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Auger-in-auger doser with active return channel for compound feed preparation

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ABSTRACT

The relevance of the subject under study is conditioned by numerous technological problems of providing livestock enterprises of the Republic of Kazakhstan with quality equipment for animal feeding and the associated need to develop and implement dosers for the preparation of compound feed mixture. This study introduces an innovative approach through the development and analysis of a novel dosing auger with an active return channel, which distinguishes itself from existing models by enhancing the precision and efficiency of feed preparation processes. The purpose of this study was to investigate the key parameters of the dosing auger with an active return channel for its further use in agricultural enterprises for preparation of compound feed. The findings of this study emphasise the significance of compliance of current trends in the improvement of prepared feed with the established zootechnical requirements from the standpoint of optimising the technological equipment used in this process. The key aspects of feed dosing sequence when using volumetric and mass dosing methods were considered. The main advantages of auger-in-auger dosers that distinguish them from all other types of dosers were described.

KEYWORDS

processes mechanisation, agrarian enterprises, determination of dosage norms, preparation of production, optimal indicators

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INTRODUCTION

As of the beginning of 2024, the share of livestock farms in the total volume of enterprises in the agrarian sector of the Republic of Kazakhstan is 45% (Livestock, 2024). These farms are predominantly dispersed in rural settlements and have the advantage of being able to provide cheap, home-made feed, given the lack of mechanisation and automation (Tesfaye et al., 2024; Mero et al., 2023). Livestock farms in Kazakhstan play a major role in the matters of rural development. Important areas for development are highlighted by a review of trends in machinery, technology, and equipment used in animal husbandry. Two areas of focus include lowering manufacturing costs and raising the quality indicators of technological process performance (Neethirajan, 2023). Therewith, animal feeding is decisive in breeding – maintenance and improvement of existing and creation of new breeds and types of animals; highly productive animal breeds are obtained only in conditions of full nutrition. With poor feeding, animals quickly degenerate and lose their valuable productive and breeding qualities. A substantial issue in this context is the maintenance of feed mix dosage rates on livestock farms. This is largely explained by technological problems associated with the unsatisfactory condition of the equipment. The use of high quality dosers for preparation of feed mixture will allow to maintain its optimal parameters, which will have the best effect on the quality of feeding and will allow maintaining and increasing the number of cattle, and in the long term – achieving better breeding characteristics (Ky et al., 2023; Kirkimbayeva et al., 2015).

Konuspayeva et al. (2023), Lozowicka et al. (2014) and Dean et al. (2024) analysed the impact of the quality of compound feed preparation on the health and general condition of agricultural farm animals in natural conditions of the Republic of Kazakhstan. It is noted that the use of high-quality technological equipment in the preparation of feed for farm animals ensures best quality parameters of the feed mixture, which objectively affects the quality of dairy products in the time following. Therewith, the issues of creating technological conditions for preparation of compound feed mixture of high quality were not covered in the research. Konuspayeva et al. (2011) considered the relationship between the facts of using high quality equipment in the preparation of feed mixtures and the presence of pathogenic bacteria in these mixtures. Mixtures of this kind are used on livestock farms in Northern Kazakhstan. According to the researchers, the use of dosing devices with an active return channel in the preparation of feed mixtures significantly accelerates mixture preparation. At the same time, the issues of technological dependence of the mixture quality on the equipment parameters were not considered. At the same time, Kirimbayeva et al. (2023) considered the problems of intensification of technological processes of preparation of compound feed in the conditions of the epizootic situation in some regions of the Republic of Kazakhstan. It is argued that maintaining the optimum feed mixture conditions is necessary to ensure quality and prompt feeding of animals. Therewith, the relationship between the spread of pathogenic bacteria among domestic animals and the quality of the equipment used has not been addressed in the current epidemiological realities.

Absametov et al. (2023) considered a range of problematic aspects of meeting the needs of agricultural enterprises in Kazakhstan for cheap feed and drinking water. According to scientists, the assessment of the current state of the equipment for preparation of compound feed suggests that it is necessary to make improvements in the quality of technological processes of preparation of dry mixtures. However, the relationship between the quality of mixtures and the supply of drinking water to agricultural enterprises has not been addressed. Kassenbayev et al. (2024) considered a range of problems of development of the agricultural industry of the Republic of Kazakhstan at the current moment. Scientists addressed the fact that the problems of lack of quality equipment for preparation of feed mixtures negatively affect the provision of agricultural enterprises of the country with compound feed in the required volumes. Therewith, the ways to solve the existing problem have not been proposed in the scientific study.

