ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

# Experimental Aspects Of Crushing Of The Stalk Forage With A Disc Cone-Shaped Working Organ With Combined Segments.

**Vladimir Jur'evich Frolov*, Denis Petrovich Sysoev, Natal'ja Jur'evna Sarbatova, and Marina Ivanovna Tumanova**

Kuban State Agrarian University, Faculty of Mechanization, Kalinina St., 13, Krasnodar 350044, Russia.

**ABSTRACT**

This article presents a classification of feed distributors, based on the analysis of which the direction was chosen in the development of a more perfect design, and a constructive technological scheme of the distributor-shredder of stalk forage was proposed, the results of experimental studies for finding the optimal combination of constructive-regime parameters of the disk cone working organ combined segments, in which feed will be cooked with a higher quality. As optimization criteria were chosen: energy intensity, time of grinding feed, weighted average length of particles.
**Keywords:** shredding, distributor-shredder of stalk forage, disc cone, segment cutting

***Corresponding author***

## INTRODUCTION

Since the labor intensity of the feeding process is 40% of the total costs of animal care, the development and application of mobile distributors-shredders for loading feed and litter, grinding and feeding them both into feeding troughs and stalls to animals are of practical interest [1].

The analysis shows that from the point of view of reducing costs in the lines of cooking and distributing feedstuffs, it is more rational to use universal machines that combine a number of technological operations in one device [2, 5]. Based on this, a classification was developed [3] and a constructive technological scheme of the distributor-shredder of stalk feeds was proposed, which makes it possible to reduce labor, money and energy costs. According to the proposed scheme, the distributor-shredder carries out transportation and distribution of the stern forages in a compressed form with simultaneous grinding and dosing.

## MATERIAL AND METHODS

The analysis of classifications and existing technical means for grinding and distribution of feeds to animals made it possible to generalize the material and to distinguish the following main classification characteristics: the kind of use; constructive design; Feeding method; design and location of the grinding apparatus; method of grinding feed; type of cutting; type of grinding elements; way of unloading the feed.

The classification analysis (Figure 1) made it possible to outline a promising direction in the development and creation of technical means in the field of distribution of stalk forage with preliminary grinding [3]. As a result of patent search and analysis of literature sources, a constructive-technological scheme of the dispenser-shredder has been developed (Figure 2), which includes: a hopper, a disk cone working member with toothed grinding elements and two-plane segments (Figure 3), an impeller, an unloading duct (patent № 2581488 of the Russian Federation).

The dispenser-shredder works as follows (Figure 2, 3).

Feeds harvested in roll bales *2* are loaded into a vertical cylindrical hopper *1* with a screw wedge *8* placed on the frame with the chassis *5* being pierced by a needle *7*. Due to the interaction of the roll bale with the guiding *8* and the forces of gravity, the material is forcibly fed to the grinding disc conical working element *3*.

When the material interacts with the grinding jaw elements *11* and the two-plane arc profile, the segments *13* grind both along and across the fibers. The crushed material enters the holes *12*, from where it is fed by means of a paddle wheel *4* into the discharge duct *6*, and then into the feeding troughs of the animals.

In the course of the experiment, it was necessary to investigate the processes of crushing the stem feed with a disc cone-shaped working organ with combined segments; evaluate the efficiency of the proposed design; find the most significant factors affecting the process of shredding feedstock, and optimize the basic parameters of the machine. The physical and mechanical properties of fodder (the density and degree of loosening of the feed during dispensing, the heterogeneity of the granulometric composition of the feed) significantly influence the qualitative indices of the grinding process [4].

The task of optimization is to find the optimal combination of design-regime parameters of the developed working body, in which the preparation of feed will be produced with higher quality and minimum energy consumption.

