Fig. 7** it can be seen that the difference between the theoretical and actual values of the mass fraction of shredded particles with a length of up to 30 mm is 1.3-3.1%, i.e. this shows the reliability of the analytical expressions obtained.



where 1 - F_t - theoretical dependence; 2 - F_e– experimental dependence; 3 - experimental values of the required power for the shredding process of roughage N_S

Fig. 7. Effect of the number of rows of counter-hammers on the value of the mass part of fraction *F* with a particle length of 30 mm and the required power on the change process the roughage N_S

In addition, the obtained power values during the shredding process show that a change in the required power is also consistent with a change in the mass fraction of shredded particles depending on the number of rows of counter-hammers, i.e. they have the same functional dependence and this proves the reliability of theoretical studies. Thus, it can be argued that a method has been developed for adjusting the fineness of shredded stem fodder in open-type machines.

Currently, on the basis of proposed method for adjusting the fineness of shredded stem fodder, we have developed universal crushers and pick-up shredders of fodder, equipped with rows of hammers and counter-hammers, which ensure the preparation of high-quality chopped hay and haylage (Abilzhanuly et al. 2016, 2017, 2016).

FINDINGS

As a result of theoretical studies, analytical expressions were obtained for determining the mass part of the required fraction depending on the number of encounters of the rows of hammers with a circulating mass and on the number of rows of counter-hammers installed at the end of shredding.

Experimental studies have been carried out to determine the mass part of the required fraction, depending on the number of rows of counter-hammers. Comparison of theoretical and actual values of the mass part of fraction with a size of up to 30 mm showed that the difference between these values is 1.3 ... 3.1%, and this proves the reliability of the analytical expressions obtained.

Comparison of the change in the mass part of the required fraction with the change in the required power for the process of hay chopping, depending on the number of rows of counter-hammers shows that they have the same functional relationship and all this proves the reliability of the developed method of adjusting the fineness of shredded stem fodder in open-type machines.

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