Research of biotechnological, physical and mechanical properties and fractional composition of pressed feed bales

Shokir G‘apparov[1*], *Sherzod* Mardonov[2], *Mamatqosim* Bekkamov[3], *Tuychi* Dusbekov[3], *Kamol* Omonov[3], *Jonibek* Ulashov[4], and *Gulnaza* Sabirova[2]

[1]Chirchiq Higher Tank Command and Engineering School, avenue Amir Temur, block of flats 1st, Chirchik, Tashkent region, 111715, Uzbekistan
[2]National research university "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers", 39, Street Kari Niyazi, Tashkent, 100000, Uzbekistan
[3]Termez State University, 43, Street Barkamol avlod, Termez, 190111, Uzbekistan,
[4]Tashkent State Transport University, City Tashkent, District: Mirabad, pass. 1st Temiryulchilar, 100167, Uzbekistan

Abstract. To develop and optimize the parameters of a compressed feed chopper device, a comprehensive understanding of the biotechnological, physical, and mechanical properties of the processed compressed feed is essential. An experiment was conducted to analyze the fractional composition of compressed straw, alfalfa, and camel thorn. The compressed feed was divided into fractions based on length categories: up to 30 mm, 30-50 mm, and 50 mm. The fractional composition was determined relative to the total mass, and size-mass indicators were analyzed. Results indicated that fractions longer than 50 mm constituted 10.42 kg or 78.2% of the straw bale, with an average mass of 13.3 kg. Fractions in the 30-50 mm range accounted for 2.34 kg or 17.6%, while fractions shorter than 30 mm made up 0.56 kg or 4.2% of the total mass. The average density of the straw bale was calculated to be 83.1 kg/m³. Subsequent experiments revealed the diameter range of stalks for straw (1.5-5.5 mm), alfalfa hay (1.5-4.0 mm), and camel thorn (2-10 mm). Samples of each feed type, ranging from 50 mm to 100 mm in length, were selected for bending and breaking experiments.

1 Introduction

It is necessary to identify the biotechnological, physical and mechanical properties of processed compressed feed in order to develop and justify the parameters of compressed feed chopper device.

The physical and mechanical properties of feed were analysed by foreign scholars such as T. Condo, K.Mizuno, T.Kato, M.Mohsenin, D.McRandal, P.McNulty, V.Sonde, P.Belkhode, C.Sakhole, A.Shal, Z.Ghorbani, Y.Jekendra, A.Kumar and others, and by

* Corresponding author: shokir_gapparov@mail.ru

scholars of Uzbekistan O.Mamadaliev, K.Astanakulov, F.Qarshiev, B.Xatamov, A.Boratov [1-8].

Aforementioned scientists studied the physical and mechanical properties of gathered, stored and raw feed. However, these researchers did not study the physical and mechanical properties of compressed feed.

In Uzbekistan compressed alfalfa, wheat, barley straw, corn stalks, camel thorn and natural grass are stored and used as a feed in winter. Physical and mechanical properties of compressed straw, alfalfa bay and camel thorn were studied in order to ensure that feed is chopped in the developed device in the specified size depending on the type of livestock and to justify its composition and parameters.

The experiments on identifying the physical and mechanical properties of straw, alfalfa and camel thorn were conducted based on the requirements of GOST 20915-2011. "Agricultural technics. Methods for determining experiment conditions" and "Physical properties of plant and animal materials" [9-10].

The research program was developed on the basis of abovementioned methodological manuals which include the determination of wheat straw, alfalfa hay and camel thorn's length, thickness, mass, ratio of their components, density, friction angle and coefficient, resistance to breaking and shearing.

2 Materials and methods

One of the important factors in developing compressed feed choppers is to understand the state of processed materials such as size-mass indicators and morphological components of compressed feed intended for chopping.

For this purpose wheat straw, alfalfa hay and camel thorn were selected and their fractional composition, mass and size were studied [11-17].

In order to determine the fractional composition of compressed wheat straw, alfalfa and camel thorn, they were separated into fractions up to 30 mm, 30-50 mm and larger than 50 mm in length and fractional composition was determined in relation to the total mass (1 va 2-rasmlar). It is calculated using the following formula

$$F_i = \frac{M_i}{M_{um}} \text{x}100\%, \quad (1)$$

Fi – the share of fractions up to 30 mm, 30-50 mm or larger than 50 mm, %;

Mi – the mass of fractions with a size of 30 mm, 30-50 mm or more than 50 mm, kg;

Mum – total mass of the sample, kg.

