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IMPACT OF THE OPERATING PARAMETERS OF A DRUM CUTTING UNIT ON UNEVENNESS OF CHAFF'S LENGTH

Summary

The impact of constructional and exploitation parameters on the degree of unevenness has been presented in this article. The studies were conducted on a stand equipped with a drum cutting unit allowing for both the performance of lateral and oblique cutting. The plant material designed for the studies was rye and oats straw. Based on the analysis of the results of the studies it was found, that the degree of unevenness of oat straw for just the same constructional and exploitational parameters of the drum cutting unit was on average 5% higher than the degree of unevenness of rye straw's chaff.
***Key words**: Drum cutting unit, examination of the degree of unevenness of chaff's length, test stand with a drum cutting unit.*

1. Introduction

The drum cutting unit is one of the basic operating units of agrarian machines, the task of which is to cut the layer of plant material into straw. It is mainly used in field and stationary chaff cutters.

The use of the drum cutting unit in chaff cutters makes it possible to achieve the required degree of plant material's shredding. In order to obtain the desired nutritional effects, short chaff of even length is required, however its length depends on individual needs of animals and the manner of their feeding [1].

Studies concerning the process of plant material's cutting were conducted most of all by: W.J. Bremer, W.J. Chancellor, A. Haffert, H. Harms, G. Liljedahl, N.E. Reznik, W.A. Sablikow, however the so far performed studies were conducted on the basis of the lateral cutting rule, and the process of plant material's cutting by the drum cutting unit has not been fully recognized yet [2, 3].

Pointing out at the directions of the development of cutting units' studies and the plants' physio-mechanical features based on the up so far state of knowledge, has been presented by Z. Kosmicki. He has found, that at the present stage of recognizing of the cutting issues, it is necessary to draw up a universal method of studies concerning cutting of stalk plants, describing precisely the phenomena taking place during the cutting process. Adjustment of the machines' construction to the changeable market requirements, is connected with providing the engineers with effective machines' mathematical models as well as information on processes taking place in them. However, empirical data should assure the possibility of these models' verification. In most of the cases, constructions of the cutting units are the result of point solutions and not of widely conducted theoretical analysis of different solutions' opportunities [4].

That is why, experimental studies of the cutting process with the drum cutting unit were conducted both for lateral as well as for oblique cut. The studies were conducted in the aspect of determination of the impact of constructional and exploitational parameters on the degree of unevenness of chaff's length and aimed at identification of a part of input data for drawing up of the adequate mathematical model of the lateral and oblique cutting process with the drum cutting unit.

2. Drum cutting unit

The essence of the cutting drum's construction (fig. 1), which is the subject matter of the studies consists in the fact, that shields with openings on which there are cutter holders *4* in the form of flat stripes, are attached to the shaft. Cutting knives *5* are fixed in the holders. These knives, depending on the drum's construction, may be simple or bended along the screw line. Moreover, there is a distinction between uniform or sectional knives. A cutting knife is warped in sidewalls of the straw cutter, thanks to what it may make rotary motions [5].

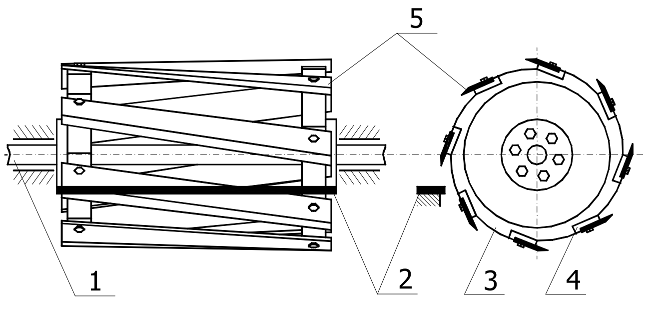

Fig. 1. Cutting drum of a straw cutter [5]: 1- cutting drum's shaft, 2 – counter cutting edge called shear plate, 3 – cutting drum's shield, 4 – cutter holder, 5 – cutting knife

The rule of the drum cutting unit's operation (fig. 2) consists in the fact, that the rotary motion of the cutting drum results in its relocation together with cutting knives. Knives *5* moving towards the immovable counter-cutting strip *6* (shear plate) result in cutting of the layer of the plant material. Supply of material between the knife's blade and the counter-blade (counter-cutting strip's edge) takes place due to the rotary movement of drawing in-squashing rollers *2* and *8*, which perform preliminary forming and thickening of plant material [5].