The purpose of this study was to investigate the characteristics of the auger-in-auger metering device, important from the standpoint of prospects for optimising the processes of compound feed preparation in livestock farming.

MATERIALS AND METHODS

Application of the method of analysis helped to establish the essential importance of small-size compound feed units in the processes of making compound feeds for farm animals. This made it possible to assess the key trends in the use of aggregates of this kind, provided that the quality of prepared feed meets the main established zootechnical requirements. Furthermore, the application of this method made it possible to evaluate the sequence of feed mixture preparation using the main methods of feed dosing: volumetric and mass dosing. The parameters of accuracy of dosing accuracy of feed mixture when using dosers of the specified types were also analysed, noting the importance of mixing and dosing operations in preparation of dry feed mixtures.

Application of the synthesis method helped to obtain the block diagram of classification of dosers with auger working bodies and the circuit diagram of auger-in-auger doser with an active return channel. This made it possible to establish the main aspects of application of auger-in-auger dosers and to determine the sequence of operations for preparation of feed mixtures. Furthermore, the principle of operation of this type of dosers was established, which helped to establish the main dependencies between the technological parameters of the device, which are of fundamental importance in the context of the organisation of the preparation of dry feed mixtures for farm animals.

Application of the method of mathematical modelling helped to obtain mathematical expressions showing the dependencies arising between different physical quantities, playing a key role in compound feed preparation involving an auger-in-auger return channel doser. Specifically, the maximum feed parameter of the doser can be calculated using formula (1) as follows:

$$Q = \frac{D_1 \pi \left(D_2^2 - D_1^2\right)}{4}, \tag{1}$$

where: Q – maximum feed parameter of the auger-in-auger doser with active return channel; D_1 – inner diameter of the dosing auger; D_2 – outer diameter of the dosing auger.

To calculate the parameter of feed supply through the discharge window, formula (2) is presented:

$$Q_i = \phi_i F_i p, \tag{2}$$

where: Q_i – feed supply through the discharge window; ϕ_i – speed of flow through the discharge window; F_i – friction force parameter in the auger; p is the dynamic resistance.

For the calculated determination of the feed flow rate through the discharge window, formula (3) is presented as follows:where: Δ – flow coefficient; g is the feed volume passing through the discharge window per unit time; R_i – hydraulic radius of the discharge window.

$$\phi_i = \Delta\sqrt{}3.2gR_i, \tag{3}$$

Transformed, the parameter of feed supply through the discharge window is presented in formula (4) as follows:

$$Q_i = \Delta\frac{\sqrt{3.2g(D_2A_i)}}{2(D_2 + A_i)}\times D_2A_i, \tag{4}$$

where: A_i – correction coefficient, which accommodates losses during feed supply to the discharge window.

The total operating time of the auger-in-auger doser is presented for calculation in formula (5) as follows:

$$q = Q_it, \tag{5}$$

where: q – quantity of feed mixture component to be loaded into the mixer, kg; t – duration of component loading into the mixer, s.

For the calculated determination of the parameter of feed mixture component supply through the return channel with an auger is presented in formula (6) as follows:

$$Q_{bi} = Q_s - Q_i, \tag{6}$$

where: Q_{bi} – feed supply on the return channel with auger, kg/s; Q_s – feed supply on the forward channel with auger, kg.

The feed parameter in the return channel with auger is determined using formula (7) as follows:

$$Q_{bi} = \frac{\pi\left(d_2^2 - d\right)}{4}\times S_h\theta n_{b2}\mathrm{o}_{bi}, \tag{7}$$

where: d_2 – diameter of the return channel; d – auger diameter; S_h – area of the return channel; θ – value of the return auger rotation frequency; n_{b2} – number of augers turns; o_{bi} – value of the loading coefficient of the interturn space of the return auger.

Considering the current changes of the dosing flap position and dosing auger supply, this expression can be transformed into formula (8) as follows:

$$Q_{bi} = \frac{\pi\left(D_2^2 - D\right)}{4}\times S_h\theta n_{b2}\mathrm{o}_{bi}, \tag{8}$$

where: D – inner diameter.

From formula (8), formula (9) is derived to determine the speed value of the return auger:

$$\theta = \left(D_2^2 - D_1^2\right)S\times n\times p\times\phi, \tag{9}$$

where: S – auger cross-sectional area; n – number of augers turns; p – dynamic resistance; ϕ – feed flow rate.

