JUSTIFICATION PARAMETERS OF MIXER DRUM FEED ADDITIVES

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Abstract. It is possible to reduce the cost of production and improve the quality of finished feed, due to a balanced composition, by producing feed additives directly on farms. It has been established that better mixing will occur with a smaller difference in the ratio of components. Some components in the compound feed are in an amount of up to 1%. It is advisable to apply a staged mixing scheme, in which a mixture of micro components will be prepared at the first stage, premixes at the second stage and compound feed at the third stage. To obtain a high-quality mixed feed, it is necessary that each premix has a higher level of it. Therefore, the mixer of micro-additives has the highest requirements regarding uniformity. The design chosen for further study allows mixing dry components of premixes, eliminating the phenomenon of segregation due to the movable mixer chamber. Due to the inclined axis of the chamber, mixing occurs not only in the transverse, but also in the longitudinal direction. To better distribute the mixing, the chamber was provided with an agitating blade along the inner surface of the chamber. It has been established that the best operating mode of the installation is 1.6-1.7 s^{-1}. When determining the duration of mixing of the components, it was found that a sufficiently high level of uniformity of feed additives of 96% is achieved within 240-360 s. The intensity of the mixing process is affected by the measure of the initial filling of the chamber. It has been established that the rational filling factor is k = 0.5-0.6, the width of the working plane of the mixing blade is s = 30-35 mm, which corresponds to the ratio of the blade width to the chamber cylinder diameter of 0.18. It has been established that the range of the drum inclination angle within 16-20º is a rational zone with a mixing time of about 300 s. In this case, uniformity of 95-98% can be achieved, which satisfies the zoo technical requirements for all groups of animals.

Keywords: components, ratio, mixer chamber, blade, uniformity.

Introduction

For the production of compound feed in the conditions of agricultural enterprises, a wide range of farmers compound feed units, the work of which is based on the use of own grain raw materials and purchased protein-vitamin-mineral supplements. Since the components of compound feed are distinguished by one or two orders of magnitude, it is advisable to carry out step-by-step mixing, starting with the components with the lowest content. More stringent requirements regarding the uniformity of mixing are imposed on the group of microcomponents. To do this, farm feed units must be equipped with appropriate mixers. Analysis of the study the literature sources showed that the problem does exist not only in agriculture but also in other industries. In general, all studies can be divided into two parts. The first is mathematical calculation and establishment of dependencies in the mixing process. The second is experimental studies of different products. There is no single vision for the quality of mixing. After all, feed mixtures have different properties.

In work [1-6] mathematical modeling and Euler approach of mixing and segregation in a rotating cylinder were performed. The aim of the research [2] is the numerical simulation of the drum mixer operation, including the identification of geometrical indicators of the material pile in a rotating drum for conducting the force analysis and determining the expended power. In work [3] was studied the discrete element method used to study the mixing phenomena of a rotating drum for different angles of inclination from 0°to 15°. In work [5] was used the video analysis method that was developed to evaluate different configurations of straight lifters in the rotary drum. A new mixing index is proposed [6], which is an improved Lacey index based on the coordination number fraction.

Works 7-13 present experimental studies of the mixers and the influence of the design features on the quality of mixing. In the work [7], the influence of the number of blades and their height on the quality of the mixture was studied. A slight (about 1%) decrease in the coefficient of variation of the mixture was established with an increase in the number of blades from 2 to 8 pieces. More influence on the quality of the mixture has an increase to 0.175 m or a decrease to 0.125 m in the height of the blades. In this case, the coefficient of variation increases from 20.6% to 34-50%. Wood sawdust of different sizes and metal shavings were used in [8]. It was found that the best mixing will be at the optimum degree of filling the drum 40-50% for spherical particles and 30-40% for particles with sharp edges. In work [9], a U-shape horizontal mixer was investigated. The investigated element was a round metal ball with a diameter of 4 mm, which does not correspond to the properties of the mixed material in agriculture. Work [10] presents a new mixing index proposed, which is an improved Lacey index based on the coordination number fraction. In work [11] the influence of the design of the blades on the mixing regime was studied.