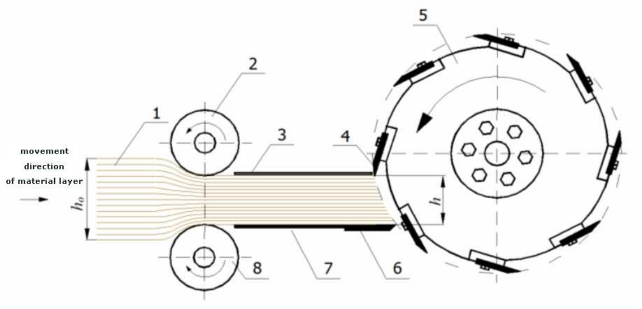

Fig. 2. Process of plant material supply to the cutting drum [5]: 1 – layer of plant material, 2 – upper drawing in-squashing roller, 3 – upper pressure plate, 4 – cutting knife, 5 – cutting drum, 6 – counter cutting strip, 7 – lower pressure plate, 8 – lower drawing in-squashing roller, h_o – height of the material layer before its thickening, h – height of the material layer after its thickening

3. Plan and programme of the studies

In order to conduct the studies, in the experiment as independent variables there were assumed [6]:
v_c – cutting speed, δ –thickness of knife's blade, h/h_o - degree of plant material's thickening, θ-angle of plant material's supply.

As a dependent variable there was assumed: λ- degree of unevenness of chaff's length.

For the listed variables, there was assumed the scheme of the studies which considers the interferers. The following ones have been included in this group: apparatus setting error, apparatus inadequacy, reading error.

4. Test stand

In order to conduct the studies with the use of the drum cutting unit, a test stand the scheme of which is show in the fig. 3 has been designed and constructed.

The driver of the cutting drum was realized through the power-take-off shaft from a farm tractor, whereas in order to eliminate the impact of resistance connected with drawing in and thickening of the plant material's layers, the power transmission of the pulling-in-crushing rollers was realized with the use of an electric motor with the use of belt transmission.

The test stand was equipped with apparatus for the measurement of the turning moment and the rotational speed. All the results were computer registered.

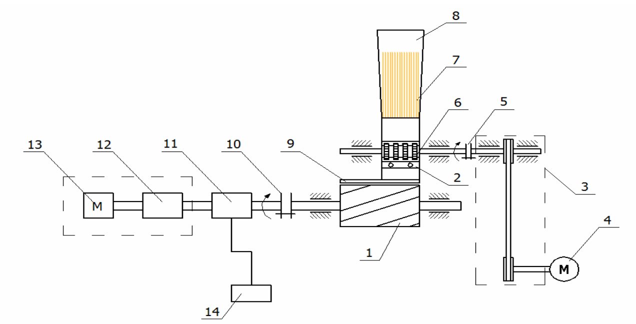

Fig. 3. Schematic diagram of a test stand: 1 – cutting drum, 2 – element regulating the height of the stalks' height, 3 – belt transmission, 4 – electric motor, 5 – overload release coupling, 6 – drawing in– squashing rollers, 7 – stalk material, 8 – trough, 9 – counter-cutting strip , 10 – overload release coupling, 11 – measurement system of the moment and rotating speed on the drum's roller, 12 – mechanical advantage of a farm tractor, 13 – combustion engine of a farm tractor, 14 – measurement system's recorder

At the test stand there was in practice realised the drawn up research programme in which apart from the lateral cutting there was also performed the oblique cut.

In order to realize oblique cutting of the plant material's layer, ensuring of the value of the plant material's feeding angle $\theta \neq 90°$ is required. Such a manner of cutting is possible to be obtained due to the application of another drum's construction, just as in the patented A. Bochat cutting unit, or by feeding material at the angle of $\theta \neq 90°$ in relation to the counter-cutting edge in a classical drum's construction.

In the designed test stand the second method was used, making use of the classical cutting drum [6].

Realization of the oblique cutting occurred through the change of the material's feeding angle in relation to the counter-cutting edge. At the drawn up test stand it was done by rotation of the assembly of the drawing in-crushing rollers together with the trough, in relation to the cutting drum's axis, with the established angle's values (fig. 4).
Fig. 5 presents the selected geometrical features describing the cutting drum's knife and location of the knife with reference to the counter blade.

