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Development Of A Techno-Technical Animal Feeding System Adapted To The Conditions Of Farms.

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ABSTRACT

This article presents the results of the analysis of the existing technology-technical system of mechanized feeding of animals and poultry in the conditions of farms and defines the requirements for its effective functioning. In accordance with the accepted requirements, a system of machines has been developed in the form of interconnected by purpose, operating conditions, parameters and modes of operation of block-modular subsystems.
Keywords: farm, household, system, energy intensity, metal consumption, model, unit, block-modular subsystem.

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INTRODUCTION

It is known that at present in the Russian Federation the share of manual labor on small farms is 60% and higher. At the same time, the machines and equipment used are energy-intensive and metal-consuming due to their lack of adaptation to the conditions of operation of farms producing milk, cattle meat, pork, rabbit meat, and also poultry, including waterfowl.

This is due to the fact that in Russia, up to now, machines and equipment that are adapted to the conditions of livestock and poultry production in small volumes have not been developed and are not created in the engineering industry. [1, 2]

Objective: to increase the efficiency of the functioning of the process of mechanized feeding of animals and poultry by creating a block-modular technological-technical system adapted to the conditions of peasant farms.

Research tasks:

- determine the requirements for the created techno-technical system (TTS) of mechanized animal feeding (MAF) on small-size farms (SSF);
- to develop an economic-mathematical model (EMM) for evaluating the functioning adapted to SSF TTS MAF conditions;
- to offer options for the use of the proposed machines, adapted to the conditions of operation of TTS on small-sized farms.

By system analysis of the existing TTS of mechanized feeding of animals and poultry on small-sized farms, the requirements for ensuring its effective functioning were determined:

- TTS should include machinery and equipment combining from three to five operations for the preparation, preparation and distribution of feed of the appropriate type;
- machines and equipment should be small-sized and convenient to operate, having the necessary performance with low indicators of energy intensity and metal intensity;
- quality of the work of these machines and equipment according to the relevant indicators (degree of grinding, homogeneity of mixing, strength of the obtained granules, degree of homogenization, content of unstable substances, etc.) must meet the requirements of zootechnical requirements.

MATERIALS AND METHODS

As the analysis showed, TTS, which contains technical means in their block-modular design, can fully meet these requirements, with the possibility of their operation both in standalone mode and according to the system of machines linked in a line (Figure 1).

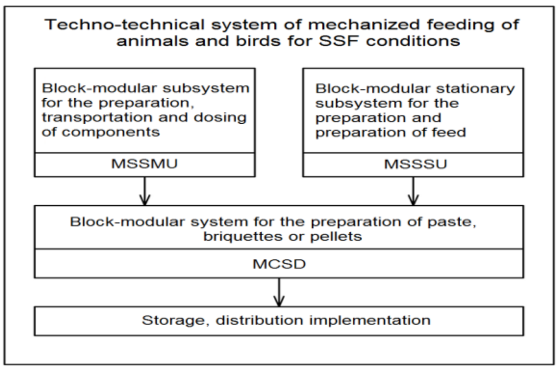


Figure 1: TTS block diagram of mechanized feeding of animals adapted to the conditions of farms

MSSMU - a multifunctional small-sized mobile unit in the form of a self-loading transporting and metering machine (feed mixture);

MSSSU - multifunctional small-sized stationary unit (dairy feed substitute - DFS);

MCSD is a multifunctional compact stationary device in the form of a homogenizer press (pasta, briquettes, granules).

Figure 2 shows the structural-functional schemes of the machines in the form of block modules that ensure the execution of processes both in standalone mode and as part of the system.