Materials and methods

Due to the large number of acting factors, such processes are random in nature and it is impossible to achieve an ideal distribution of particles in the total mass of the feed portion. Therefore, methods for assessing the uniformity of a mixture are based on the use statistical approaches, where the study is carried out with one control component, and all the others are combined into the second (conditional component). According to the degree of distribution the control component in the conditional mass conclusions are drawn about the quality of the mixture. Of the general nomenclature of drum mixers, the preferred indicators for the quality of the mixture has a mixer with a cylindrical chamber, the symmetry axis of which is shifted relative to the horizontal axis of rotation, and mixing blades are placed on the inner surface of the chamber along the generatrix of the cylinder. We have developed and presented a scheme (Fig.1) of a drum mixer with an inclined axis of the chamber relative to the axis of rotation.

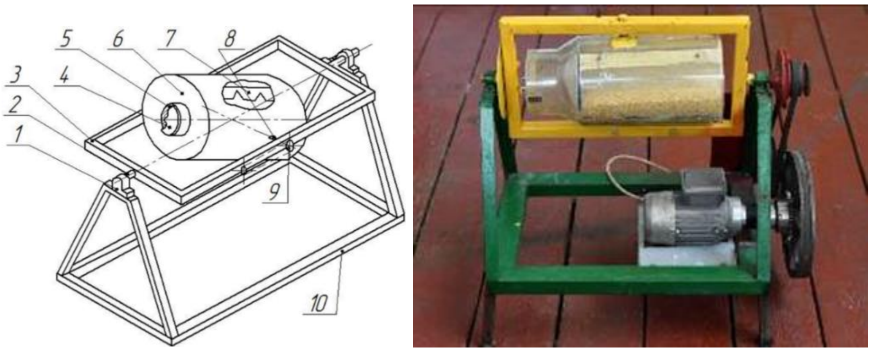

Fig. 1. **Scheme of a drum mixer with an inclined axis of the chamber relative to the axis of rotation and a general view:** 1 – bearing units; 2 – trunnions of the frame; 3 – frame; 4 – cover; 5 – window; 6 – camera; 7 – scapula; 8 – chamber trunnion; 9 – tilt mechanism; 10 – support

As a filler, crushed grain of barley, wheat, peas, oats in equal proportions and minerals (salt, chalk) were used. Given that most researchers, when analyzing the process of mixing feed materials, take the coefficient of variation of distribution ν of the control component in it as a criterion for assessing the quality of a loose mixture, these studies were also based on its definition.

$$\nu = \frac{100}{\overline{C}} \sqrt{\frac{\sum \left(C_i - \overline{C}\right)^2}{n-1}}, \quad (1)$$

where C_i – experimental value of the concentration of the control component in the i-th sample;
$\overline{C}$– arithmetic mean of the concentration of this component;
n – number of analyzed samples.

The degree of uniformity of the mixture P was determined as follows:

$$P = 100 - \nu . \quad (2)$$

Of the known sampling methods for assessing the quality of a mixture in batch mixers, the point sampling method has become widespread. A sampler was used for sampling. It could take up to 4 samples simultaneously along the mixing chamber.

The maximum number of sampling places located in the plane of the perpendicular section of the cylinder ranged from 3 to 5. The experiments were performed in 3 repetitions. The parameters of the study were the angle of inclination of the drum axis, width, number, and the angle of inclination of the blades, the filling factor and the mixing time.

Results and discussion

Depending on the filling of the chamber and the frequency of rotation in the plane of the cross section of the drum, three modes of movement of the material can take place: movement with collapse, circulation movement and closed movement mode. For a reliable technological process, it is necessary to observe the circulation mode of movement, when the material from the upper layers of the raised monolith breaks away from the lower layers and falls back into the free space of the chamber, that is, the mutual movement of the bulk mass occurs. In the circulation mode of operation of the mixing drum, the kinematic parameter is usually supplied through the angular velocity.