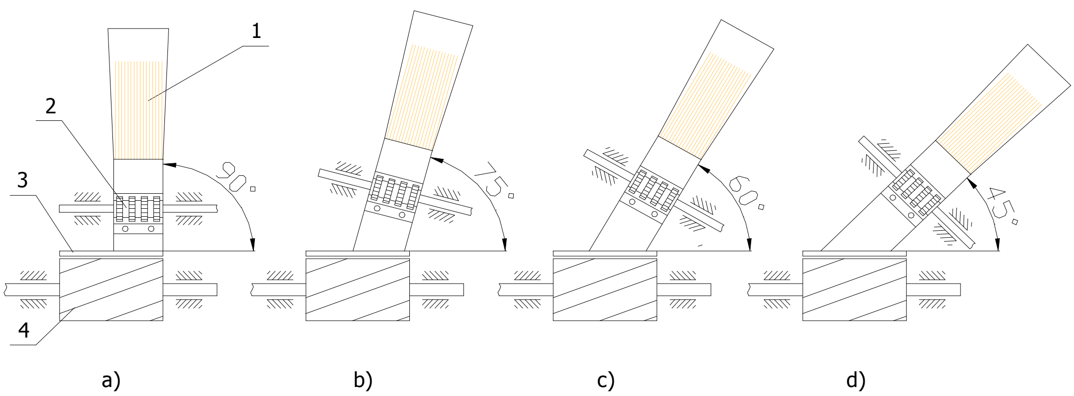

Fig. 4. Scheme of realization of the process of cutting: a) lateral, b-d) oblique: 1 – plant material, 2 – drawing in-squashing rollers, 3 – counter-cutting strip, 4 – cutting drum

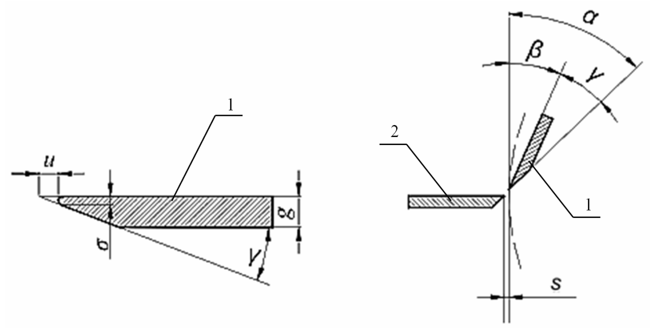

Fig. 5. Selected geometrical features of the knife and its location with reference to the counterblade (description of the features included in table 6.2): 1 – knife, 2 – countercut strip (shear plate)

Values of the selected geometrical features of the cutting knife presented in table 1.

Table 1. Values of the selected geometrical values of the cutting knife

Symbol	Geometrical feature of the cutting knife	Value accepted for studies
γ	Knife's entrance value	γ=18º
β	Knife's clearance angle	β=12º
α	Cutting angle	α=30º
s	Slot among the blade and counterblade	s<0,5mm
δ	Thickness of the blade	δ=(40-300)μm
g	Thickness of the knife	g=5,2mm
u	Distance between the points of the sharp knife and blunt knife	u=(120-900)μm

For the measurement of the rotational speed of the roller shaft and the Turing moment, there was used the two-channel measuring unit MW2006-4, with software PP203 and a torque meter MiR-20, that was assembled among the power take-off shaft and the joined shaft transmitting the drive from the tractor to the cutting drum.

5. Methodology of the studies

The plant material designer for the studies there was the rye and oat straw. The material was supplied from the field, where the stalk was cut off with a sharp tool at the height of (60-100) mm, which corresponds to the cutting height by the machines equipped with the shear-finger cutting blocks. The plant material was stored in a dry room, and humidity on the day of conducting of the studies amounted to w=12%. Humidity of the material was determined on the basis of the random selected samples with the drying method.

In order to prepare the plant material for the studies, samples were prepared in such a manner, that ears were cut and bound in sheaves of the average length $l_{s\dot{z}}$=850 mm for rye straw and l_{so}=650 mm for oat straw.

The made samples in the form of sheaves were placed in the channel of a straw cutter and cutting was performed.