ISSN: 0975-8585

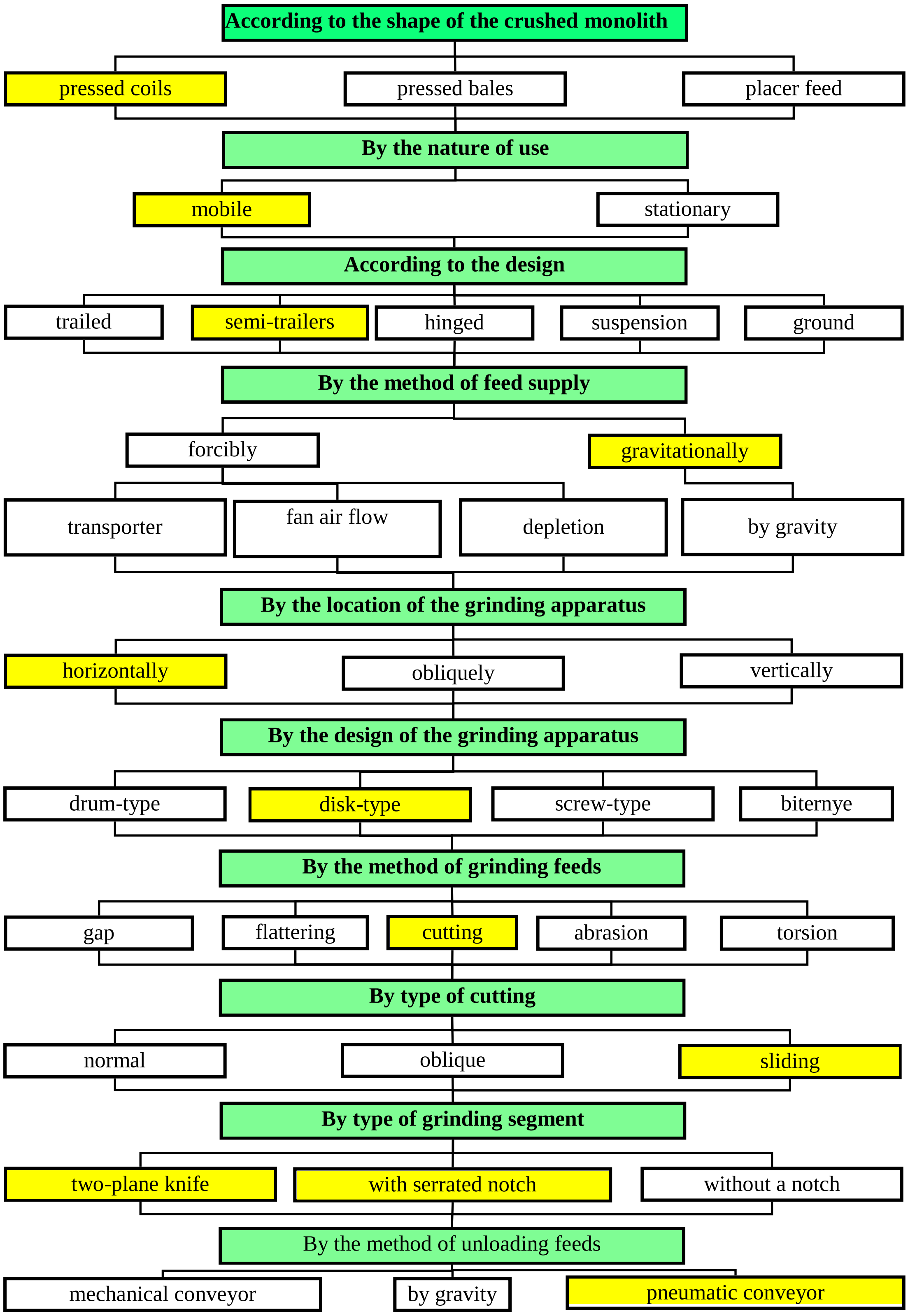



**Figure 1: Classification of distributors-shredders of stem feed**

ISSN: 0975-8585

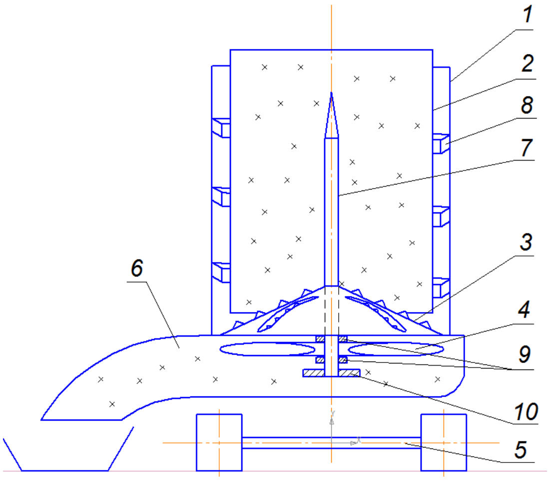



Figure 2: Scheme distributor-shredder

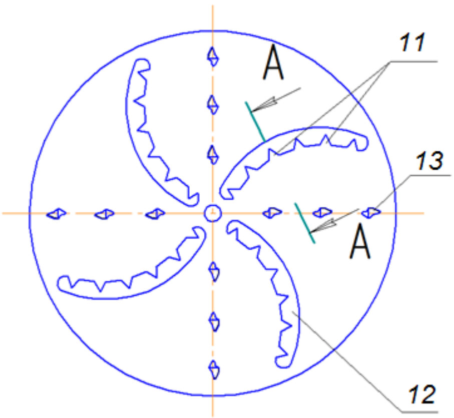



Figure 3: Grinding disc cone workpiece

## RESULTS AND DISCUSSION

Experimental studies were carried out on the basis of the works of V.R. Aleshkin, G.V. Vedenyapin, F.S. Zavalishin, G.M. Kukty, M.G. Mantsev, S.V. Melnikov, P.M. Roshchin, A.M. Semenikhin, M.A. Tishchenko and other authors.

Criteria for assessing the performance of the grinding working body is the operability, quality indicators and energy intensity of processes, which are determined by known methods.

The studies were carried out on an experimental setup (Figure 4), the scheme of which is shown in Figures 2 and 3.

Figure 4: General view of the experimental plant for shredding feedstuffs

As optimization criteria, the energy intensity ($Y_1$), the material grinding time ($Y_2$) and the weighted average particle length ($Y_3$) were selected.

Analysis of a priori information and search studies showed that the most significant factors were the angular velocity of the working member ($\omega$ - $X_1$), the number of tooth segments located along the perimeter of the working member (z - $X_2$), the number of two-plane segments of the arc profile (n - $X_3$) and the angle between the surface of the working element and the horizontal gear elements ($\alpha$ - $X_4$). The levels of factor variation are shown in Table 1.