When analysing the size of wheat straw bales of abovementioned compressed feed used in livestock feeding, it was found that their length is mainly between 60 sm to 90 sm, their width is around 50 sm and height is 40 sm.

Fig. 1. Compressed wheat straw and its fractional composition: a) compressed wheat straw bale; b) length up to 30 mm, c) length between 30-50 mm d) fractions with length more than 50 mm.

a b

Fig. 2. Camel thorn and alfalfa bales: a) Camel thorn bale; b) Alfalfa bale;

When compressed feed bales were cut, it was found that bales length increased to 3-5 sm, width and height increased to 1-2 sm.

3 Results and discussion

Analysing the size-mass indicators and fractional composition of compressed wheat straw, It was found that fractions longer than 50 mm accounted for 10.42 kg or 78.2 percent of straw bale with average mass of 13.3 kg. Fractions ranging from 30-50 mm accounted for 2.34 kg or 17.6 percent, and fractions shorter than 30 mm accounted for 0.56 kg or 4.2 percent of the total mass (Table 2.1). The average density of straw bale was determined to be 83,1 kg/m^3.

It can be seen that the part of the compressed straw that needs to be chopped is 78,2 percent.

Table 1. Fractional composition of compressed straw.

Indicators	X_{min}	X_{max}	$M_{o'rt}$	The ratio to total mass, %
Total mass of straw bale, kg	9.75	16.89	13.32	100
Larger than 50 mm, kg	7.99	12.85	10.42	78.2
Between 30-50 mm, kg	1.62	3.15	2.34	17.6
Up to 30 mm, kg	0.14	0.89	0.56	4.2

Based on the results of the experiment on determining the fractional composition of compressed camel thorn the mass of one camel thorn bale varies from 13,8 kg to 19,14 kg, the length is on average 80 sm, the width is 50 sm and the height is 40 sm. After cutting the thread the bale changed in length and increased to 2,3-3,7 sm. Its density was on average 102,9 kg/m^3.

It is identified that the average mass of camel thorn bale is 16,47 kg, 84,5 percent of it are fractions with the length larger than 50 mm, 12,8 percent are fractions with the length of 30-50 mm, 2,7 percent are fractions with the length of smaller than 30 mm (Table 2).

Table 2. Fractional composition of camel thorn.

Indicators	X_{min}	X_{max}	$M_{o'rt}$	The ratio to total mass, %
Total mass of camel thorn bale, kg	13.8	19.14	16.47	100
Larger than 50 mm, kg	11.56	15.98	12.77	84.5
Between 30-50 mm, kg	2.91	2.73	2.76	12.79
Up to 30 mm, kg	0.33	0.43	0.94	2.71

Table 2 shows the largest part which comprises 84,5 percent of compressed camel thorn are the fractions with the length larger than 50 mm and this part of compressed camel thorn needs to be chopped.

According to the data obtained from studies on the fractional composition of alfalfa hay, its weight varies from 11,3 kg to 16,4 kg, average length is 80 sm, width is 50 sm and the height is about 40 sm, after cutting the thread the bale changed in length and increased to 1,2-3,4 sm. Its average density was 103,1 kg/m^3.

Table 3. Fractional composition of compressed alfalfa.

Indicators	**X_{min}**	**X_{max}**	**$M_{o'rt}$**	**The ratio to total mass, %**
Total mass of alfalfa bale, kg	11.3	16.4	14.4	100
Larger than 50 mm, kg	9.85	14.43	12.73	88.4
Between 30-50 mm, kg	0.85	1.18	1.11	7.72
30 mm gaCha, kg	0.6	0.79	0.56	3.58

It is found that the average mass of compressed alfalfa is 14,4 kg, 88,4 percent of which are fractions larger than 50 mm, 7,72 percent are fractions with a length of 30-50 mm, 3,58 percent are fractions with the length smaller than 30 mm (Table 3). The part of alfalfa hay which should be chopped will be more than 88 percent.

According to the experiment tha main part of the compressed wheat straw, camel thorn and alfalfa hay is made of fractions larger than 50 mm and the device to be developed should chop these fractions at the level of zootechnical requirements.