The degree of unevenness of chaff's length λ, was assumed as a criterion of assessment of the operation's quality of the applied drum cutting unit. In order to determine the above indicator, from each experiment there were taken the number of samples equal to the number of repetitions. The mass of each sample amounted to 50±2g. These samples were divided into 10 class ranges with regard to the length of chaff and their mass was determined.

The measurement of the chaff's length Turing the experimental studies was conducted with the use of an electronic slide caliper make LIMIT, of preciseness ±0,01 mm. Determination of the value of the degree of unevenness of chaff's length λ was conducted with the use of statistical methods.

6. Analysis of the studies' results

In order to conduct the analysis of the result of the experimental studies, equations of the multidimensional regression function has been drawn up.

Initially, for a dependent variable determined in the programme of the studies, there were selected 9 regression coefficients, solving the matrix equation. The significance of regression coefficients on the level of significance of α_{pi} =0,05 was analysed, for which t_{kr} =1,98. The value of t_{kr} was determined on the basis of distribution of t-Student for 108-9-1 degrees of freedom.

The analysis of significance of regression coefficients was conducted by stages. In each of these stage, from the general regression function the least essential part was rejected, that is the one that met the inequality $t < t_{kr}$.

If in a given stage of study of the regression function from the significance test it resulted that the regression coefficients were significant, they were accepted to determine the function of the dependent variable.

In such a manner final formulas for the degree of unevenness of rye straw chaff's length $\lambda_{\dot{z}}$ and oat straw λ_o with consideration of the regression coefficients were received:

$$\lambda_{\dot{z}} = 18{,}61 - 0{,}058838\theta - 1{,}132v_c - 15{,}077\frac{h}{h_o} + 1{,}333\cdot 10^{-3}\delta + 2{,}181\cdot 10^{-4}\theta^2 + +0{,}06978\left(\frac{h}{h_o}\right)^2 + 12{,}97\delta^2 \quad (1)$$

$$\lambda_o = 17{,}73 - 0{,}05386\theta - 111{,}1v_c - 14{,}265\frac{h}{h_o} + 1{,}175\cdot 10^{-3}\delta + 1{,}926\cdot 10^{-4}\theta^2 + 0{,}06868\left(\frac{h}{h_o}\right)^2 + 12{,}34\delta^2 \quad (2)$$

where:

θ – feeding angle of the plant material, ...º,
v_c – cutting speed, m/s,
h/h_o – degree of thickening of the plant material,
δ – thickness of knife's blade, μm.

From formulas (1) and (2) it results, that all the dependent variables have an essential impact on the degree of unevenness of chaff's length.

In the figures 6, 7, 8 and 9 there are graphically presented exemplary dependencies: $\lambda_{\dot{z}}=f(\theta)$, $\lambda_{\dot{z}}=f(v_c)$, $\lambda_o=f(h/h_o)$, $\lambda_o=f(\delta)$ for the selected fixed parameters.

Figure 6 illustrates the dependency of the degree of unevenness of the rye straw chaff $\lambda_{\dot{z}}$ on the material feeding angle θ. As a result of the conducted studies it was fund, that together with the increase of the angle θ there increases the degree of unevenness of the length of chaff of both the rye straw $\lambda_{\dot{z}}$ as well as the oat straw λ_o , assuming the lowest value for lateral cutting (θ=90°).

In figure 7 there is presented the diagram of dependency of the degree of unevenness of rye chaff $\lambda_{\dot{z}}$ on the cutting speed v_c.

The results of the studies showed, that together with the increase of the cutting speed v_c the value of $\lambda_{\dot{z}}$ and λ_o decreases in accordance with the quadratic dependence.

Figure 8 illustrates the dependence of the degree of unevenness of the length of oat straw's chaff λ_o on the degree of material's thickening h/h_o.

As a result of the analysis of experimental results, its is hard to state unequivocally, for what value h/h_o assumed for the studies, the degree of unevenness of oat chaff's length λ_o and rye chaff's length $\lambda_{\dot{z}}$ is the lowest one. On the basis of the drawn up regression function it was fund, that the lowest value λ_o occurs for h/h_o=0,58, while the lowest value $\lambda_{\dot{z}}$ occurs for the value h/h_o=0,54.

In figure 9 there is presented the dependence of the degree of unevenness of the chaff's length of oat straw λ_o on the value of knife blade's thickness δ.

