Development chopper device that chops baled rough fodders

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Abstract. Livestock in Uzbekistan is one of the main sectors of agriculture and it is based on family livestock farms. In family farms, animals are fed with rough fodder, including corn stalks, alfalfa hay, camel-thorn, and pressed straw. However, households, due to the lack of small shredders, provide compressed feed to animals without chopping. As a result, 25-30% of the feed goes to waste, and losses increase. Therefore, a small installation was developed for chopping compressed coarse feeds and mixing them with concentrated feeds, and its chopping apparatus and type of knives were experimentally investigated. The density of stalks of alfalfa, corn, camel thorns, and wheat straw was 81.9 kg/m3; 81.3 kg/m3; 82.5 3 kg/m3 and 78.4 kg/m3 and their main part 76.2-94.4% were stems, and the rest of the leaves, branches, and panicles. When the rotor speed increased from 1200 to 1350 rpm, the stems are chopped qualitatively, i.e. fully comply with the original requirements. At the same time, the splitting of the stems is 83.5 - 94.0%, which also corresponds to the initial requirements. Depending on the type of knives, the cutting fraction with a length of 30-50 mm is 68.6 - 82.0%, the fractions with a length of more than 50 mm - 3.3 - 26.3%, and the fractions with a length of less than 30 mm - 5.1 - 14.7%. The splitting of the stems varies from 78.9% to 94.7%.

1. Introduction
Livestock breeding is one of the most important agricultural sectors in Uzbekistan and is based on family livestock farms. The presence of mountain and steppe pastures in Uzbekistan and the ability of the population to graze cattle from ancient times has further facilitated the development of animal husbandry [1]. While Uzbekistan's livestock farming has been largely based on cattle and sheep breeding, several new areas such as goats, horse breeding, and camel breeding are currently being established. In family farms, livestock feeds on rough feeds, including corn stalks, alfalfa hay, sage and wheat stalks, and sunflower stalks mixed with concentrated feeds [2-5]. However, as these farms do not have suitable small-size choppers, feed preparation is still carried out manually. In most cases, the feeds collected, especially from presses are fed to the livestock without chopping.

As a result, about 25-30% of all fodder is wasted, it is very destructive and the use efficiency is low. The main roughage in Uzbekistan is pressed wheat, corn stalks, and alfalfa. Whereas in Uzbekistan coarse fodder is harvested in small rectangular forms, a large amount of rolls are also harvested abroad. Due to this fact, feed chopping abroad are being developed for chopping rectangular or baled rough feeds [6-8]. Some of these devices are designed to work in one place, while others are portable. The design of these devices is compact and energy-efficient, but their chopping apparatus is mainly for chopping alfalfa and straw, and is less effective in chopping corn, pressed bush, and stem. Also, they are mainly intended for chopping of coarse fodder and do not mix blended crumbs with concentrated feed. Devices for chopping feed and mixing feeds are mainly of large size and large
farms and can be used for chopping of rectangular or rolled baled feeds. These machines are designed to be used as stationary and portable as well as to mix and disperse the concentrated feeds, as well as to chop the pressed coarse nuts. They operate from an electric motor or tractor power supply. The machines used for the chopping and mixing of the foregoing feeds are intended for large farms and do not allow them to be used in small farms with high metal and energy capacity and high cost. Therefore, it is important for these farms to develop a small chopping machine for individual use.

2. Methods
In defining the work-quality indexes of the cutting used State and International standards 11448-2002, testing conditions chopping device were determined according to State standards 20915-2011. The technological scheme of a small device for chopping and mixing coarse nutrients has been developed based on the analysis of the existing devices for chopping and preparing feeds and the structure of their chopping apparatus. The experiments were performed on the device's experimental sample. The experiments were performed on chopping straw at a rotor speed in the range from 900 to 1500 rpm with an interval of 150 rpm. The rotor diameter was 350 mm and the number of knives was 20 pieces, i.e. on each row 5 pieces knives. To select the optimal type of chopper knives, 3 types of knives were made. For the criteria for evaluating the work of the chopper, the quality of chopping, and the splitting of the stems were adopted.