The subsequent experiments were conducted to determine the compressed feed stalks strength. The morphological structure of compressed feed consist of stems, leaves and branches. While cutting the maximum force is applied against the stems and minimum force is applied to other remaining parts. In order to grid the compressed feed, the following methods are used: shearing, cutting, chopping and breaking. Among these griding methods shearing and cutting are considered acceptable for raw feed, but for griding dry feed with hard stalks the most productive and energy consuming are considered to be chopping and breaking [5-8].

For this purpose, experiment was conducted and DIGITAL FORCE GAUGE AMF-500 dynamometer was used to determine the bending and breaking force of compressed wheat straw, alfalfa hay and camel thorn. In the experiment, wheat straw stalks with the diameter ranging from 1,5 mm to 5,5 mm, alfalfa hay with diameter ranging from 1,5 mm to 4,0 mm and camel thorn with diameter ranging from minimum of 2 mm to maximum of 10 mm were used. From each type of feed, 25 samples with a length of 50 mm to 100 mm were taken and experiments were conducted (Figure 3).

In the samples with a diameter of 1,5 mm to 5,0 mm of straw stems, the bending stregth of stems was 2,1-3,0 N, and breaking strength was from 3,4 N to 12,6 N. In the experiment conducted on wheat straw it was found that the resistance to breaking in the stem joints was higher that in other parts ranging from 14,2 N to 22,3 N.

Similar experiment was conducted on alfalfa stems with a diameter of 1,5 mm to 4 mm. In the conducted experiment it was found that the bending strength of stems was 2,5-4,0 N and breaking strength was from 3,6 N to 15,2 N.

It is necessary to take into account the strength of stems to bending and breaking when justifying the working process of chopping device and determining the parameters of its working parts and operating mode.

Fig. 3. Samples of wheat straw (a), alfalfa hay (b) and camel thorn (c).

The bending and breaking strength of camel thorn were also determined by AMF-500 dynamometer. In order to carry out the experiment, this device allowed to fully test the samples and the results were obtained (Figure 4).

In the experiment conducted to determine the bending and breaking strength of camel thorn, stems with minimal diameter of 2,0 mm and maximum diameter of 10 mm were used. The results carried on stems with the diameter of 2-10 mm were observed as follows (Figure 4).

Fig. 4. The results of resistance strength of feeds taken by AMF-500 dynamometer.

It was found from obtained results that the breaking strength of stems with diameter of 2 mm was 29,4 N, while the strength of resistance of stems with a diameter of 10 mm was on average up to 352,2 N. It was the highest result.

According to the results of the experiment, the resistance to breaking of wheat straw and alfalfa stalks is much smaller than the resistance to breaking of camel thorn. Therefore, we consider the resistance strength of camel thorn stems as the highest resistance to breaking.

If we compare camel thorn and wheat straw stems breaking strength, the results of camel thorn compared to wheat straw were much higher (Table 4.).

Table 4. Bending and breaking indicators of camel thorn.

Stems' wet % (average)	**Stems' diameter, mm**	**Average $M_{o'rt}$, N**	**Average kv. deviation ±G, N**	**Coefficient of variation V, %**
16.2	2	29.4	0.94	3.19
	4	65.7	1.27	1.93
	6	215.4	1.00	0.47
	8	276.3	1.33	0.48
	10	352.2	1.33	0.38

Breaking is considered one of the main types of destructive deformation of the chopped materials and the most complete mechanical description for it is the break force [10-13]. It was determined in previous researches that the breaking force of wheat straw was 9-11 MPa, rye was 10.5-13 MPa, corn was 14-18 MPa, hay and wild grass was 19,6-26 MPa [11-16]. However, these results were obtained on stems that were not compressed, were not affected by mechanical effects. Stems in the compressed feed change its strength and subject to mechanical effects during the pressing process.

4 Conclusion

The size and mass characteristics of compressed feed vary withing the following limits depending on the type of feed: the average mass of wheat straw bale is 13,32 kg, the average mass of camel thorn bale is 16,42 kg, and the average mass of alfalfa bale is 14,4 kg. The bales' average length is 80 sm, width is 50 sm and height is 40 sm.

The breaking strength of stems depends on the diameter of the stems and its breaking strength varies from 1,5 kN to 3,5 kN.

Depending on the type of compressed feed, their density is also different as it is 93,2 kg/m3 for compressed wheat straw, 107,4 kg/m3 for compressed camel thorn and 101,4 kg/m3 for compressed alfalfa bales.

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