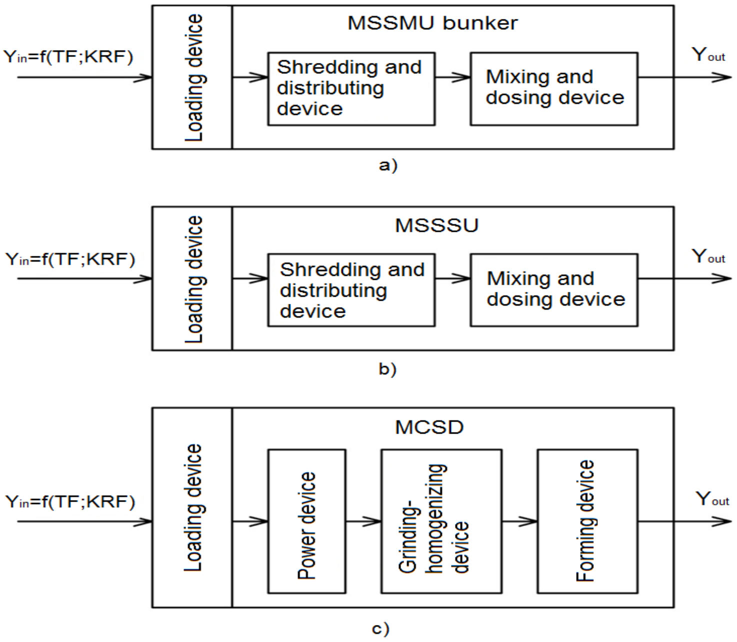


Figure 2: Structural and functional schemes of the developed machines in the form of block modules.

To assess the technology-technical system, which includes three block-module subsystems (Figure 2 a, b, c), the following EMM is proposed:

$$\left.\begin{aligned} Z &= \sum_{i=1}^{u}(Z_i) \to min; \\ C_I &= C_1 + C_2 + C_3 \to max; \\ E_{II} &= D_{conIII} \cdot k' \cdot Q_{II} \cdot t_i \cdot d \cdot n \to max; \\ E_{III} &= D_{conIII} \cdot k' \cdot Q_{III} \cdot t_i \cdot d \cdot n \to max \end{aligned}\right\} (1)$$

where Z – costs for three basic subsystems;

Z_i – operating costs;
u –number of processes and operations performed by one machine;
C_1, C_2 – cost of additional products from better quality mixing and dosing processes;
C_3 – energy savings by reducing energy intensity;
E_{II}, E_{III} – economic effects obtained by the consumer from the adequate replacement of traditional products with innovative ones (feed mixture, DFS, pasta, briquettes and granules);
D_{conII}, D_{conIII} – consumer income from adequate replacement of feed products for the second and third block-modular subsystems;
k – tax rate;
Q_{II}, Q_{III}– performance modular subsystems;
t_i – module operation time;
d – number of days of work of modules per year;
n – feeding multiplicity.

RESULTS AND DISCUSSION

The analysis of production technological lines for the preparation and distribution of stalk and succulent fodder on cattle farms, from the point of view of the presence of functionally necessary structural elements, as well as the design features of the technical means used, showed that they are metal-intensive and energy-intensive. At the same time, the most effective from the point of view of reducing these indicators, especially for conditions of small farms, is the use of multifunctional units, combining in themselves two or more operations of the technological process.

These machines, combining at least three operations (delivery of feed, mixing and distribution), can reduce the cost of labor and resources and, thereby, reduce the cost of production.

A preliminary analysis also found that machines are used abroad that, to varying degrees, make it possible to combine up to five operations, such as loading, grinding, delivery, mixing and distribution. It is quite obvious that in terms of cost reduction - W, these technical solutions are the most effective.

$$Z = \sum_{j=1}^{n}(Z_j) \rightarrow min\ , \qquad (2)$$

where n – number of operations;

Z_j– operating costs for the relevant operations performed by the self-loading MSSMU (self-loading transporting and metering machine) (Figure 2 a).

On the other hand, it has been established that these technical means are not highly reliable in performing technological operations and, in particular, in terms of the quality of work. Moreover, they must be universal, in terms of processed feed.

For this type of hardware, the following indicators for evaluating their performance have been adopted:

Firstly, uneven or inaccurate dosing of feed - δ_r,% to animal feed troughs or feeds to feed preparation machines (granulators, etc.) is essentially a coefficient of variation

$$\delta_r = f(TF; KRF) \geq [\delta_r]\ , \qquad (3)$$

where TF – combination of technological factors;
KRF – set of design-mode factors.