3. Results and Discussion
The tools used for chopping and preparing feeds, the type of chopping machine, and their knives used for chopping straw and other stems were studied [9-20]. Based on the research, a technological scheme small-scale chopping and mixing of fodder for family livestock farms has been developed (Figure 1).

The device consists of a coarse feed hopper 1, a transmitter 3, a horizontal chopping rotor 4, a chopping chamber 5, a concentrated feed bunker 6, a feed mixing chamber 7, a drum mixer 8, opposite cutter 9, and an exit rod 10.

Based on the developed scheme, an experimental version of the chopper device was prepared (Figure 2).

![Technological scheme of the fodder preparing equipment](image-url)

Figure 1. Technological scheme of the fodder preparing equipment
In Uzbekistan, the main coarse fodder is baled wheat straw, alfalfa straw, corn straw, camel-thorn. It is important to know their physical and mechanical properties for chopping [21, 22]. As the chopper was designed to chop straw, corn, wheat, alfalfa, and camel-thorn, their physical and mechanical properties were determined.

| Properties                             | Wheat straw bale | Alfalfa straw bale | Corn straw bale | Camel-thorn straw bale |
|----------------------------------------|------------------|--------------------|-----------------|------------------------|
| Length of bale (cm)                    | 88.6             | 89.9               | 87.8            | 89.8                   |
| Width of bale (cm)                     | 45.6             | 45.4               | 45.3            | 45.1                   |
| Height of bale (cm)                    | 41.4             | 40.9               | 40.2            | 40.2                   |
| Average of stem length (cm)            | 18 – 55          | 20 – 62            | 70 – 112        | 30 – 53                |
| Mass of bale (kg)                      | 11.7             | 12.7               | 16.4            | 12.6                   |

According to the results in table 1, the length of the wheat straw press is 88.6 cm, its width is 45.6 cm, its height is 41.4 cm, its weight is 11.7 kg, and its stem length is 18–55 cm. The same sizes are 88.9 cm, 45.4 cm, 40.9 cm, 20–62 cm and weighing 12.7 kg, according to the alfalfa press 87.8 cm, 45.3 cm, 40.2 cm, 70–112 cm and weighing 16.4 kg, and in camel-thorn 89.8 cm, 45.1 cm, 40.2 cm, 30–53 cm and weigh 12.6 kg.

Determination of the morphological composition of the press and the density of stalked coarse fodder showed that they have a certain density. The experimental data are shown in table 2. According to the table, the density of stalks of alfalfa, corn and camel thorns is 81.9 kg/m3; 81.3 kg/m3 and 82.5 kg/m3 and are close to each other, and the density of wheat straw differs from other feeds and amounts to 78.4 kg/m3. The main part of the baled fodder is stems (76.2–94.4%), and the rest of the leaves, branches, and panicles.

| Type of bales     | Moisture | Morphological content, % | Density, kg/m³ |
|-------------------|----------|--------------------------|----------------|
|                   |          | stalk | leaf | extensions and whisk | X   | ±σ   | V, % |
| Alfalfa straw     | 13.7     | 79.0 | 6.6  | 14.4              | 81.9 | 9.6  | 11.7 |
| Wheat straw       | 14.4     | 94.4 | 5.6  | –                | 78.4 | 6.9  | 8.8  |
| Corn straw        | 13.1     | 87.5 | 10.1 | 2.4              | 81.3 | 8.2  | 10.1 |
| Camel-thorn straw | 15.2     | 76.2 | 5.1  | 18.7             | 82.5 | 9.7  | 11.8 |
From table 2 it is seen that the density of the bale of the stalks of alfalfa, corn and camel thorns is 3–5% higher than the press of the stalks of wheat straw. This may affect the performance of the chopper during its operation. To determine the nature of the change and determine the quality indicators of the work of the chopper, experiments were carried out on chopping straw at a rotor speed in the range from 900 to 1500 rpm with an interval of 150 rpm.