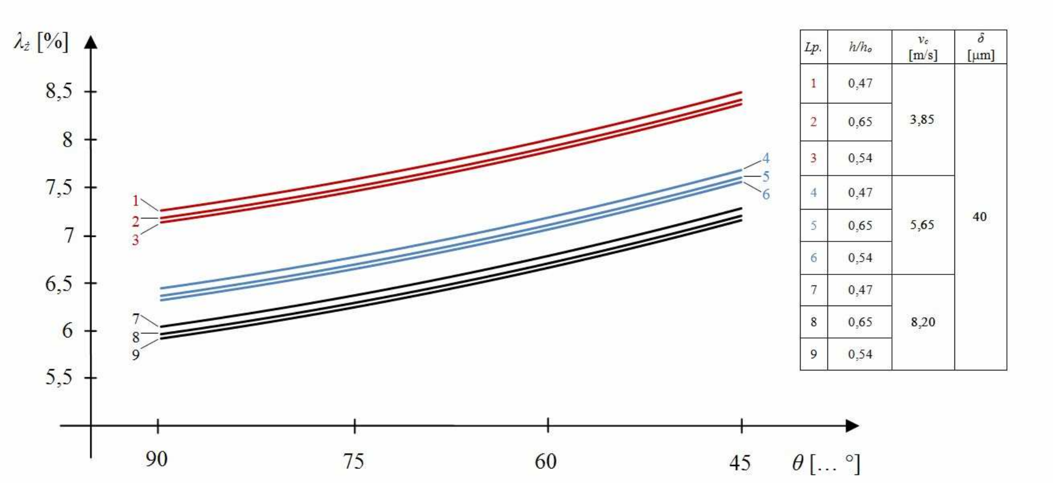

Fig. 6. Impact of the material feeding angle θ on the degree of unevenness of rye straw chaff's length $\lambda_{\dot{z}}$ for the value of the cutting speed v_c, degree of thickening h/h_o and the thickness of the blade δ [6]

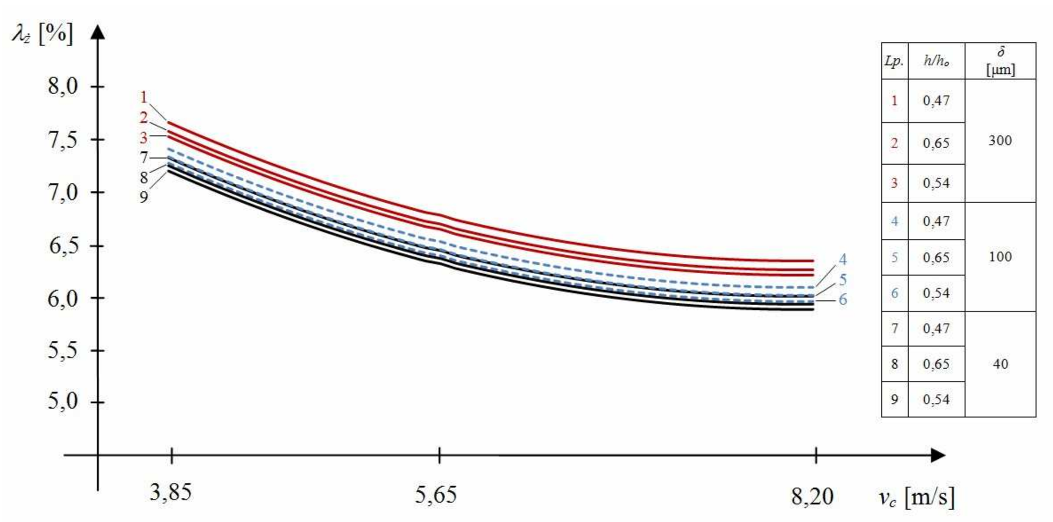

Fig. 7. Impact of the cutting speed v_c on the degree of unevenness of the length of chaff $\lambda_{\dot{z}}$ for lateral (θ=90°), value of the degree of thickening of the plant material h/h_o and the blade's thickness δ [6]

