Improving the technology of crushing root crops

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Abstract. The relevance of the article is due to the fact that the efficiency of production of livestock products largely depends on the quality of the feed base, the preparation of which requires special attention. Today, farmers use various types of feed: coarse, juicy, concentrated, fermented. Due to some advantages (high yield, easy digestibility, good eating, beneficial effect on the physiological state of animals), a valuable type of juicy food is root crops. When processing root crops, including preparation for feeding, it is mandatory to grind them, which is the main focus of this article. According to zootechnical requirements, root crops are crushed to particles of 10...15 mm for cattle, 5...10 mm for pigs and 4...5 mm for poultry. Analysis of existing shredders today has shown that they are characterized by high energy consumption, complexity of construction, low productivity. Crushed in most of these machines, the feed does not meet the zootechnical requirements, being a porridge-like state, which leads to the loss of juice and nutrients. Therefore, the proposed method of preparation in the article, in our opinion, will allow you to get food that meets the zootechnical requirements for all groups of animals with minimal energy consumption.

1. Introduction

In order to increase the quantity and improve the quality of feed, agricultural producers are looking for ways to intensify feed production. Special attention is paid to increasing the volume of raw materials for the production of feed per unit of land area, while minimizing the cost per unit of feed. Therefore, the most important raw material in feed preparation are root tubers. Before feeding animals, root crops are pre-processed. According to zootechnical requirements, root crops are cleared of foreign impurities (contamination should not exceed 2%), crushed to particles of 10...15 mm for cattle, 5...10 mm for pigs and 4...5 mm for poultry. Shredding should be done immediately before feeding. This is due to the fact that the crushed feed is quickly oxidized [1].

Root crops can be crushed in three ways: by cutting, by a combined blow, and by insulting. The most common method of preparing root crops for feeding is chopping by cutting. For its implementation, machines with grinding organs in the form of disks are most often used[2,3]. Let's look at the designs of some of them. A universal feed shredder is known, which consists of a base 1 (figure 1), a crushing chamber 2, side knives 3, a cross-shaped knife 4, a shaft 5, knife 6, removable internal side plates 7 and replaceable sieves 8, two guides 9 for fixing removable sieves 8, shredders 10 and a removable sleeve 11, a removable hopper 12 with a gate 13. for crushing juicy feeds, the shredder provides a removable knife 14, which has additional vertical ribs 15.
Figure 1. Feed shredder under patent № 94042038
1-base; 2-crushing chamber; 3-side knives; 4-cross-shaped knife; 5-shaft; 6- knife; 7-removable pads; 8-removable sieves; 9-guides; 10-shredding; 11 - removable sleeve; 12-removable hopper; 13-gate; 14-removable knife; 15-additional vertical ribs.

Another method of grinding, which has significant differences, is proposed by A. p. Blazhko, whose feature is the design of knives for grinding various agricultural products, which, according to the author, increases the productivity of the device (figure 2).

Figure 2. Shredder under patent No. 68,921
1-housing; 2-inclined element; 3-Cup; 4-electric motor; 5-pocket; 6-removable cover; 7-ventilation grate; 8-sieve; 9-grinding chamber; 10-grinding body; 11, 12-lower and upper covers; 13-loading hopper; 14-flap; 15-return spring; 16-discharge pipe; 17-corner; 18-blade; 19-knife; 20-plate; 21-grater.

The considered shredder grinds the root vegetables into a pulp, thereby increasing power consumption and contributing to the release of juice, which leads to a loss of nutrients.
The disadvantage of this installation is the complexity, and the simultaneous drive of two disks at once leads to increased power consumption when grinding one component of feed.

We also reviewed several other installations of this type. As shown by the analysis, the existing shredders have a high energy consumption, are complex in design, do not have protection of working bodies in case of stones or metal inclusions, or have low productivity. Almost all the considered units for crushing root crops are not able to cut them into slices. The design of most of the considered shredders is the impossibility of timely withdrawal of the finished product from the cutting zone, which leads to over-grinding of root crops, loss of juice, and, consequently, of nutrients [4,5,6,7].

2. Experimental part
To study the features of the process of cutting root crops, we developed a laboratory installation of a chopper.

The root crop chopper consists of a housing 1 (figure 3), an electric motor 2, a belt drive 3, a support bearing mounting bracket 4, a cover 5, a loading hopper 6, an additional inclined partition 7, an unloading neck 18, a cutting disc 12 mounted on the shaft 19 and including a disk 20 (figure 4), vertical 11 and horizontal knives 9, which are attached to the knife disk 20 with screws 10, blades 21 and a safety clutch consisting of a screw 15, a pressure plate 16 and a landing 17 pucks. On the cutting disc 12, radially arranged Windows are made, in which vertical knives 11 are installed.

