Study of physical and mechanical properties of feed additives for cattle

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Abstract. The article presents a study of the physical and mechanical properties of feed additives for cattle used in the farms of the Leningrad region. The choice of the investigated factors is due to their influence on the mixing process and design parameters of the mixer. When determining the particle size distribution, it was revealed that most of the materials under study have a particle size of $d = 0.5$-$2$ mm. The bulk density for most of the additives was $500$-$800$ kg/m$^3$. The moisture content of the main part of the investigated materials did not exceed $10\%$. The research results will make it possible to establish the influence of individual components on the property of the mixture and substantiate the optimal design and operating parameters of the mixer for feed additives.

1. Introduction
Ensuring the fullest use of the nutritional value of feed is an essential factor in the sustainable development of the livestock industry. A necessary condition for maintaining the health of animals and increasing their productivity is the balance of diets with protein-mineral-vitamin supplements (BMVD) [1]. A wide range of supplements produced allows specialists to compose optimal rations in terms of nutritional value, macro and microelements and vitamins, depending on the conditions of maintenance, productivity and other factors [2-4]. Additives are included in the complete feed mixture at the rate of $10$-$300$ g / head. With such a relatively small proportion of additives, the problem arises of ensuring mixing efficiency and uniformity of distribution of micro components in the volume of the feed mixture, which is about $45$-$50$ kg / head.

One of the solutions to this problem can be the preparation of a mixture from BMVD with subsequent addition to the main mixing process [5]. To substantiate the most optimal parameters of the created mixer for the preparation of a mixture of BMVD, it is necessary to study their physical and mechanical properties. So the parameters of material flow depend on the particle size [6-7]. Granulometric characteristics determine the specific area of interaction. The difference in particle size distribution and bulk density predetermine the process of spilling of smaller and heavier particles between large and light ones during mixing, which leads to the separation of the mixture into fractions [8-9]. The bulk density must be taken into account when determining the mixer volume, filling factor, calculating the energy consumption for mixing. The moisture content of materials affects the fluidity, bridging, lumpiness, density [10]. Previously, the most rational values of the angle of inclination of the working surfaces and the angle of installation of mixing devices were determined [11].
2. Materials and methods

Based on the analysis of the diets of several farms in the Leningrad Region, the most widely used additives were selected for the study, included in the feed mixture in a fraction of less than 300 g/head:

- Fungistat;
- Dry polysaccharides;
- Premix P-60;
- Chalk;
- Granulated soybean shell;
- Soybean meal;
- Rapeseed meal;
- Beet pulp;
- Elitox;
- Levisel;
- Protected fat;
- Salt.

Laboratory samples weighing 100 ± 0.1 g are formed and placed in specialized sealed containers. In the course of the research, the following were determined: granulometric composition, bulk density and moisture. The choice of factors is due to their influence on the mixing process and the design and operating parameters of the mixer. The studies were carried out in triplicate. The arithmetic mean was taken as the final result.

The study of the granulometric composition was carried out on an installation for sieve analysis, the installation diagram is shown in figure 1. The installation consists of a frame 1; vibration exciter 2, in the form of an electric motor with an eccentric on the output shaft; racks 3; set of sieves 4; clamping bars 5. For sieving, a set of sieves according to GOST R 51568-99 (ISO 3310-1-90) [12] was used. Nominal mesh sizes of sieves in mm: 2.0; 1.4; 1.0; 0.5; 0.316; 0.16; 0.05.

![Figure 1. Installation for sieve analysis.](image)

The material sample was placed on the top sieve with the largest nominal mesh size, the sieve was covered with a lid, which was fixed by a clamping bar. Then the vibration exciter was turned on. Sieving was carried out for 15 minutes with a frequency of 150 ± 10 vibrations per minute. After that, the weight of each sieve with the material was set with an accuracy of 0.1 g. For weighing, we used a platform mobile balance VSP-0.5 / 0.1-1 with a measurement error of ± 0.1 g (verification date March 12, 2020).

The average particle size for each fraction was determined by the formula 1 [13]:

\[
d_{sr} = \frac{w_i + w_{i-1}}{2}
\]
Where $w_i$ - is the nominal size of the cells, mm.

On the basis of the obtained values, the weighted average particle size of each material was determined according to formula 2 [13]:

$$D_{sr} = \frac{\sum d_{sr}^i \cdot x_i}{\sum x_i}$$

Where $x_i$ - is the mass fraction of each fraction, g.

Determination of bulk density was carried out on the installation, the diagram of which is shown in figure 2. The installation consists of a rack 1, a funnel 2, a glass 3, weighing 127 ± 1 g and a volume of 0.0001 m$^3$ and a pallet 4. A measuring container in the form of a glass is installed on a pallet. The funnel is installed coaxially with the bowl so that the distance from the funnel nozzle to the bowl edge is 50 ± 2 mm.

Figure 2. Installation for the study of bulk density.

A sample of the material was poured through a funnel into a beaker. The filling was carried out before the material began to fall down the formed hill onto the pallet. Then the material was leveled with the edge of the glass, dropping excess material onto the pallet. Then the glass with the material was weighed to the nearest 0.1 g. The bulk density was determined by the formula 3:

$$\rho_u = \frac{G_1 - G_2}{V}$$

Where $G_1$ - is the average mass of the material, kg;
$G_2$ - glass weight without material, kg;
$V$ - is the internal volume of the glass, m$^3$.

Weighing was carried out using a platform mobile balance VSP-0.5 / 0.1-1 with a measurement error of ± 0.1 g.