After making the necessary adjustments, formula (9) was converted into formula (10) as follows:

$$N_i = \frac{n_1 \sqrt{DA}}{2(D_2 + A_i)}, \tag{10}$$

where: N_i – filling factor of the return auger; n_1 – rotation speed of the return channel with the return auger.

To determine the parameter of the loading factor of the interturn space of the return auger, formula (11) is presented as follows:

$$\mathrm{O}_{bi} = \frac{(Q_i - Q_h)}{Q_h}, \tag{11}$$

where: Q_h – feed rate of the return auger at fully loaded interturn space, kg/s.

Formula (12) shows the procedure for determining the fill factor of the return auger:

$$\mathrm{O}_{bi} = \frac{\pi \frac{\left(D_2^2 - D\right)}{4} * \frac{S_h \theta n_{b2} \mathrm{O}_{bi} \sqrt{DA}}{2(D_2 + A_i)}}{d_2^2 - d_2^1} S_h n_{h2}. \tag{12}$$

The use of the specified combination of methods helped to obtain graphical dependences of the volume of the dispensed feed mixture on the time of its formation, as well as changes in the non-uniformity of the dispensed feed mixture on the time of its formation.

RESULTS

Small-sized compound feed aggregates ensure production of compound feed from available components according to generally accepted recipes or according to recipes made by farm specialists in small and medium-sized livestock farms. Their widespread use is determined by a fairly quick payback and relatively low cost. The main tendency of improvement of this kind of aggregates is reduction of metal and energy consumption under condition of conformity of quality of prepared feed to the established zootechnical requirements.

For agricultural enterprises of relatively small scale, it is preferable to use the technological scheme of forming preliminary mixtures of raw materials of different types: grain, protein-mineral with additional dosing (Penkova and Kharenko, 2023; Denysiuk et al., 2022). In such a scheme, one or more types of different mixtures are supposed to be formed, and this is determined by the current production needs and the established stages of the work programme. The pre-prepared mixtures are sent to over-dosing hoppers before being fed for additional dosing through the main dosing channel with mixing (Joseph et al., 2019; Tykhonova et al., 2021). Auxiliary dosing greatly complicates the technology and increases the overall cost of operation. However, in this case the accuracy of dosing is considerably increased, which allows for substantially improving the overall quality of the feed mixture obtained.

To enrich the feed mixture, premixes and protein-vitamin supplements are used, including vitamins, antibiotics, a variety of medicines, synthetically produced amino acids, trace elements, and biological stimulants of various types, with up to 50 different components (Abutalip et al., 2024). Some additives are used in feed mixtures in amounts ranging within 0.01–0.001%. Following zootechnical requirements, the maximum heterogeneity of the animal mixture should not exceed 10%. In the technological process of making dry loose feed mixtures, the operation of dosing and mixing is obligatory and special units – doser and mixer – are used for its proper implementation. To ensure the quality of the mixture at minimum specific energy costs, the dosing units provide the required quality of component dosing into the mixing chamber.

In the world practice, two methods of feed dosing are known – volumetric and mass dosing (Sarsembayeva et al., 2018). The dosers involved in this process can be fully functional both in continuous mode and in batch feeding of the prepared feed. Mass dosers are characterised by a high accuracy of mixture dosing, which ranges within 0.1–1%. For mass dosing systems, a common disadvantage is the complexity of the device. They require highly qualified personnel for maintenance, have a low flow rate and high inertia. All this constrains their spread in feed preparation.

Volumetric dosers are simpler, cheaper, and their quality parameters allow them to be used in the preparation of all types of feed (Burova et al., 2022). There are different types of volumetric dosers: fixed-volume measuring containers, chamber-piston, sector, chain-scraping, auger, rotary vane, drum. Measuring containers, chamber piston, and sector dosers can only dispense feed in portions. Chain-scraping dosers contaminate the feed with mechanical impurities when they come into contact with the working elements. Rotary vane dosers can only dispense dry loose feed mixtures. Auger dosers are reliable, simple in design, and versatile (Shahini et al., 2023). They work well when dosing loose feed mixtures. They can function stably in batch and stable mode, horizontal, inclined, and other positions, and are reliable in operation. Auger dosers show high unevenness of dosing (±15%) due to the disturbance of filling of the interturn space of the working body.

The most promising are auger dosers with an active return channel and regulation of the standard dispensing values in the space of the loading window. Their key advantages are simplicity of design, as well as the ability to dose different consistency and composition of feed in batch and continuous modes, to quickly change the feed from the smallest parameter to the largest, while completely eliminating the possibility of pressed feed in the zone of the discharge window, evenly fill the space between the turns of the auger, which contributes to achieving stability in feed distribution. Figure 1 shows a schematic diagram of the classification of dosers with auger operative parts.