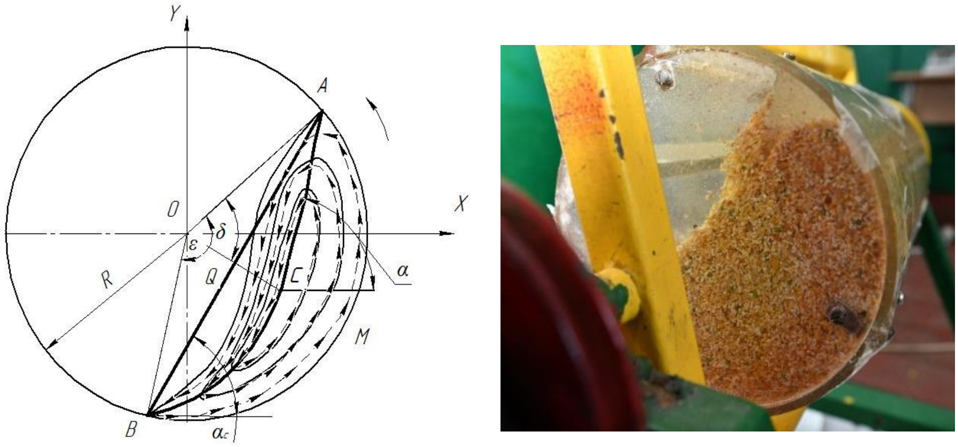

Fig. 2. **Scheme and general view of the movement of bulk material in the drum mixer**

To determine the rational speed of movement, consider the movement of the slice in the drum during mixing. The feed particle first moves together with the barabar to the separation point *A*. The location of this point depends on the rotation speed of the drum and the filling factor of the chamber. After the material particle reaches the point *A*, it begins to move to the lower zone, Fig. 2. This surface, with a sufficient degree of assumption, can be taken as the chord of a material segment with the sector angle of 2*δ*.

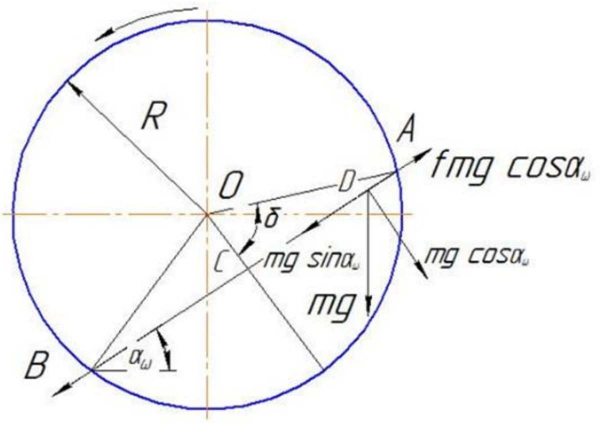

Fig. 3. **Scheme of the action of forces on the material during rolling**

The accelerated motion at this point in time can be described by the equation, Fig.3:

$$m\ddot{x} = mg \sin \alpha_{\omega} - fmg \cos \alpha_{\omega}, \quad (3)$$

where m – particle mass, kg;
α – angle of inclination of the material to the horizon, deg;
g – free fall acceleration, m·s^{-2};
f – coefficient of internal friction, rel. units.

which, under the initial conditions: t = 0, V = 0, x = 0, has a solution:

$$x = 0.5gt^2(\sin\alpha_\omega - f\cos\alpha_\omega). \tag{4}$$

Substituting the value of the distance measured by the length of the chord *AB*:

$$x = 2R\sin\delta, \tag{5}$$

where δ – half of the central angle, bounding the segment filled with material, you can determine the duration of the movement of the slice to the point *B*:

$$t = \sqrt{\frac{4R\sin\delta}{g(\sin\alpha_\omega - f\cos\alpha_\omega)}}. \tag{6}$$