To determine the moisture content, an MX-50 moisture analyzer was used with a measurement error of ± 0.1 g. During the determination, a sample with a known initial weight was dried, the residue was weighed, and the relative weight change was calculated. The study was carried out in accordance with the instruction manual. Within the framework of the study, two parallel experiments were performed. The mass fraction of moisture was calculated by the formula 4 [14]:

$$W = \frac{m_1 - m_2}{m_1} \cdot 100\%$$

Where $m_1$ - is the mass of the material before drying, g;
$m_2$ - weight of material after drying, g.

The arithmetic mean of the results of the two determinations was taken as the final result of the study. The studies were carried out at an air temperature of 20 ± 2 °C and a relative air humidity of 40
± 2%. The processing of the research results was carried out by the well-known methods of mathematical statistics with the determination of average values.

3. Results
Table 1 shows the results of determining the particle size distribution. Figure 3 shows the distribution of the weighted average particle size $D_{sr}$.

| No | Material                  | 0.2 | 0.4 | 0.5 | 0.8 | 1.3 | 1.6 | 1.9 | 2.3 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
|----|---------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 1  | Fungistat, g              | 0   | 0.4 | 0.8 | 52.3| 22.5| 15.9| 8.3 | 0.5 | 0.05| 0.16| 0.316| 0.5 | 0.16| 0.05| 0.05| 100.7|
| 2  | Dry polysaccharides, g    | 0.9 | 4.6 | 7   | 25.2| 19.2| 31  | 11.9| 0.2 | 100 | 0.53|
| 3  | Premix P-60, g            | 0   | 0.7 | 1.3 | 15.8| 29.4| 34.3| 17.8| 0.7 | 100 | 0.37|
| 4  | Chalk, g                  | 0   | 2.3 | 9.1 | 48.3| 15.6| 19.9| 4.8 | 0.2 | 100 | 0.63|
| 5  | Granular soy casing, g    | 96  | 0.9 | 0.8 | 1.3 | 0.5 | 0.4 | 0.1 | 0   | 100 | 1.96|
| 6  | Soybean meal, g           | 12  | 22  | 17.6| 31.8| 8.5 | 5.3 | 2.9 | 0.2 | 100 | 1.11|
| 7  | Rapeseed meal, g          | 6   | 12.2| 11.5| 32.4| 17.8| 13.7| 6.1 | 0.5 | 100 | 0.82|
| 8  | Beet pulp, g              | 66.3| 26.2| 4.5 | 2.4 | 0.2 | 0   | 0.1 | 0   | 99.7| 1.85|
| 9  | Elitox, g                 | 0   | 0   | 0.4 | 1.1 | 19.8| 55.6| 23.2| 0.8 | 100 | 0.25|
| 10 | Levisel, g                | 0   | 0.2 | 3.1 | 71.1| 23.9| 1.1 | 0.6 | 0.1 | 100 | 0.67|
| 11 | Protected fat, g          | 0   | 0.3 | 8.6 | 86.9| 3.9 | 0.1 | 0   | 0   | 99.8| 0.78|
| 12 | Salt, g                   | 61.5| 22.8| 7.1 | 6.5 | 1.2 | 0.3 | 0   | 0   | 99.4| 1.75|

Figure 3. Weighted average particle size $D_{sr}$.

The results of determining the bulk density are presented graphically in figure 4 in the form of a histogram. The results of moisture determination are presented graphically in figure 5.
4. Discussion
The total mass of the fractions was within 99-101 g. The deviation of the initial mass of the sample for all determinations was no more than 1%. It was revealed that most of the studied feed additives belong to the class of fine-grained materials with an average particle size $D_{sr} = 0.5-2$ mm [10; 14]. At the same time, there is a significant proportion of materials with a weighted average particle size of less than 0.2 mm, which affects the characteristics of material mobility [5]. The granulated soybean shell has the largest particle size, 96% of the particles of which have a size of more than 2 mm. In addition, beet pulp and salt have a weighted average particle size of 1.85 mm and 1.75 mm, respectively. Elitox has the smallest particle size - 0.25 mm. The presence of large particles has a positive effect on the mixing process, preventing the formation of stagnant zones by small particles. A decrease in the proportion of large particles less than 13% leads to the need to increase the rotational speed of the working body of the mixer, and as a consequence to the compaction and grinding of the components [15]. It should also be taken into account that most feed additives have a complex non-spherical particle shape, which increases the mixing intensity [16].

According to the bulk density, bulk materials are distinguished: light (up to 600 kg / m$^3$), medium (600-1100 kg / m$^3$), heavy (1100-2000 kg / m$^3$), very heavy (more than 2000 kg / m$^3$) [10; 14]. Most of the studied feed additives in terms of bulk density refer to average ones (600-1100 kg / m$^3$) (figure 5).
The heavy ones (1100-2000 kg / m$^3$) include salt and P-60 premix. Light pulp (up to 600 kg / m$^3$) includes beet pulp, levisel, protected fat and rapeseed meal. In general, most of the materials are in the range of 500-800 kg / m$^3$.

Rapeseed meal has the highest moisture content, 10.28%. Chalk has the lowest moisture content - 0.68%. In general, the field of scatter of humidity values does not go beyond 10%.

5. Conclusion
According to the granulometric composition, most of the studied materials belong to the class of fine-grained with an average particle size of d = 0.5-2 mm. Most feed additives have a complex non-spherical particle shape. The bulk density of most additives is in the range of 500-800 kg / m$^3$. Humidity generally does not go beyond 10%. Rapeseed meal has the highest moisture content - 10.28%, and the least chalk - 0.68%. It is necessary to consider the possible averaging of indicators of physical and mechanical properties in further calculations. The research results will be used to substantiate the optimal design and operating parameters of the mixer for feed additives. Also, the obtained data can be used to model the properties of a mixture of BMVD as a whole, with various combinations and proportions of individual components, which will allow predicting the property of mixtures with known properties of the initial components.

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