**Table 1: Factors and levels of their variation in the experimental study of the process of grinding the stalk forage with a disc cone-shaped working organ with combined segments according to patent No. 2581488 RF**

| | Factors | | | |
|---|---|---|---|---|
| Notation | $X_1$ | $X_2$ | $X_3$ | $X_4$ |
| Upper level (+) | 1,6 | 9 | 9 | 40 |
| Basic level (0) | 3,2 | 6 | 6 | 35 |
| Lower level (-) | 4,8 | 3 | 3 | 30 |

The results of the experiment are presented in Table 2, data processing was carried out, and mathematical models were constructed. In the process of experimental studies, a compromise problem was solved between three optimization criteria: energy intensity ($Y_1$); time of material grinding ($Y_2$); weighted average particle length ($Y_3$).

**Table 2: Matrix and results of a full-factorial experiment**

| № | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $Y_1$ | $Y_2$ | $Y_3$ |
|---|---|---|---|---|---|---|---|
| 1. | + | – | – | – | 1,5 | 15 | 12 |
| 2. | – | + | – | – | 1,3 | 30 | 7,8 |
| 3. | – | – | + | – | 1,4 | 35 | 9 |
| 4. | + | + | + | – | 1,42 | 6 | 4,8 |
| 5. | + | – | – | + | 3,8 | 15 | 14 |
| 6. | – | + | – | + | 1,29 | 29 | 7,7 |
| 7. | – | – | + | + | 1,33 | 32 | 8,2 |
| 8. | + | + | + | + | 1,45 | 8 | 6,0 |
| 9. | 0 | 0 | 0 | 0 | 2,07 | 20 | 6,1 |
| 10. | 0 | + | – | + | 2,01 | 19 | 6,0 |
| 11. | – | 0 | – | – | 1,41 | 29 | 7,8 |
| 12. | + | 0 | + | + | 4,8 | 6 | 6,1 |
| 13. | – | + | – | 0 | 1,3 | 32 | 7,9 |
| 14. | – | 0 | + | + | 1,6 | 33 | 8,2 |
| 15. | 0 | + | + | – | 2,02 | 20 | 5,4 |
| 16. | + | – | + | 0 | 3,8 | 7 | 7,4 |
| 17. | + | – | 0 | + | 4,0 | 9 | 7,5 |
| 18. | 0 | – | + | – | 2,05 | 20 | 6,0 |

As a result of data processing in the Statistic program, regression equations are obtained in coded form for:

– energy intensity ($Y_1$):

$$Y_1 = -8{,}26028 - 0{,}00037X_1 + 0{,}7526667X_2 + 1{,}0124X_3 + 0{,}857933X_4 - 0{,}0001X_1X_2 + 0{,}0000036X_1X_3 + 0{,}000099X_1X_4 + 0{,}0185X_2X_3 - 0{,}0232X_2X_4 - 0{,}0071X_3X_4 - 0{,}05X_2^2 - 0{,}0773667X_3^2 - 0{,}01103X_4^2$$

– material grinding time ($Y_2$):

$$Y_2 = 51{,}323167 - 0{,}011167X_1 + 3{,}432033X_2 - 5{,}7651X_3 - 1{,}7806X_4 - 0{,}0001X_1X_2 - 0{,}001X_1X_3 - 0{,}00004X_1X_4 - 0{,}6866X_2X_3 + 0{,}0778X_2X_4 + 0{,}0559X_3X_4 + 0{,}00000063X_1^2 - 0{,}2463X_2^2 + 0{,}5349X_3^2 + 0{,}018766667X_4^2$$

– weighted average particle length ($Y_3$):

$$Y_3 = 25{,}83167 - 0{,}00647X_1 - 1{,}115967X_2 - 2{,}3392X_3 - 1{,}224367X_4 - 0{,}0004X_1X_2 - 0{,}0006X_1X_3 + 0{,}000013X_1X_4 + 0{,}0895X_2X_3 - 0{,}0056X_2X_4 + 0{,}013X_3X_4 + 0{,}0000023X_1^2 + 0{,}0616X_2^2 + 0{,}1638X_3^2 + 0{,}01767X_4^2$$

The adequacy of models is confirmed with probability $R_d$ = 0,965 at correlation coefficients $R_1$ = 0,94203 and $R_2$ = 0,98269.

Passing from the coded values of factors ($X_1$, $X_2$, $X_3$, $X_4$) to natural ($\varpi$, N, n, $\alpha$), the following dependencies are obtained for:

– energy intensity ($Y_1$):

$$N = 2{,}571283 + 0{,}582433\varpi + 0{,}061233N + 0{,}798067n + 0{,}753\alpha - 0{,}0002\varpi N + 0{,}0001\varpi\alpha - 0{,}0001N\alpha - 0{,}0001n\alpha - 0{,}0055\varpi^2 - 0{,}0006N^2 - 0{,}0077667n^2 - 0{,}0073\alpha^2$$

– material grinding time ($Y_2$):

$$T = 18{,}43992 - 11{,}41393\varpi + 1{,}47030N - 5{,}33787n - 1{,}92323\alpha - 0{,}0001\varpi N - 0{,}0008\varpi n + 0{,}0000475\varpi\alpha - 0{,}0017Nn - 0{,}00007N\alpha + 0{,}0009n\alpha + 0{,}1089\varpi^2 - 0{,}0139N^2 + 0{,}0521667n^2 + 0{,}0184667\alpha^2$$

– weighted average particle length ($Y_3$):

$$L_{av} = 5{,}633467 - 1{,}953067\varpi - 1{,}8963N - 2{,}908n - 0{,}2482\alpha - 0{,}0003\varpi N - 0{,}0005\varpi n + 0{,}00003\varpi\alpha + 0{,}0002Nn - 0{,}00007N\alpha + 0{,}0000068n\alpha + 0{,}0191\varpi^2 + 0{,}018N^2 + 0{,}0283n^2 + 0{,}00247\alpha^2$$

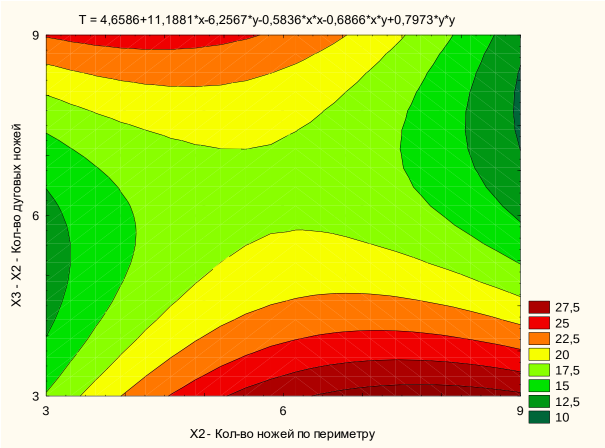
After obtaining adequate mathematical models of the process, the optimum coordinates were determined and the response surfaces were studied.