The results of the experiments are given in table 3.

| Work indicators                  | Rotation frequency of the rotor (rpm) |
|---------------------------------|--------------------------------------|
|                                 | 900  | 1050 | 1200 | 1350 | 1500 |
| Stalk chopping Kc (%)           | 81.5 | 89.0 | 94.1 | 96.9 | 95.4 |
| Empiric formula                 | -0.00006n² + 0.178n - 27.0           |
| Stalk splitting Rs (%)          | 83.5 | 86.2 | 88.0 | 94.1 | 97.5 |
| Empiric formula                 | 0.000018n² - 0.0194n + 86.4          |

As can be seen from table 3, with an increase in the rotor rotation frequency from 900 to 1350 rpm, the quality of chopping (Kc) of the stems begins to grow rapidly from 81.5 to 97.0%, i.e. Within these limits of the rotor speed, the total number of chopped stems consists of segments 3-5 cm long. However, a further increase in the rotor rotation frequency (up to 1500 rpm) has led to the fact that the quality of shredding of the stems begins to deteriorate.

This is explained by the fact that an increase in the rotor rotation frequency above 1350 rpm leads to an increase in the number of chopped stems up to 3 cm long, which is unacceptable from the point of view of zoo-technical requirements since excessive chopping of feed (meaning less than 3 cm) causes colic in ruminant animals. So, at a rotor rotation frequency of 1200 to 1350 rpm, the stems are chopped qualitatively, i.e. fully comply with the original requirements. At the same time, the splitting of the stems is 83.5 - 94.0%, which also corresponds to the initial requirements.

This means that with the same feeds, with an increase in the rotor speed, the multiplicity of hammer blows on the stems increases, which is naturally the reason for the increase in the size of the stalks and their splitting. To select the optimal type of chopper knives, comparative studies of various types of chopping knives were performed.

During the tests three types of chopper knives were compared (fig. 3).
The evaluation criteria when choosing the optimal type of knives were the quality of the chopping of the stems and their splitting. The experimental results are presented in table 4 from which it follows that the quality of work for the compared types of chopper knives is not the same. Depending on the type of knives, the crushed fraction 30-50 mm long 68.6–82.0 %, fractions longer than 50 mm – 3.3–26.3%, and fractions less than 30 mm – 5.1–14.7%. The splitting of the stems varies from 78.9% to 94.7%.

| Variants | The content of fractions by size, mm | Split stems |
|----------|-------------------------------------|-------------|
|          | longer than 50 | 30-50 | Shorter than 30 |
| I        | 18.2         | 74.4  | 7.4        | 81.2 |
| II       | 3.3          | 82.0  | 14.7       | 94.7 |
| III      | 26.3         | 68.6  | 5.1        | 78.9 |

Depending on the type of chopper knives, performance varies over a wide range. Therefore, the method of univariate analysis of variance determined the significance of the difference in the quality indicators of chopping stems from various types of chopper knives.

Testing the hypothesis of the relative significance of the average indicators of the quality of chopping stems using the multiple Duncan criterion showed that there is a significant statistical difference in the differences in the quality of chopping the stems, and these indicators are not statistically significant at a significance level of $q = 0.05$.

4. Conclusions
A small scale chopper was developed for family farms for chopping coarse feed and mixing them with concentrated fodder, and its chopping apparatus and type of knives were investigated experimentally. When the rotor speed increased from 1200 to 1350 rpm, the stems are qualitatively chopped, i.e. fully comply with the original requirements. At the same time, the splitting of the stems is 83.5 - 94.0%, which also corresponds to the initial requirements. Depending on the type of knives, the chopped fraction with a length of 30-50 mm is 68.6-82.0%, the fractions with a length of more than 50 mm are 3.3-26.3 % and the fractions with a length of less than 30 mm are 5.1-14.7%, and the splitting of the stems varies from 78.9% to 94.7 %.

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