Secondly, the homogeneity of mixing of feed components - θ,% which also depends on the combination of technological - TF and design-regime factors - KRF

$$\theta = f(TF; KRF) \geq [\theta]\ , \qquad (4)$$

where $[\theta]$ – permissible according to technological requirements homogeneity of the mixture.

Thirdly - the degree of grinding - λ of feed products, as well as the heterogeneity of the particle size distribution of the crushed products - ν.

The values of both indicators also depend on a set of technological and design-mode parameters:

$$\left.\begin{array}{l} E_n = f(\lambda; Q_u) \rightarrow min; \\ \lambda = f(TF; KRF) \rightarrow opt; \\ Q_s = f(TF; KRF) \rightarrow opt \end{array}\right\}, \qquad (5)$$

where Q_s – shredding capacity.

At the same time, the analysis revealed that in order to fully and objectively evaluate the operation of the machines, it is necessary to take into account the so-called effect of obtaining additional products. According to the direction of research we have adopted, this effect is the effect of increasing the homogeneity of the mixture and the uniformity of its distribution.

The cost of additional products, expressed in terms of these indicators of quality of work, is determined by the following expressions:

- for the process of obtaining straw-pumpkin mixture:

$$C_1 = R_1 \cdot \theta \cdot U_1 \rightarrow max \ ;(6)$$

- for the process of its distribution to animals:

$$C_2 = R_2 \cdot \delta_r \cdot U_2 \rightarrow max \ ;(7)$$

where R_1, R_2 –coefficient taking into account the increase in productivity and unproductive feed consumption by 1% of the quality indicator, respectively, for the mixing process and the process of distribution of the resulting straw-pumpkin mixture;

U_1, U_2 – indicators of the conversion of the nutritional value of feeds and their quantity into products according to the corresponding processes.

For these processes, you can write that

$$\left.\begin{aligned} U_1 = q_1 \cdot N_f \cdot D \cdot C_r \cdot E'_{к}/E_p \\ U_2 = q_2 \cdot N_f \cdot D \cdot C_r \cdot E''_{к}/E_p \end{aligned}\right\}, \qquad (8)$$

where q_1, q_2 – nutritional value of the daily ration per animal in feed units, equal to

$$q = \sum_{i=1}^{n} a_i \cdot m_i / \sum_{i=1}^{n} a_i \ , \qquad (9)$$

where a_i –amount of the i-th component in the mixture; m_i – nutritional value of the i-th component in the mixture; N_f –number of heads of animals on the farm; D –duration of the stall period; C_r – sales price of products; $E_к$ – energy value of feed unit, MJ; E_p – energy costs per unit of production, MJ.

At the same time, the effect of reducing energy costs - ΔE_N on the processes of grinding and distribution of feed components can be represented as a condition

$$\Delta E_N = \frac{N_b}{Q_b \cdot \lambda_b} - \frac{N_{per}}{Q_{per} \cdot \lambda_{per}} > 1 \qquad (10)$$

where N_b, N_{per} – respectively, the cost of energy for the basic and proposed options;
Q_b, Q_{per} – performance on the base and proposed options;
λ_b, λ_{per} –degree of grinding on the base and the proposed options.

In the transition to cost performance indicators, we have

$$C_z = (E_b \cdot Q_b \cdot \lambda_b \cdot t_b - Э_{per} \cdot Q_{per} \cdot t_{per} \cdot \lambda_{per}) \cdot C_e, \qquad (11)$$

where C_e – energy unit cost (kW * h);
t_b, t_{per} – work time for the base and proposed options.

This expression can be represented as

$$C_z = \Delta N_e \cdot t_{year} \cdot C_e, \qquad (12)$$

where ΔN_e – the difference in energy costs between the basic and the proposed options.