The obtained analytical dependencies express a functional relationship between the design and regime parameters affecting the grinding process. These dependencies allow us to identify the qualitative and quantitative aspects of the influence of the factors under investigation with certain assumptions and assumptions.

With the optimal combination of factors on the process, the response surfaces $Y_1$, $Y_2$ and $Y_3$ were constructed. For this, the original regression equations were reduced to equations with two factors, leaving the rest at constant levels.

To simplify the analysis of these surfaces, cross sections of responses were constructed (Figures 5, 6). Analysis of the dependencies (Figure 5) shows that the grinding time of a material weighing 1 kg varies from 10 to 28 seconds. With the number of toothed segments located along the perimeter of the grinding tool Z = 9 pieces, the grinding time was T = 10 s, which is the optimal parameter, with the necessary number of grinding two-plane segments of the arc profile n = 8 pieces.

Analysis of the dependencies in figure 6 shows that at the optimal grinding time T = 10 s, the angular rotation speed $\varpi$ of the working member varies from 4.6 to 4.8 $s^{-1}$, with the number of toothed segments located along the perimeter of the grinding tool Z = 9 pieces, which is confirmed by the analysis of the previous relationship.



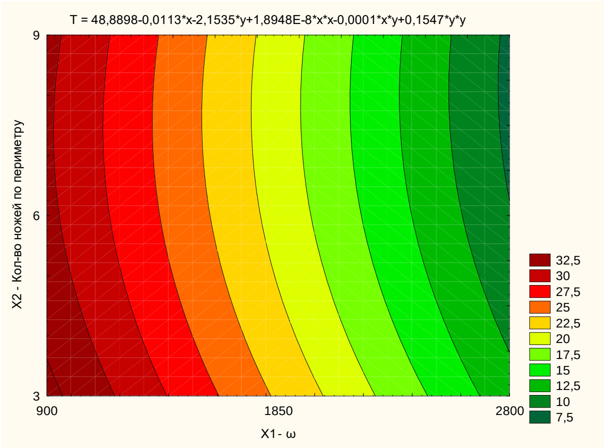




**Figure 5: Cross-section of the surface of time of grinding material onto a plane $X_1 = +1$ ($\omega = 4{,}8\ s^{-1}$) и $X_4 = +1$ ($\alpha = 40^0$)**

**Figure 6: Cross-section of the time surface of the material's grinding on the plane $X_3 = +1$ ($n = 9$) и $X_4 = -1$ ($\alpha = 30^0$)**

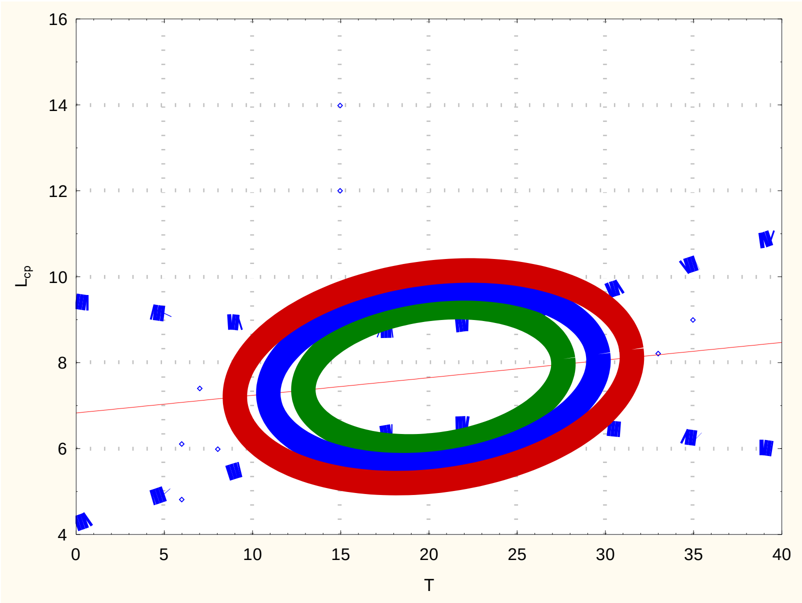



**Figure 7: Graphs of the dispersion of optimization criteria**

From the analysis of the dispersion curves (figure 7) for the criteria for optimizing the material grinding time (X-T) and the average particle length (Y-$L_{av}$), $L_{av}$ can vary from 50 to 100 mm, which corresponds to the time T from 10 to 30 seconds.