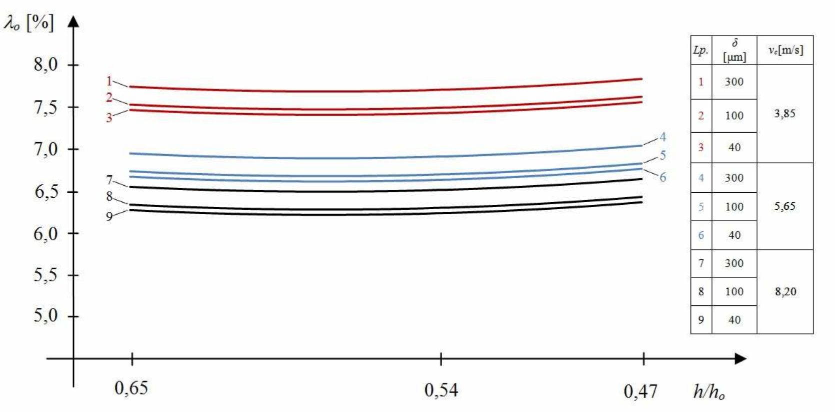

Fig. 8. Impact of the degree of plant material's thickening h/h_o on the degree of unevenness of the length of oat chaff λ_o for lateral cutting (θ=90°), value of the cutting speed v_c and the blade's thickness δ [6]

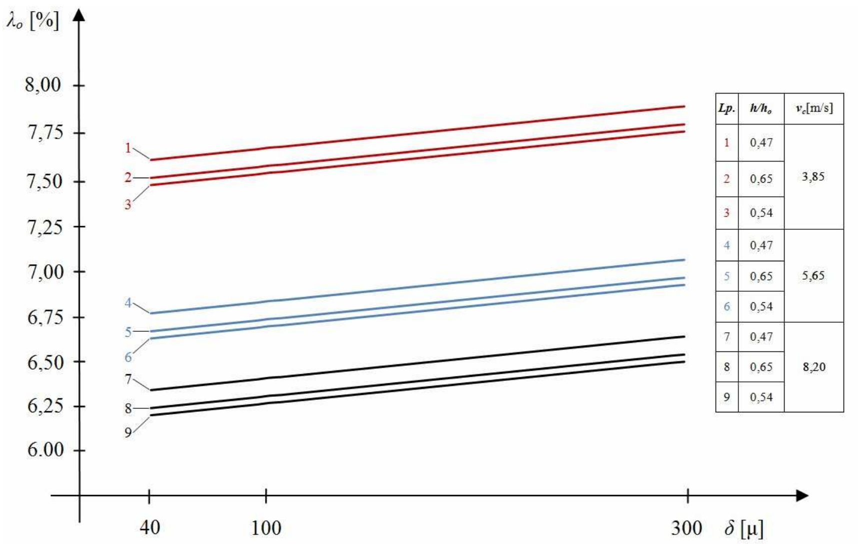

Fig. 9. Influence of blade's thickness δ on the degree of unevenness of oat chaff's length λ_o for lateral cutting (θ=90°), value of cutting speed v_c and the level of concentration h/h_o [6]

The results of the studies showed, that together with the increase of the value of blade's thickness δ there increases the value of the level of unevenness of oat chaff's length λ_o similarly like for rye chaff $\lambda_ż$. It most probably results from the fact, that in the conditions of a blunt knife's interaction (δ=300 µm) the cutting conditions get worse and the cut plant material very often is subject to jerking.

7. Conclusions

1. On the basis of the analysis of the results from the conducted studies it may be fund, that the degree of unevenness of the length of oat chaff's length λ_o for the same parameters is on average 5% higher than the degree of unevenness of the rye straw chaff's length $\lambda_ż$, what should be explained with a bigger irregularity of shapes of oat stalks, their bigger deformation as a result of the force of a knife caused by less stiffness.
2. As a result of experimental studies, the value of the degree of unevenness of the length of rye and oat straw's chaff was determined. This value assumes the values lowest for thr rye straw $\lambda_ż$ =6,04% and oat straw λ_o=6,24% for the following independent variables: θ=90°, v_c=8,20 m/s, h/h_o=0,58, δ=40 µm, and the values highest for the rye straw $\lambda_ż$ =9,26% and oat straw λ_o=9,72% for the following variable independent values: θ=45°, v_c=3,85 m/s, h/h_o=0,47, δ=300 µm.
3. Application of the manners of cutting other than lateral ones is connected with the change of chaff's shape, so it shall be necessary to check whether and in what manner such a change influences the effectiveness of the animals' feeding process.

8. References

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