To ensure the circulation movement, it is necessary that the time to overcome the chord *AB* approaches the time of lifting the slice along the arc *AB* due to the friction of the material on the metal surface of the drum. We determine the lifting time, taking into account the angular velocity of the drum and the angle δ, which is half the central angle of the material segment:

$$t = \frac{2\delta}{\omega}. \tag{7}$$

Equating formulas (6), which determines the time of the particle movement along the inclined surface of the material, and (7), which determines the time of ascent along the arc *BA* together with the drum, we obtain:

$$\omega = \delta\sqrt{\frac{g(\sin\alpha_\omega - f\cos\alpha_\omega)}{R\sin\delta}}. \tag{8}$$

Formula (8) determines the dependence of the change in the angular velocity of the drum with a change in the angle δ, which reflects the degree of filling the mixing chamber. The fill factor of the drum is defined as the ratio of the area of the material segment to the cross-sectional area of the drum:

$$k = \frac{2\delta - \sin 2\delta}{2\pi}. \tag{9}$$

Combining expressions (8) and (9) into a system and solving it, we obtain the dependence of the angular speed of rotation of the drum on the fill factor of the mixing chamber at which the circulation mode of motion will take place:

$$\begin{cases} \omega = \delta\sqrt{\dfrac{g(\sin\alpha_\omega - f\cos\alpha_\omega)}{R\sin\delta}} \\ k = \dfrac{2\delta - \sin 2\delta}{2\pi}. \end{cases} \tag{10}$$

This dependence makes it possible to determine the rational kinematic parameters of the drum mixer, which will ensure high productivity of the equipment and the quality of the feed mixture corresponding to zootechnical conditions, which is determined by the uniformity of mixing of the components.

The next stage of the research was experimental studies determining the rational zones of influence of the kinematic regime on the duration and quality indicators of the mixture. Increasing the frequency of wrapping the drum in the range $n = 0.55\text{-}0.85$ s^{-1} improves uniformity in a straight line. The subsequent increase in frequency leads to a closed mode of movement and violates the technological reliability of work. The interaction with other factors of the mixing process (the angle of displacement of the axis of the drum, the filling factor of the chamber, the width, number and inclination of the mixing blades) was determined by multivariate experiments.

After processing the data of multivariate experiments and decoding the regression equation, the following equation was obtained:

$$P = 77.78 - 10.38 \cdot k - 3.20 \cdot k^2 - 0.87 \cdot N + 1.31 \cdot k \cdot N + 0.04 \cdot S + 0.35 \cdot k \cdot S + 0.09 \cdot t - 23.18 \cdot \alpha - 3.15 \cdot k \cdot \alpha + 0.27 \cdot N \cdot \alpha + 0.06 \cdot S \cdot \alpha + 9.87 \cdot \alpha^{2} + 72.51 \cdot \beta - 16.04 \cdot k \cdot \beta + + 0.57 \cdot N \cdot \beta - 0.35 \cdot S \cdot \beta - 0.5 \cdot t \cdot \beta + 22.57 \cdot \alpha \cdot \beta - 68.13 \cdot \beta^2. \quad (11)$$

This mathematical model characterizes the dependence of the uniformity of the prepared mixture by the drum mixer on the studied factors. The analysis shows that the uniformity index *P* is determined primarily by the angle of inclination of the drum axis *β* and the chamber filling factor *k*. Other factors (blade width *S*, their number *N* and the inclination angle of the blades) have less effect on the uniformity of the mixture.