In the course of experimental studies, the effect of the structural-regime parameters of the working organ on the qualitative and energy parameters of the grinding process was revealed.

As a result of search studies and approximation of the regression equations, the optimal number of toothed segments located along the perimeter of the working member Z = 6-9 pieces was obtained; grinding two-plane segments of arc profile n = 7-9 pieces; angle between the surface of the working member and horizontal gear elements $\alpha$ = 30-35 °.

Further experimental studies on the optimization of the structural-regime parameters of the working element were carried out at the above rational values.

Analyzing the dependence of $L_{av}$ weighted average length of particles of crushed forage (Figure 8) on the angular velocity of rotation of the working member, one can see that for an insignificant angular velocity ω = 1.6 $s^{-1}$, the particle size is 80 mm and higher, due to the frictional resistance and inertia working organ. As the angular velocity increases, the mechanical energy is transferred to the stems of unmilled feed and under the influence of centrifugal forces, the food enters the two-plane segments of the arc profile and the dentate segments located along the perimeter of the working organ on the cutting edges that are crushed both along and across the fibers. At an angular velocity ω = 3.14 $s^{-1}$ and above, the weighted average particle length was $L_{av}$ = 45 mm, which corresponds to the zootechnical requirements for hay crushing for cattle, the particle size of which should be within $L_{av}$ = 20-50 mm.

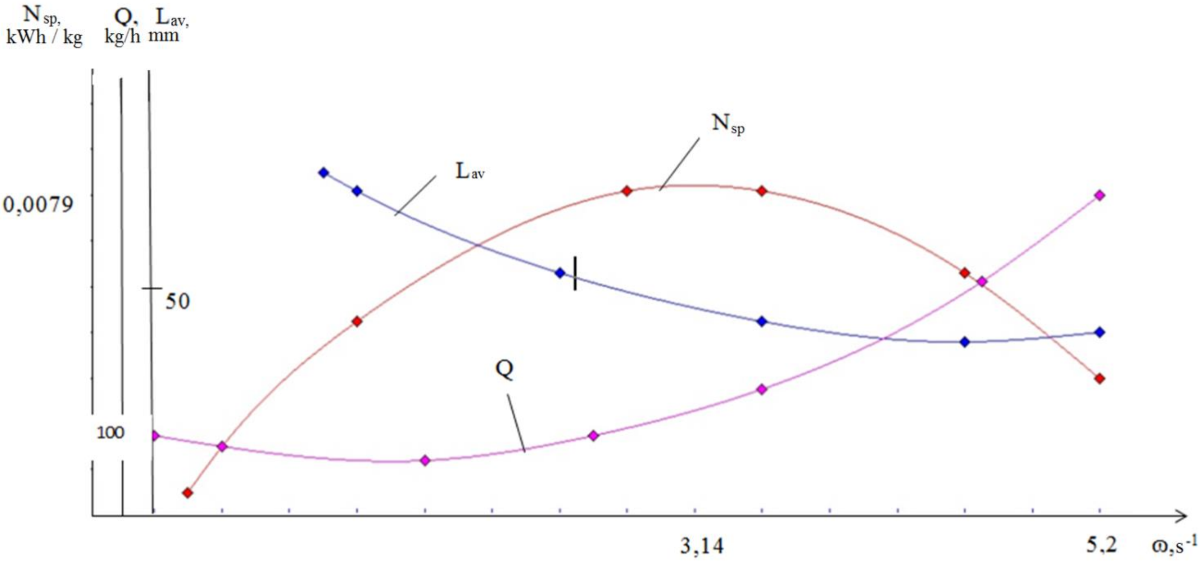



**Figure 8: Dependence of specific energy consumption, productivity and weighted average particle length on angular velocity of rotation of the working body**

Analysis of the dependence of productivity Q showed that with the increase in the angular velocity of rotation of the working member from 2.1 to 5.2 $s^{-1}$, the productivity of the machine also increases from 110 to 800 kg / h. The change is due to the increase in mechanical energy and centrifugal forces, as well as the additional air flow created and the effect of suction of food into the gap between the disc and the wall of the hopper, and therefore the grinding of the feed occurs faster than at a low speed of rotation of the working member.