**Figure 3.** Shredder of root crops: a – photo; b – design scheme; 1 – housing; 2 – electric motor; 3 – belt drive; 4 – mounting bracket for support bearings; 5 – cover; 6 – loading hopper; 7 – inclined partition; 8 – loading window; 9 – horizontal knife; 10 – screw; 11 – vertical knife; 12 – cutting disc; 13 – bump; 14 – discharge window; 15 – screw; 16 – pressure washer; 17 – landing washer; 18 – discharge neck; 19 – drive shaft; 20 – tensioning device.
The shredder works as follows. Root crops are loaded into the loading hopper 6. Under their own weight, they roll down an additional inclined partition 7 to the loading window 8 located on the periphery of the cutting disk 12 and through it enter the grinding chamber formed by the cutting disk 12 and the bump 13. On the periphery in the fold of the loading neck 8 rotate the knives of the cutting disk 12. When approaching the root crop, vertical knives 11 make vertical incisions in it, and horizontal ones 9 follow-cut off the chips. The distance between the vertical knives 11 will determine the thickness of the slice to be cut, and the speed of rotation of the cutting disc – its height. The cut slices are moved through the radial Windows located on the cutting disk by the blades 21 to the discharge window 14 and through the discharge neck 18 are removed from the grinding chamber.

**Figure 4.** Diagram of a cutting disc with two horizontal knives.

**Figure 5.** Laboratory installation for determining the cutting force and pinching angle: 1-chopper; 2 - bracket; 3-hinge; 4-plate.
To study the process of pinching the tuber to the shredder, a device (figure 5) was made, consisting of a bracket 2 and a plate 4 connected to it by a hinge 3, simulating the wall of the loading hopper.

3. Results and considerations

Approbation of the root crop chopper (figure 6) was carried out in JSC «Pokrovskaya Sloboda» of the Nizhny Novgorod region in June 2017 when chopping root crops for feeding to cattle.

The tests were carried out at the set optimal parameters: the cutting angle of horizontal knives $\gamma = 25^\circ$, the number of horizontal knives $N = 2$, cutting speed $V_p = 12$ м/с, knife flight $h = 19$ мм, gap $S = 28$ мм. The diameter of the crushed tubers was $d_{cl} = 45...65$ мм. 

![Figure 6. Root crop shredder in the process of testing.](image)

The test revealed that the content of particles with a size of 3 to 15 mm was 45 ... 60 %, the productivity of the shredder - 740...760 kg/h, the cost of electricity attributed to the unit of mass of the finished feed-50 ... 65 W*h/t.

4. Conclusion

In the course of the study, it was found that for guaranteed pinching of the tuber between the horizontal knife and the wall of the loading hopper in the developed chopper, the gap $S$ between the edge of the hopper wall and the cutting disc must be performed at a minimum ($S = 20$ мм), the knife $h$ – maximum ($h = 20$ mm), the angle of inclination of the hopper wall when chopping root crops up to 80 mm can be equal to $90^\circ$, and when chopping tubers larger than 80 mm – at least $60^\circ$, the cutting angle should not exceed $50^\circ$.

It was found that:

- to reduce the cutting force, the angle of the hopper wall should tend to $90^\circ$, the cutting angle of horizontal knives should not exceed $50^\circ$;
- to reduce specific power consumption, increasing plant efficiency and the content of fractions of crushed roots 15 mm in size is necessary to increase the number of horizontal knives and a cutting speed.

The optimal values of the chopper's tuning parameters are fixed: the cutting angle of horizontal knives $\gamma = 45^\circ$, the number of horizontal knives $N = 3$ and cutting speed $V_p = 12$ м/с when chopping root crops for poultry; the cutting angle of horizontal knives $\gamma = 25^\circ$, the number of horizontal knives $N = 2$ and cutting speed $V_p = 12$ м/с when chopping root crops for cattle; the cutting angle of horizontal knives $\gamma = 35^\circ$, the number of horizontal knives $N = 2$ and cutting speed $V_p = 10$ м/с when chopping root crops for pigs.

It was found that when grinding root crops for cattle, the productivity of the shredder is 740...760 kg/h, the content of particles with a size from 3 to 15 mm is 45 ... 60 %, the specific energy consumption is 50 ... 65 W*h / t. The use of this technology will allow more efficient implementation
of the feed preparation process, which will eventually lead to an increase in the overall efficiency of production by 12-15%.

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