Based on the obtained mathematical model, flat graphical dependencies were built. For an example Fig. 4 shows the dependence that characterizes changes in uniformity from the angle inclination of the drum *β* and the mixing period *t*. The zone of minimum values of uniformity falls on the combination of the lower limits of the interval *β* and *t*. With their increase, the surface acquires a convex shape, and in the upper limits there is a tendency to worsen uniformity. Moreover, the duration of mixing more significantly affects the improvement of uniformity. Uniformity can vary from 89 to 97%. The extreme section of the response surface is at the point (*β* = 19º; *t* = 300 s).

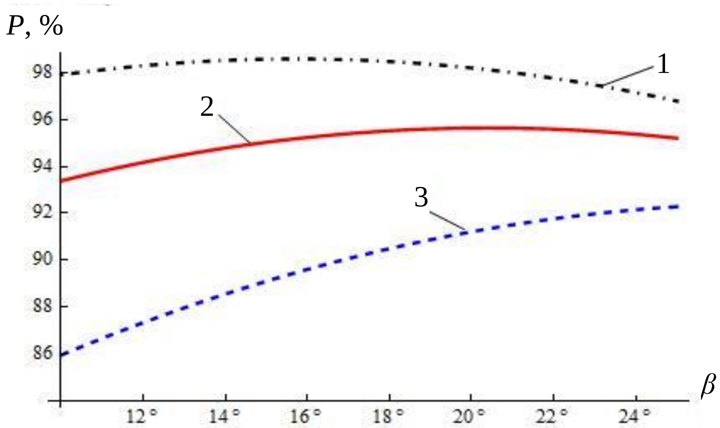

Fig. 4. **Dependence of uniformity of the mixture p on the angle of inclination of the drum axis with such combinations of fixed factors:** 1 – *S* = 30 mm; *N* = 12 pcs.; *α* = 0º; *k* = 0.55; *t* = 360 s; 2 – *S* = 40 mm; *N* = 8 pcs.; *α* = 15º; *k* = 0,45; *t* = 240 s; 3 – *S* = 20 mm; *N* = 6 pcs.; *α* = 25º; *k* = 0,4; *t* = 120 s

The range of angles *β* = 16-20º (Fig. 4) is a rational saturation zone with a mixing time of at least 240 s. In this case, uniformity of 95-98% can be achieved, which satisfies the zootechnical requirements for all groups of animals.

To establish a rational combination of variable parameters, which is associated with the need to prepare mixtures for different types of animals, the cartography method was used with a section of the response surface by planes parallel to the horizontal plane of the coordinate system. Lines of changes in uniformity confirm that at an angle *β* = 10º, already after 120 s of mixing, the uniformity index reaches 89%. The subsequent increase in β and t improves the uniformity of the distribution of components in the mixture. The width of the working plane of the mixing blade does not affect the homogeneity of the mixture. Changes in the coefficient uniformity with a change in the angle of deviation of the blade from the radial position indicate a deterioration in uniformity. Based on the analysis of the created mathematical models of the process of mixing feed components with a laboratory installation of a drum mixer and their graphical interpretation, the optimal parameters and operating modes were determined.

Conclusions

1. The mathematical dependences of particle motion in the drum are established. These dependencies make it possible to determine the rational kinematic parameters of the drum mixer, which will ensure high performance of the equipment and the quality of the feed mixture, which corresponds to the zootechnical conditions, determined by the uniformity of mixing the components.

2. It is experimentally established that the conditions of technological reliability of the drum mixer of periodic action in the circulating mode depend on: properties of the investigated material, angular speed of movement, duration and speed during mixing. The width of the mixing blade does not significantly affect the mixing process, which confirms the data of previous studies.
3. The uniformity of the distribution of components in the mixture in accordance with the zootechnical requirements (95-98%) is determined by structural and technological factors. It has been established that the optimal parameters of the drum mixer are: chamber filling factor – 0.5-0.6; drum rotation frequency – 1.6-1.7 s^{-1}; angle inclination of the drum axis to the axis of rotation, 16-20 degrees; number of mixing blades - 9 pcs.; mixing period in the chamber – 240-360 s.

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