Then, in general, the economic-mathematical model for evaluating the efficiency of the line for preparing and distributing feeds to animals can be represented as:

$$\left.\begin{aligned} Z = \textstyle\sum_{j=1}^{n}(Z_j) \rightarrow min; \\ at\ C_1 = R_1 \cdot \theta \cdot U_1 \rightarrow max; \\ C_2 = R_2 \cdot \delta_r \cdot U_2 \rightarrow max; \\ C_z = \Delta N_e \cdot t_{year} \cdot C_e \rightarrow max \end{aligned}\right\}, \qquad (13)$$

where C_1 –cost of additional products from better quality of the process of mixing feed components (increasing the productivity of animals);

C_2 –cost of additional products from a better implementation of the distribution process (reduction of unproductive feed consumption);

C_3 – energy savings in monetary terms, obtained by reducing the energy intensity of the processes.

Based on the analysis carried out, a structural diagram (Figure 3) of a multifunctional small-sized mobile unit (MSSMU) has been developed, and performing the following operations:

- loading of feed and feed components into the MSSMU bunker;
- grinding with the simultaneous distribution of feed or feed components in the MSSMU bunker;
- transportation to the destination and back;
- mixing layers of food components arranged in the MSSMU bunker during the distribution of the mixture;
- dosed supply of feed products to feed machines (granulators and briquetting machines).

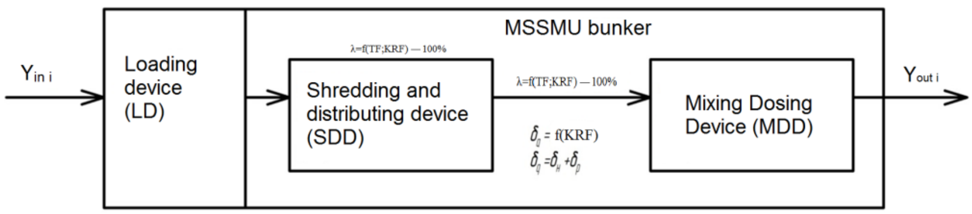


Figure 3: Block diagram of a multifunctional mobile small-sized unit for the preparation of straw-pumpkin feed mixtures

$Y_{in.i}$, $Y_{out.i}$ – input and output parameters; TF – technological factors; KRF – constructive-mode factors; δ_q – uneven distribution of mass along the length of the feed monolith; δ_n – uneven mass distribution over the height of the feed monolith; δ_r - uneven distribution of mass in density of the feed monolith.

For the adopted MSSMU scheme, in general, the functional dependences of the above indicators of the quality of the corresponding mixing and dispensing processes can be represented as

$$\left.\begin{aligned} \theta = f(H_l; \lambda; \beta; \ldots) \rightarrow max; \\ \delta_r = f(H_l; \lambda; \beta; \ldots) \rightarrow min \end{aligned}\right\} \qquad (14)$$

where H_l – layer height in the MSSMU bunker;

λ - degree of grinding of the feed product;

β - lattice angle.

Thus, as a result of the theoretical analysis, an economic-mathematical model for evaluating the process of cooking and dispensing straw-pumpkin mixture was obtained, and the MSSMU block diagram developed on its basis, and also a set of main factors affecting the efficiency of the cooking cattle farms.

