Study of drum mixer operation during feed mixture preparation

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Abstract. The purpose of the studies was to check the applicability of the drum mixer for the preparation of concentrated feed mixtures and to identify the dependencies of the change of mixture quality and energy consumption for mixing in the drum mixer with bent flat blades with holes on the following parameters: drum inclination angle, the fraction of control component and mixing cycle. Adequate representative regression nonuniformity models of mixture and energy consumption for mixing are obtained depending on the drum axis inclination angle in the range of 15-35 degrees, mixing time up to 20 min and the fraction of control component from 1 to 20%. Extreme values are not present. The reduction of the drum inclination angle and increase of the mixing time improves the quality of the mixture, as well as significantly increases the energy consumption of mixing. As the fraction of the control component increases from 1% to 10%, the quality of the mixture improves. Further increase in the fraction of the control component has little effect on the quality of the mixture. The variation coefficient of the control component content is reduced to 19% with the fraction of the control component equal 10% or more. As the fraction of the component decreases, the quality of the mixture decreases to 21%. As the quality of the mixture improves, the energy consumption increases. Such drum mixer may be used to prepare pre-mixtures only regardless of the fraction of the control component. In order to prepare high-quality feed mixtures, it is necessary to modernize the blades and their setting parameters.

1. Introduction

It is possible to increase the economic efficiency of livestock production by reducing the cost of purchased technological equipment and costs for its operation, including energy intensity of operations, as well as by improving the quality of fodder prepared for animals, including by using balanced and well-mixed fodder mixtures. If the composition of the feed mixture is determined by animal diets, the costs of feeding are related, inter alia, to the composition and type of applied technical facilities. Modern livestock technologies rely on the use of mixed feed for pigs and poultry, as well as mixed feed-concentrates for cattle. Mixed feed produced at feed milling plants is highly efficient, but small farms
try to save by using cheap forage and purchased premixes or protein-mineral supplements. Under these conditions the preparation of feed mixtures requires the use of mixers [1].

For preparation of mixtures it is possible to use blade [1, 2], screw [3], vibratory [4] and other mixers, including mixers with combined working tools [5] and those performing complex spatial motions [6]. Drum mixers are one of the options with low power consumption [7–9]. They are also used for preparation of feed mixtures [10, 11]. However, the acquisition and operation of original devices is costly, and the use of mass-production items is significantly less expensive. Thus, drum concrete mixers are widespread on the market. They ensure proper quality of construction mixes [12]. At the same time, such mixers may have quite different design of their blades. However, it is not fully known how such mixers will behave in the preparation of feed mixtures, especially with a particular shape of blades. It is known that a more horizontal rotation axis improves the quality of the mixture [13].

The purpose of the studies was to check the applicability of the drum mixer for the preparation of concentrated feed mixtures and to identify the dependencies of the change of mixture quality and energy consumption for mixing in the drum mixer with bent flat blades with holes on the following parameters: drum inclination angle, the fraction of control component and mixing cycle.

2. Methods and materials
The research procedure included the study of the mixer at a fraction of control component equal 1, 10 and 20% by weight. The number of tests to determine the variation coefficient of control component in tests (mixture inhomogeneity) \( \nu \), % – 20 pcs. Barley grains were used as a control component. The weight of the sample made 100 g. The main composition of the mixture included wheat and barley chop (1:1) with the heap density of 610–620 kg/m\(^3\).

The drum installation angle in relation to horizon \( \alpha \) (degrees) was changed through the study: 15, 25 and 35\(^\circ\). The mass \( M \) of the prepared mixture was 40, 70 and 78 kg, respectively. The mixing time of components \( T \) during the experiment was 60, 180, 300, 600, 900 and 1200 sec. The wattmeter measured the power of the drive \( P \), W.
The energy intensity of mixture preparation $Y$ (J/kg) was calculated by the following formula [1]:

$$Y = \frac{P \cdot T}{M}. \tag{1}$$

Considering that with the same duration of mixing $T$ there are different sizes of mixture inhomogeneity $v$, we determined the adjusted size of power consumption $Y_k$ (J/kg) [1]:

$$Y_k = \frac{P \cdot T}{M(1 - 0.01v)}. \tag{2}$$

The results of the studies were processed in Statistica 5.5 to obtain regression equations of the considered indicators from the previously mentioned factors.

3. Experimental part

To describe the mass of the mixture $M$ (kg) in the drum, an expression with correlation $R=0.93386$ is obtained:

$$M = -1800 + 1709.66 \cdot a^{0.028}. \tag{3}$$

For the studied drum installation angles (15, 25 and 35°) the power consumed by the drive made about 480-500; 420-430 and 380-400 W, respectively.