A classification scheme for dosers with auger operative sections is shown in Fig. 1, which also lists the various varieties and their corresponding functions. The graphic classifies dosers according to design elements such whether a return channel is present or not, what kind of auger mechanism is being utilized, and if the doser runs in batch or continuous mode. This categorization aids in determining the best kind of doser for particular feed preparation requirements, such as those involving an active return channel, which provide notable benefits for feed efficiency and consistency.

Practical application of this type of dosers assumes the possibility of feed entering from the storage hopper 8 directly into the feeding chamber of the dosing auger 3, through the cut-off

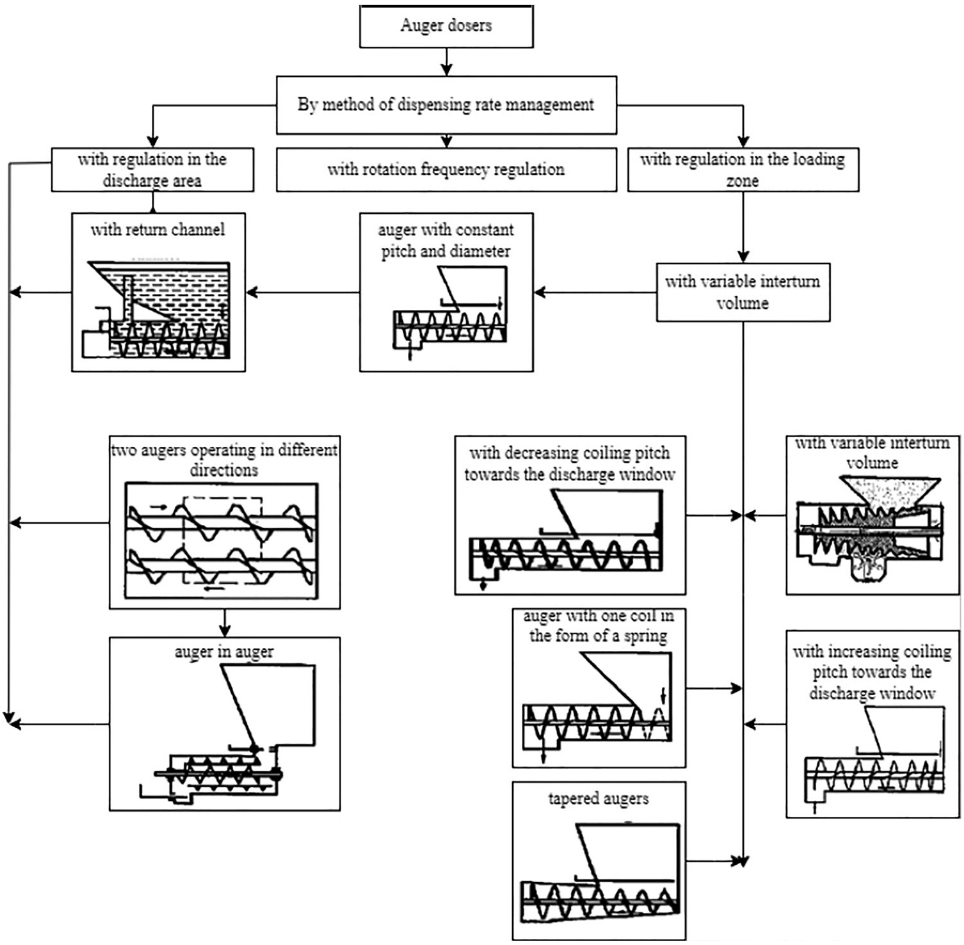

Fig. 1. Classification scheme for dosers with auger operative parts
Source: compiled by the authors of this study.

flap, which is open at the moment. Subsequently, the feed is guided by the dosing auger 3 to the discharge window. A certain amount of feed, which is cut off by the current position of the dosing flap 5, is loaded into the mixer, after which the remaining feed enters the auger 4 of the return channel and is directed into the feed portion of the dosing auger. The use of this working scheme makes it possible to solve the problem of ensuring forced circulation of feed with stable functioning augers and allows filling the space between the auger turns evenly. This completely eliminates pressing, increases the uniformity of feed discharge from the doser, and improves dosing accuracy. A schematic of an auger-in-auger doser with an active return channel is presented in Fig. 2.