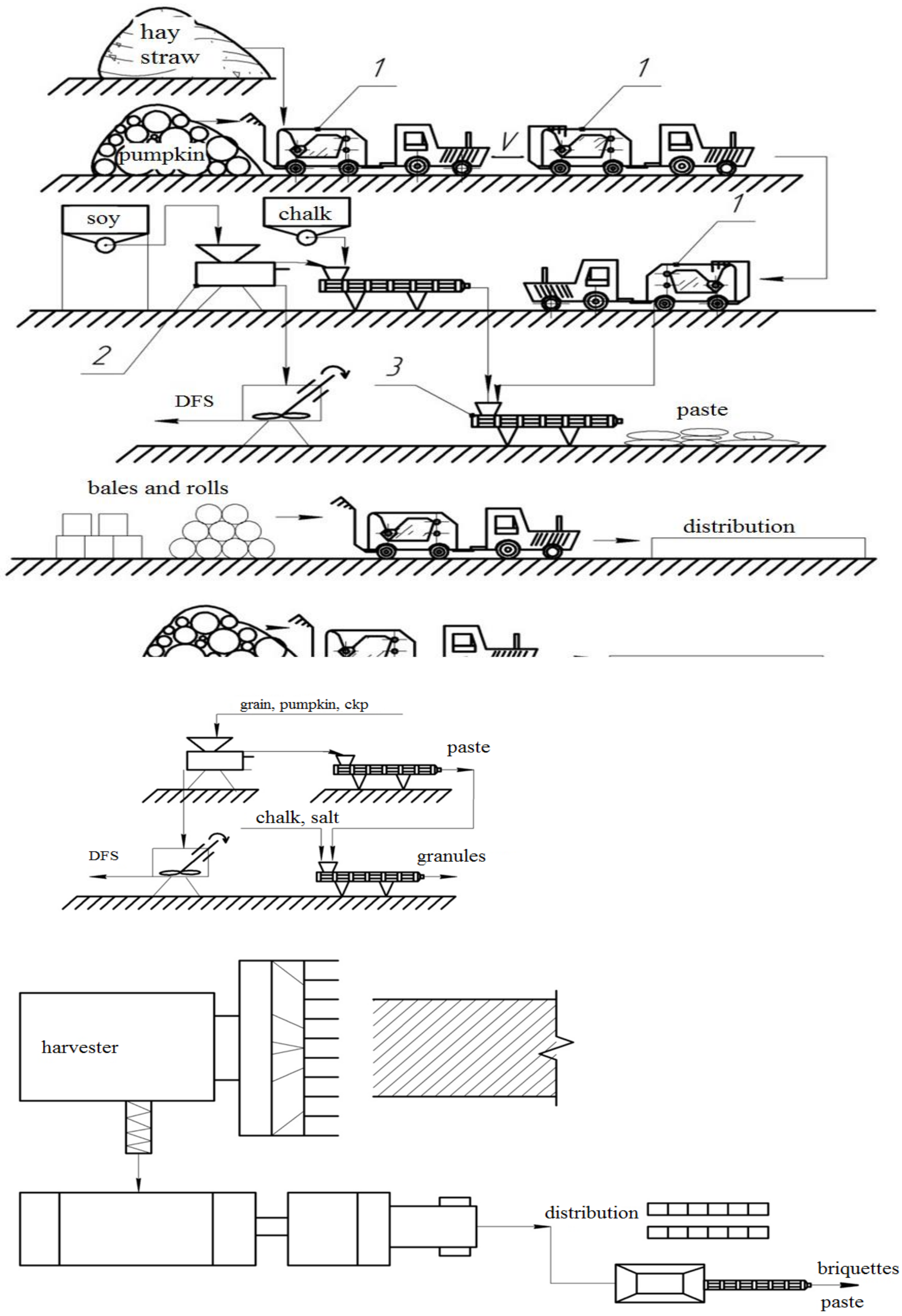
Consumer income for the second and third block-modular subsystems (BMS) from adequate replacement of feed products:

- DFS, paste: $D_{perII} = \sum_{i=1}^{m} C_{TpII}^{ration} - C_{uнII}^{ration} \rightarrow max$;
- paste, briquettes, granules: $D_{perIII} = \sum_{i=1}^{m} C_{TpIII}^{ration} - C_{uнIII}^{ration} \rightarrow max$;

where C_{TpII}^{ration}, C_{TpIII}^{ration} – cost of replaceable feed products according to traditional technology for the second and third BMS;

$C_{uнII}^{ration}$, $C_{uнIII}^{ration}$ – cost of replaceable feed products using innovative technologies for the second and third BMS.

Options for the use of block-modular hardware adapted to the operating conditions of the TTS on SSF



1 – Block module in the form of MSSMU;
2 – Block module in the form of MSSSU;
3 – Block module in the form of MCSD.

Figure 4: Flow diagrams of cooking lines, distribution of feed, and the introduction of litter material.

CONCLUSION

Basic requirements have been developed for a set of TTS animal and poultry feeding machines for SSF conditions, on the basis of which a set of technical tools has been developed that are interconnected by purpose, operating conditions, economic and zootechnical indicators, as well as technical parameters of block-modular design adapted to the SSF functioning system proposed schemes for their implementation.

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