The processing of the obtained data during experimental studies made it possible to obtain the expression of mixture inhomogeneity with correlation coefficient $R=0.91930$, %:

$$v = 13.1 + 0.1566 \cdot e^{(0.241 \cdot D_k^{1.11} + 5.26 \cdot T^{-0.067} + 0.003 \cdot a^{4.764})}. \tag{4}$$

The calculated inhomogeneity values of the mixture correspond well to the experimental values (Figure 3d). As the mixing time increases and the installation angle decreases (Figure 3a, b, c), the quality of the mixture improves – the variation coefficient of the control component content decreases to 19% at the fraction of the control component equal to 10 and 20%. As the fraction of the component decreases, the quality of the mixture decreases to 21%. As the inclination angle of the drum increases, the quality of the mixture begins to decrease sharply to 45%. This is particularly noticeable at the initial period. The difference in the first 5-8 minutes is most noticeable. The reason for this is the accumulation of fodder at the bottom of the inclined drum. The blades do not actively move the material from the bottom. This impairs mixing thus reducing the quality of the mixture.

The energy intensity of the mixture is described by the representative expression (J/kg):

$$Y = -342.2 + 2.541 \cdot e^{(0.018 \cdot D_k^{0.36} + 1.536 \cdot T^{0.186} + 3.426 \cdot a^{-48.8} + 17.5 \cdot M^{-0.49})}. \tag{5}$$

The correlation coefficient $R=0.99909$ and F-test=0.996722 show high adequacy of the obtained model. The design values of energy intensity correspond well to experimental values (Figure 4d). As mixing time increases and installation angle decreases (Figure 4a, b, c), the energy consumption of mixing increases. The fraction of the control component does not affect the energy consumption. As the inclination angle of the drum increases, the energy consumption decreases. This is affected by reduced power consumption when the inclination angle is lifted. The presence of the mixture mass component in the obtained expression of energy consumption compensates the influence of other factors. In the absence of the mass component $M$ of a mixture portion it was not possible to obtain an adequate energy consumption equation.
Figure 2. Results of statistical data processing of mixture inhomogeneity: a, b, c – two-dimensional section of mixture inhomogeneity $v$ (%) depending on mixing duration $T$ (s) and the installation angle $\alpha$ (degree) for a fraction of a control component – 1, 10 and 20%; d – compliance of calculated and experimental data

Figure 3. Results of statistical data processing of mixture inhomogeneity: a, b, c – two-dimensional section of mixture power consumption $Y$ (J/kg) depending on mixing duration $T$ (s) and the installation angle $\alpha$ (degree) for a fraction of a control component – 1, 10 and 20%; d – compliance of calculated and experimental data
In order to take into account the influence of the mixture quality on the energy consumption, the index of adjusted energy consumption (J/kg) is introduced and the corresponding expression is obtained (Figure 5a, b, c):

\[ Y_k = -633.8 + 142.8 \cdot e^{0.128 \cdot D_k^{0.4405} + 0.579 \cdot T^{0.27} + 477.26 \cdot \alpha^{-2.3}}. \] (6)

**Figure 4.** Results of statistical data processing of mixture inhomogeneity: a, b, c – two-dimensional section of adjusted power consumption \( Y_k \) depending on mixing duration \( T \) (s) and the installation angle \( \alpha \) (degree) for a fraction of a control component – 1, 10 and 20%; d – compliance of calculated and experimental data

The correlation coefficient \( R=0.99203 \) and \( F\)-test=0.969947 show good adequacy of the obtained model. The calculated values of adjusted energy intensity correspond well to experimental values (Figure 4d). The trends of adjusted energy intensity and energy intensity coincide. There are minor differences in numerical values only, which are proportional to mixture inhomogeneity (Figures 4a, b, c and 3a, b, c). The weight of the mixture portion is not present in the resulting expression.

4. Conclusion

Adequate representative regression nonuniformity models of mixture and energy consumption for mixing are obtained depending on the drum axis inclination angle in the range of 15-35 degrees, mixing time up to 20 min and the fraction of control component from 1 to 20%. Extreme values are not present. The reduction of the drum inclination angle and increase of the mixing time improves the quality of the mixture, as well as significantly increases the energy consumption of mixing. As the fraction of the control component increases from 1% to 10%, the quality of the mixture improves. Further increase in the fraction of the control component has little effect on the quality of the mixture. The variation coefficient of the control component content is reduced to 19% with the fraction of the control component equal 10% or more. As the fraction of the component decreases, the quality of the mixture decreases to 21%. As the quality of the mixture improves, the energy consumption increases. Such drum mixer may be used to prepare pre-mixtures only regardless of the fraction of the control component.
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