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The Evaluation of Efficiency of Using Technologies for Preparation and Distribution of Fodder at Small Farms.

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ABSTRACT

The economical and mathematical model of evaluation of the process of preparation and distribution of fodder by means of dispenser and mixer of fodder with screw conveyer work member is presented in this article. The structural and technological scheme, which determines the influence of external in internal factors and hierarchy of factors pointed by the realization of the operating process.

Keywords: economical and mathematical model, the preparation and distribution of fodder

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INTRODUCTION

There is a problem of supplying people with qualitative livestock production. Although, small farms and personal subsidiary plots in our country produce about 57% of the whole gross output of agriculture, including dairy products more than 50%, meat – 55%. Just taking into account official figures, in Krasnodar region (except subjects of small entrepreneurship), during the last year, livestock production is in decline. Therewith, people's needs in livestock production grows stable as well in different areas, as in the whole country [4, 6].

One of ways of raising livestock production in current market conditions is raising of animals' productivity at the cost of rational using of fodder in prepared type and in mixture with another components with the high quality of preparation [5].

Also, there is a low rate of mechanization. So, if the comprehensive mechanization at dairy farms in the whole country takes 80%, small farms take only 18%. So, the problem of mechanization of technological processes of preparation and distribution of fodder at small farms is quite daunting.

Analysis of existent preparing and distributing technique shows, that serially produced machines are metal-consuming, power-intensive and are used with low efficiency because of deficiency in management, technical and technological fields, what is quite unacceptable in conditions of farms and small farms. As a consequence, growing of the level of mechanization of feeding at small farms is an actual scientific and technical problem, the solvation of which has a great scientific and practice meaning [9].

In this connection, taking into account the features of management practice and inquires of production, it is needed to supply farmers with high effective decisions at the cost of designing alternative technologies and developing new small multifunctional hardware for the preparation and distribution of fodder.

MATERIALS AND METHODS

The analysis of processing line of preparation and distribution of mixtures at livestock farms shows, that this technology can be realized by the range of technical decisions for small livestock farms (patent № 67815, № 2331191) (figure 1), which were founded as a working process of mixing with cutting of fodder components loaded layer by layer at the same time. At the expense of integration of such technological operations as loading of components layer by layer, transportation them to the place of distribution, dosage with cutting and mixing and distribution at the same time, the reducing of energy-intensity and shrinking of cycle time for the preparation and distribution of fodder is possible and can be presented with the formula:

$$t_{ц} = t_{п} + t_{тр} + t_{изм+см+в}, \tag{1}$$

where $t_{п}$ – time for loading of the components layer by layer, second; $t_{тр}$ –time for transportation, second; $t_{изм+см+в}$ – time for dosage of the material with cutting and distribution of the fodder prepared at the same time, second.

In order to raise the operational effectiveness of using of distributor-mixer of fodder we suggest to use replaceable working members (screw, with beater, transport), which allow to distribute different by physical-mechanical properties fodder dosated with the least power inputs and use the whole net volume of a bunker if it is necessary.

The efficiency of distributor-mixer of fodder by cutting and mixing at the same time is substantiated by the formula:

$$Q = Q_{изм} + Q_{см}, \tag{2}$$

where $Q_{изм}$ – efficiency of cutting segments, kg/s; $Q_{см}$ – efficiency of winding of screw conveyer, kg/s.

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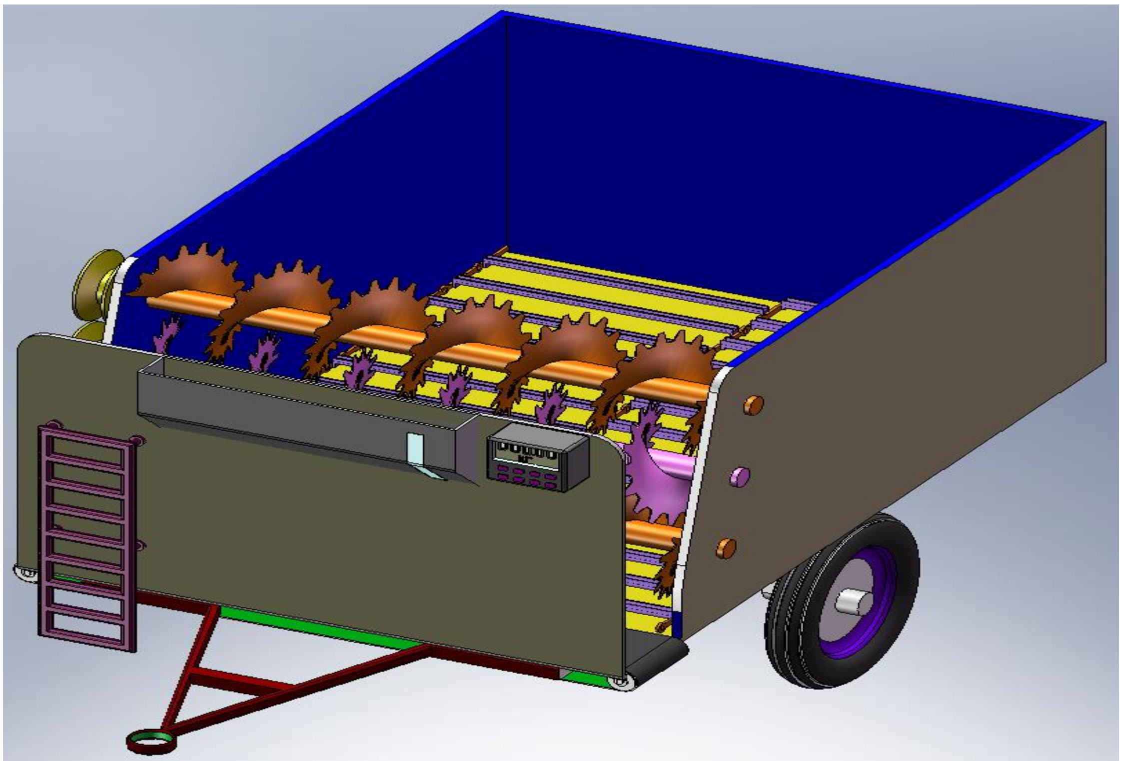