A thorough schematic diagram of the auger-in-auger doser with an active return channel is shown in Fig. 2, which also names important parts including the dosing flap, storage hopper,

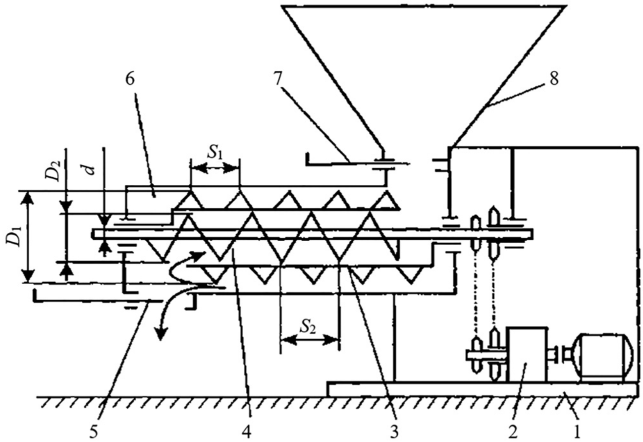

Fig. 2. Schematic diagram of an auger-in-auger doser with active return channel
Note: 1 – frame; 2 – drive of auger working parts; 3 – dosing auger with a return channel; 4 – return channel auger; 5 – dosing flap; 6 – dosing auger housing; 7 – cut-off flap; 8 – storage hopper.
Source: compiled by the authors of this study.

return channel auger, and dosing auger. Every part, including the dosing flap, return channel auger, and dosing auger, has a distinct function during the dosing procedure. The feed processing inside the doser is depicted in the diagram, which guarantees uniform mixing and doses with the least amount of waste and highest level of efficiency. Comprehending this concept is essential to realizing the advantages of the auger-in-auger doser over conventional dosers.

The maximum feed parameter of a screw-in-auger doser with active return channel can be calculated with the feed parameter of the dosing auger with the dosing flap maximally open according to formula (1). Feed supply through the discharge window Q_i is set by the position of the dosing flap from minimum to maximum and is determined according to formula (2). The expression for determining the flow rate through the discharge window accommodates the physical and mechanical properties of the components of the dosed feed and the dimensions of the discharge window determined by the position of the dosing flap and is determined by the formula. After transforming formula (2), formula (4) is obtained for determining the feed parameter of the auger-in-auger doser through the discharge window. In this case, the position of the dosing flap changes from zero to $A_i = S_1$, i.e., $Q_i \leq A_i \leq S_1$.

When the control damper is fully open (Ai = S1), the feed fed by the dosing auger is discharged into the mixer. To maintain uniformity of feed feeding into the mixer, the feed rate of the dosing auger must match the feed rate through the discharge window. When dispensing a feed portion into the mixer, the duration of the doser (5) must be factored in. In case of partial and complete overlapping of the discharge window by the dosing flap, the excess feed supplied by the dosing auger to the discharge window is transported through the return channel with the return auger to the loading part of the dosing auger. Supply of the feed mixture component through the return channel with an auger is determined according to formula (6).

The feed rate in the return channel with return auger can also be determined according to formula (7). Variation of the return auger interturn space fill factor values depends on the amount of feed to be transported from the discharge window to the feed area of the dosing auger. The amount of this feed depends on the position of the dosing flap and the feed of the dosing auger. Then formula (7) can be represented in the form of formula (8). The speed of the return auger from formula (8) is determined after the transformation in the form of formula (9).

Since the return channel where the return auger is placed rotates at speed n_1, the required feed rate of the return auger can be achieved at a lower speed of the return auger. Considering this adjustment, the speed of the return auger is determined according to formula (10). The value of the loading coefficient of the interturn space of the return auger o_{bi} is determined according to formula (11). After transforming formula (11), formula (12) is obtained for determining the filling factor of the return auger. The factors, their variation levels, and evaluation criteria for the auger-in-auger doser are presented in Table 1.

The auger-in-auger doser's variables, levels of variation, and evaluation standards are listed in Table 1. Important factors that directly affect the dispensed dose (q) and the irregularity of auger rotation (vq) are the position of the dosing flap (A) and the frequency of auger rotation (n). The device can administer the highest dose when the dosing flap is fully open and the auger is spinning at its fastest speed, but there is a chance that the irregularity will also rise. When the system needs to quickly provide massive amounts of feed, this scenario comes in handy.

Figure 3 illustrates the dependence of the delivered dose on the time of its formation. The graph shows that as the time of dose formation increases, the amount of feed delivered also increases. At the highest auger rotation speed (3.9 s^{-1}), the system delivers up to 9.5 kg of feed in 10 s, which is ideal for rapid feeding processes. Conversely, at the lowest speed (1.03 s^{-1}), only 0.39 kg is delivered in the same time frame, highlighting the system's ability to adjust to various operational needs.