The dependence of the specific energy intensity in Figure 8 shows that the maximum value of $N_{sp}$ = 0.0079 kWh / kg is at the angular velocity of rotation of the working member ω = 3.14 $s^{-}1$. At the initial time, the energy costs are minimal and amount to $N_{sp}$ = 0.005 kWh / kg, so at first the specific energy intensity is low and then increases.

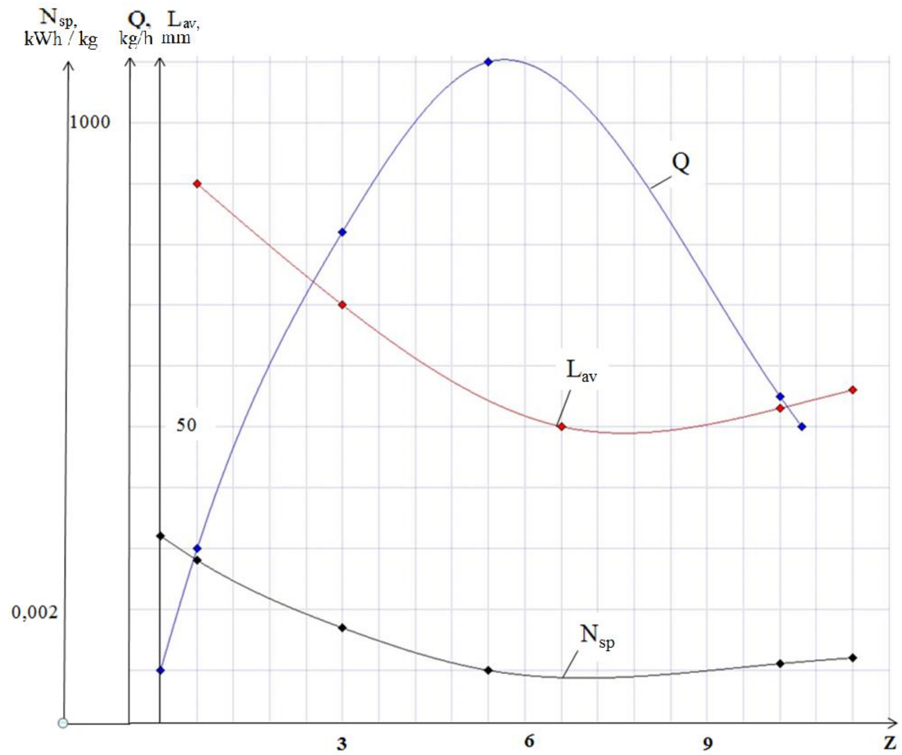



**Figure 9: Dependences of the specific energy intensity, productivity and weighted average length of particles on the number of serrated segments located along the perimeter of the working member**

Analyzing the dependence (figure 9) of the Q productivity, it can be noted that with the number of toothed segments located along the perimeter of the workpiece Z = 6 pieces the value of Q = 1100 kg / h, while the analysis of the dependence of the weighted average particle length showed that $L_{av}$ = 50 mm also at Z = 6 pieces, and the dependence of the specific energy at Z = 6 shows the minimum value $N_{sp}$ = 0.0013 kWh / kg.