Figure 4 shows the relationship between the non-uniformity of the dispensed dose and the time of its formation. Increasing the time of dose formation from 2 to 10 s reduces non-uniformity by approximately 33%, ensuring a more consistent feed mixture. This reduction in non-uniformity is crucial for meeting zootechnical requirements, particularly in systems where feed consistency directly impacts livestock health.

At these parameters, the irregularity does not exceed 4.6%; the rate of feed mixture component delivery varies within 0.39–9.53 kg, which is quite consistent with the specified normative values. Analysis of the data presented in Figs 3 and 4 suggests that the most rational parameters of the position of the "auger-in-auger" doser (according to the criteria of quality indicators)

Table 1. Factors, their variation levels, and evaluation criteria for auger-in-auger doser

Parameters	Variation levels of factors	Evaluation criteria
Position of the dosing flap, A, m.	High	Dependencies:
Auger rotation frequency, n, s^{-1}	Medium	Dispensed dose, q, kg.
	Low	Auger rotation irregularity, vq, %

Source: compiled by the authors of this study.

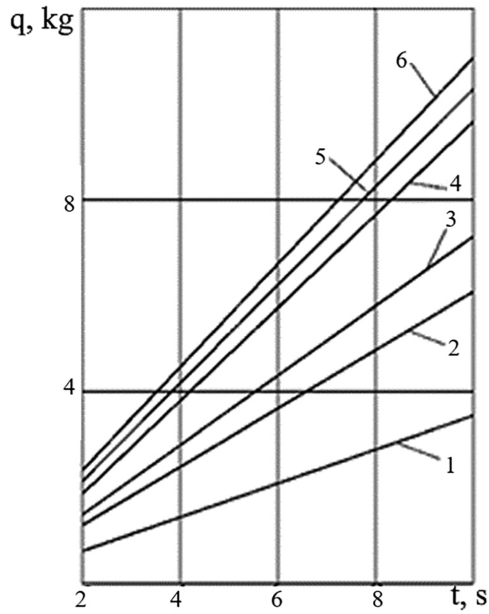

Fig. 3. Dependences of the dose delivered on the time of its formation
Note: q is the dependence of the delivered dose; t is the time of dose formation; 1–6 at $n = 1.03$; 1.87; 2.2; 2.93; 3.9 s^{-1}.
Source: compiled by the authors of this study

should be considered as follows: rotation frequency – the interval within 2.9–3.9 s^{-1}, the time required to prepare a portion of feed – the interval within 2–10 s. Maintaining these parameters during the preparation of feed mixture indicates the achievement of the best conditions for this process necessary for obtaining a high-quality mixture corresponding to the current needs of the agricultural enterprise in animal feed.

Implementing the auger-in-auger doser with an active return channel provides substantial economic benefits for animal farm businesses in Kazakhstan. The advanced technology significantly improves the accuracy of feed dosage, thereby directly decreasing feed wastage and enhancing the quality of animal nutrition. The aforementioned outcomes result in improved livestock health, reduced expenses related to veterinary care, and enhanced productivity in terms of milk and meat production, so leading to increased revenue. Moreover, the doser's energy-efficient design effectively decreases operational costs, while its automation further streamlines labour needs, thereby further reducing expenses.

The initial upfront expenditure in this sophisticated dosing system is promptly balanced by the financial benefits resulting from decreased feed waste, improved energy efficiency, and reduced labour expenses. By virtue of its very short payback period, the technology not only enhances profitability but also fortifies the competitiveness of farms in the market. In summary, the adoption of the auger-in-auger doser is a financially prudent choice that promotes both economic development and sustainable farming methods.

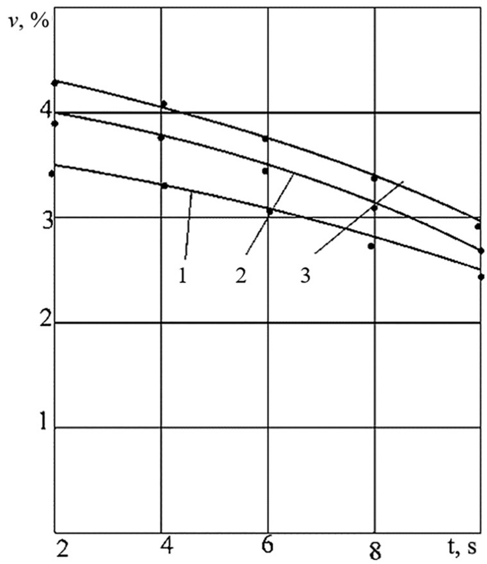

Fig. 4. Dependences of change in the non-uniformity of the dispensed dose of a feed mixture component on the time of its formation

Note: n is 2.93 s^{-1}; 1 is 0.01 m; 2 is 0.014 m; 3 is 0.02 m.

Source: compiled by the authors of this study

DISCUSSION

The findings of this study show the presence of dependence between the parameters of the auger rotation speed and the volume of feed mixture delivery, expressed in the form of mathematical formulas. Furthermore, it was possible to obtain the principal block diagrams of the auger-in-auger doser and the classification of dosers with interchangeable working parts.

De Quelen et al. (2021) and Konovalov et al. (2022) investigated a range of problematic aspects of the preparation of environmentally friendly feed formulations in pig production for their subsequent preparation in the practice of farms. The researchers note that the animal feed formulation process is a critical part of farm animal care. The scientists concluded that using the proper ingredients in the preparation of animal feeds ensures the creation of high-quality feed mixture and favours the consistency of the mixture as it passes through the auger space of the dosing device. These conclusions are fully consistent with the findings obtained in the current study, as they confirm the existence of a pronounced relationship between the parameters of the feed mixture and the technical characteristics of the auger doser.

He et al. (2021) addressed a wide range of issues related to predicting body weight growth of domestic pigs based on their feeding patterns using modern machine learning algorithms. The researchers concluded that the use of different models of feed mix preparation allows for variation in animal feeding strategies, which enables a reduction in labour and monetary costs for feed mix preparation. Furthermore, this improves the overall quality of the feed preparation substantially. The conclusions of the scientists are in line with the results obtained in this study, as they emphasise the significance of preparing high-quality feed when caring for farm animals.

At the same time, Riekert et al. (2020), in their study on the sequence of positioning of a group of domestic pigs during feeding with feed mixtures, note that the use of mixtures of different compositions in feeding domestic pigs has an adverse effect on the condition of the auger doser and can lead to its premature failure and even to its destruction. Such conclusions seem debatable since the findings obtained in the present study do not determine in any form the relationship between the composition of the feed mixture and the prospect of disruption of the auger doser, much less stipulate the prospects of its potential destruction.

Bhoj et al. (2024) investigated the prospects of introducing automation principles in agriculture in the care of domestic animals and specifically in their feeding. It is noted that mechanisation of livestock enterprises is necessary to address food security issues, increase production and proper organisation of labour in agricultural enterprises. The researchers concluded that with proper planning of feed mixture output volumes from the doser, it is possible to achieve an effective solution for supplying agricultural livestock enterprises with feed mixtures in the required quantities and at clearly defined time intervals. Such conclusions coincide with the findings of the present study, as they demonstrate a pronounced dependence between the planning of volumes of prepared feed mixtures and the workload of production equipment of an agricultural enterprise.

The topic of organising proper care for farm animals has been raised by Gross et al. (2023) in the study on the impact of antibiotic use in the feed of domestic pigs. According to the researchers, there is a need to monitor the use of antibiotics in feed in pet care, as excessive use of antibiotics causes substantial harm to health. It is concluded that, generally, the composition of the mixture does not substantially affect the change in the dynamic characteristics of the equipment designed for the preparation of compound feed for domestic animals. Such conclusions appear controversial since the mathematical dependencies obtained in this study indicate the opposite.

Trillo et al. (2017) discussed an analogous topic in their study. Scientists addressed the fact that when preparing feed mixtures, as well as during their subsequent pass through the auger space of the dosing device, the time of preparation of the mixture and its final composition must be considered. According to the researchers, there is a clear, expressed relationship between the nature of feed mixture preparation and its supply when feeding domestic animals, as individual parameters of the mixture can influence the change of dynamic characteristics of the dosing device during its operation. The conclusions of the researchers correspond to the findings obtained in this study, since the change in the parameters of the feed mixture inevitably affects the nature of its feeding through the auger space of the dosing device, which affects the efficiency of the animal feeding process.

Turiello et al. (2018) raises a wide range of problematic issues on the use of auxiliary ingredients in the preparation of animal feeds for small farm animals. It is noted that the comparison and processing of different information regarding different feed rations is necessary to develop relevant feeding strategies for farm animals, considering the technological parameters of the equipment used for the preparation and feeding of the feed mixture. It is concluded that the use of higher quality mixtures does not cause difficulties in feeding them through the auger space of the doser, while the dynamic characteristics of the doser itself do not change with the return run. These conclusions are fully consistent with the findings of the present study, as they emphasise the relationship between the high quality of the feed mixture and the nature of its delivery through a doser with an active return channel.