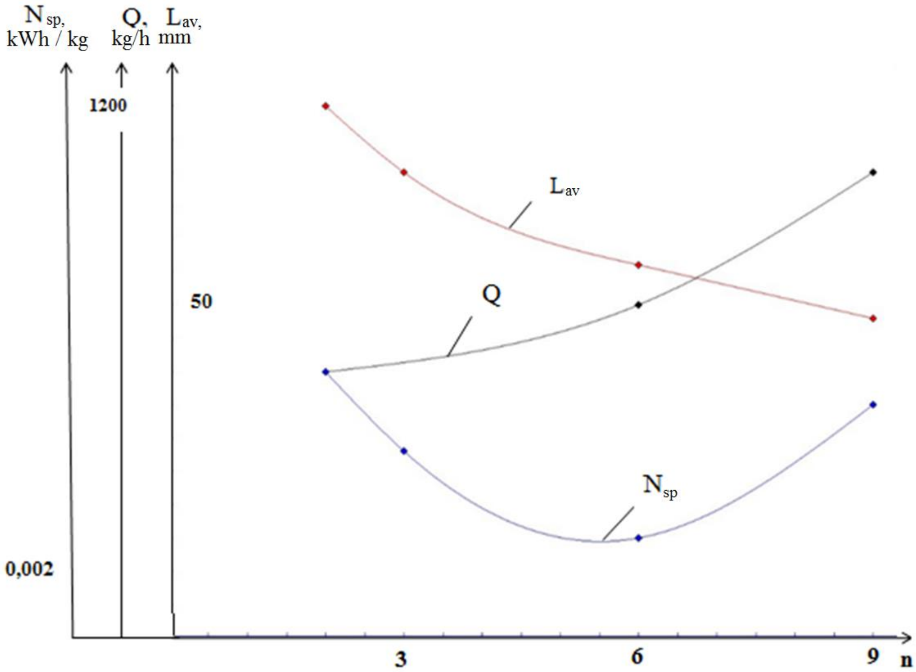



**Figure 10: Dependence of the weighted average length of particles, specific energy intensity, productivity on the number of grinding two-plane segments of the arc profile, n**

Analyzing the dependence of the specific energy intensity (figure 10), it can be noted that with the number of grinding two-plane segments of the arc profile n = 6 pieces, the value $N_{sp}$ = 0.002 kWh / kg is minimal, with the weighted average particle length $L_{av}$ = 50 mm, and the productivity Q = 1100 kg / h, which confirms the previously obtained results.

## CONCLUSION

1. Analysis of research materials on foreign and domestic literary sources shows that a promising direction of harvesting and storing stalk feeds is their pressing into rolls and bales. The classification of technical means for distribution of feeds has been clarified, it is possible to determine the perspective direction in the creation of these means that ensure the grinding process is carried out by gravitational feeding of the stem material to the grinding segments into the dispenser-chopper hopper and subsequent separation of the feed layer equal to the height of the segments.
2. Based on the studies carried out, a constructive technological scheme of the distributor-shredder of the stalk forage harvested harvested in a compressed form (patent No. 2581488 of the Russian Federation) was developed, a program and a methodology for experimental studies were developed.
3. Experimental studies have confirmed the theoretical premises [6, 7] for determining the optimal design and operating parameters of the distributor-shredder, such as: angular rotation speed of the grinding tool $\omega$ = 4.6-4.8 $s^{-1}$, the number of toothed segments located on the perimeter of the working element z = 9 pieces; number of two-plane segments of the arc profile n = 8 pieces; angle between the surface of the conical working element and horizontal gear milling elements $\alpha$ = 40 ° at which the specific energy intensity of the process was $N_{sp}$ = 0,05-0,079 kWh / kg.

## REFERENCES


[1] The evaluation of efficiency of using technologies for preparation and distribution of fodder at small farms Frolov V.J., Sysoev D.P. Research Journal of Pharmaceutical, Biological and Chemical Sciences. – 2016, T. 7, № 1. – p. 1264–1271.

[2] Frolov V.Yu., Sysoev D.P., Tumanova M.I. Improvement of the livestock production efficiency / British Journal of Innovation in Science and Technology. – 2016, T. 1, № 1. – p. 25–34.

[3] Frolov V.Yu., Sysoev DP, Tumanova M.I. Classification of distributors of shredders of feeds / Technology and equipment for the village. – 2015, № 7. – p. 18–20.

[4] Frolov V.Yu., Sysoev D.P., Zhurtov A.Kh. Justification of the curvature of the cutting edge of the knife / Rural mechanizer. – 2015, № 2. – p. 34–35.

[5] Frolov V.Yu., Sysoev D.P., Sarbatova N.Yu., Marchenko A.Yu. Resource saving technologies of cooking and distribution of fodder on cattle-breeding farms of small forms of management / Technology and equipment for the village. – 2013, № 3 (189). – p. 15–19.

[6] Frolov V.Yu., Tumanova M.I. Perfection of technologies and technical means for preparation and distribution of coarse feed from coils / Mechanization and electrification of agriculture. – 2016, № 10. – p. 3.

[7] Frolov V.Yu., Tumanova M.I. Concerning the preparation and distribution of coarse forages of rolled billet / Proceedings of the Kuban State Agrarian University. – 2013, № 40. – p. 178–180.