Peeler et al. (2023), Nasirian (2023) considered a range of issues in the preparation of feed for farm animals in the context of finding the best way to prevent the spread of disease among them. Therewith, scientists note that the creation of the best model of agricultural feed preparation implies the need to consider the dynamic characteristics of dosing devices for feed supply, because it depends on the speed of preparation of feed and the speed of its supply. The opinion of the researchers is fully consistent with the results obtained in this study, since it is confirmed by the data of the study of mathematical dependencies between the various parameters of the auger-in-auger doser with an active return channel.

Singh et al. (2024) reviewed problematic aspects of the importance of dairy farm infrastructure and operation, including feed preparation and feeding equipment, in the spread of infectious diseases among domestic animals. The scientists concluded that the use of substandard equipment in the preparation of agricultural feed can lead to irregularities in the preparation of feed mixtures, resulting in feed quality problems and potentially causing disease among the farm's domestic animals. The scientists' conclusions are not directly supported by the findings of the present study and require further practical verification.

The auger-in-auger doser with an active return channel presents technological advancements that may help animal husbandry in different areas with comparable issues, such feed efficiency and quality. This doser could ensure feed preparation consistency and lower costs in resource-poor or arid locations, such as sections of Africa, Eastern Europe, and Central Asia. By lowering energy usage and increasing feed accuracy, the device could improve sustainability and efficiency in more mechanized farming systems, like those in Western Europe or North America. The doser's versatility allows it to be used in both large-scale industrial operations and small-scale farms, making it a useful tool for raising livestock productivity and health across the globe. Through investigating its use in various farming scenarios, this research adds to international initiatives to improve feed preparation procedures, thereby promoting more environmentally friendly farming methods (Grosu and Caisîn, 2020).

Practical situations may provide difficulties for the auger-in-auger doser with an active return channel, including initial expense, integration with current automated systems, and a learning curve for farm personnel not familiar with the advanced features. A phased implementation approach, beginning with larger farms and progressively modified for smaller operations, could be used to alleviate problems. It might be possible to create modular parts that can be retrofitted into current systems, negating the need for a total redesign. To make the most of the doser's capabilities, operators might benefit from training programs and user manuals. By taking proactive measures to solve these issues, livestock farming can become more productive and efficient.

Because of its accurate feed dosage management and reliable feed quality, the auger-in-auger doser with an active return channel is perfect for automated feeding systems in contemporary agriculture. It is simple to include into automated feeding lines, enabling modifications in real time according to sensor inputs. The doser's enhanced interoperability with current systems arises from its flexibility to adjust to both continuous and batch feeding modes. Through integration, feed efficiency may be maximized, labor expenses can be decreased, and livestock output and health can be increased. Subsequent investigations may include complementary automation technologies such as intelligent sensors and AI-powered feed management platforms (Kassenbayev et al., 2024).

Thus, the discussion of the findings obtained in this study, in the context of their comparison with the results and conclusions of other researchers working in adjacent thematic areas, suggest their fundamental correspondence in a range of key parameters of scientific research.

CONCLUSIONS

Using an active return channel, the auger-in-auger dosing device's primary parameters were examined in this study in an effort to streamline the complex feed preparation procedures used in livestock farming. The main objective was achieved, and the results verify that the doser design greatly improves feed preparation precision. This study directly tackles the goal of enhancing the quality indicators of feed mixture preparation by determining the ideal values for the auger's rotating speed and the dosing flap's position. The findings showed that keeping the dosing flap position between 0.01 and 0.02 m and the rotational speed between 2.9 and 3.9 s^{-1} guarantees that there is as little non-uniformity in the feed mixture as possible, which is in line with the study's objective of attaining compliance with zootechnical requirements.

Additionally, the study's goal of highlighting the benefits of the auger-in-auger doser was effectively accomplished. Of particular note were the device's versatility and capacity to maintain feed mixture uniformity under a variety of feeding conditions. These findings highlight the doser's potential for wider use in automated feeding systems and emphasize how crucial it is to ensuring farm animals are fed effectively, which was the main goal of this study. In order to further contribute to the study's long-term goal of improving livestock feeding efficiency, future research should build on these findings by investigating the integration of this doser design with contemporary automated feeding systems.

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