Figure 1: Distributor-mixer of fodder

The formula of determination of efficiency of the screw conveyer winding:

$$Q_{см} = 2\frac{2}{3}\pi^3 r_{ср}^3 \omega \sin\alpha(\cos\alpha - f\sin\alpha)\rho\, k_з k_{пр}, \qquad (3)$$

where $r_{ср}$ – screw conveyer average radius, m; ω – angular velocity of the screw conveyer, second^{-1}; α – the angle of helix; ρ – density of the material, kg/m^3; $k_з$ – coefficient of filling of screw conveyer; $k_{пр}$ – slipping motion coefficient;

Efficiency of cutting segments is substantiated by formula:

$$Q_{изм} = \pi\, l_п^{\,2} S\, Z_1 \omega \frac{\varphi_1}{360^0}\rho\; k_з k_{пр}, \qquad (4)$$

where $l_п$ – outlet of cutting segment, m; S – helix lead, m; Z_1 – amount of segments at one wind of the screw conveyer, ones; ϕ_1 – the angle, which limits the sector of working zone of interaction of segments and material.

Formulas (3) and (4) allow to calculate the main constructive parameters of active part of cutting and mixing working member of screw conveyer.

The theoretical analysis of the process of simultaneous distribution and mixing of fodder with screw conveyer allowed to get the formula for determination of power density:

$$N = N_{изм} + N_{см}, \qquad (5)$$

where $N_{изм}$ – power for cutting of fodder, kilowatt; $N_{см}$ – power for mixing of components of fodder, kilowatt.

The substantiation of the energy intensity of the process of cutting of feed.

The power consumption for cutting is determined by the formula offered by I.A. Ulanov:

$$N_{изм} = q\frac{dF}{dt}\left(1 + f\,'\,\mathrm{tg}\tau\right), \qquad (6)$$

where q – the specific linear pressure of the blade to feed, H/m;

$\frac{dF}{dt}$ – the square of the cut in unit time, m^2/s;

f ' – the coefficient of sliding cutting;

τ – the angle between the direction of the movement of the blade and the normal line of the cutting edge of the blade, grad.

The share of power inputs of distributor-mixer on the winding of the screw conveyer is determined with the formula:

$$N_{см} = 0{,}03L\pi^3 r_{ср}^3 \omega \sin\alpha\,(\cos\alpha - f\,\sin\alpha)\,\rho\,k_з k_{пр} k_{сопр}, \qquad (7)$$

where L – the length of mixing working member of screw conveyer, m; $k_{сопр}$ – the coefficient of restriction for movement of fodder.

RESULTS AND DISCUSSION

The solution of the problem how to raise efficiency of work of process lines and hardware for preparation and distribution of fodder can be reduced to minimization of material and labour expenses and presented as a economic and mathematical model as a set of successive working operations, which transform row material into finished feedstuff by the determination of certain limits on quality criterions of carrying out the appropriate operations [1]:

$$\left.\begin{array}{c} ПЗ_i = \left(И_i + EK_i\right)Q_i \cdot t_i \cdot d \to min \\ Y_i = 0{,}01\cdot\left(1-\Theta_{см}\right)\left(Q_i\cdot t_i\cdot\right)Ц_i \cdot d \to min \\ Q_i t_i \geq G_{ni} \quad при \quad t_i \leq \left[t_i\right] \\ \gamma_i = \Theta_i^{комп} + \Theta_{см} + \Theta_i^{поед} \to max \\ 0 \leq \gamma_i \leq \left[\gamma_i\right], \;\; Э_i \leq Э_н \end{array}\right\}, \qquad (8)$$

where $ПЗ_i$, $И_i$, K_i – accordingly, reduced, specific operating costs and specific capital investment by carrying out of technological process of distribution of fodder mixture, rub./kg; E – normative coefficient of efficiency; Q_i – hourly efficiency of the processing line by i-kind of component of fodder mixture kg/h; $[t_i]$, t_i – accordingly time allowed by zoo technical requirements and time for the preparation and distribution to animals of i component of fodder mixture, h; d – quantity of workdays per year ; Y_i – losses, rub; $(1–\Theta_{см})$ – heterogeneity of fodder mixture; $Ц_i$ – price of 1 kg of i component of fodder mixture; G_{ni} – quantity of i-production produced, kg; γ_i – qualitative factors of the process; $\Theta_i^{комп}, \Theta_{см}, \Theta_i^{поед}$ – accordingly quality of raw components, homogeneity of mixture prepared and eating of i component of the mixture; Эi, $Э_н$ – accordingly power inputs and nominal power inputs by producing of I-production, MJ.

According to model (8), concerning the processes of preparation and distribution of fodder mixture, it is needed, that time for preparation and distribution of fodder is in accordance with zoo technical time, energy datum does not exceed nominal power inputs and qualitative index correspond to acceptable [3, 7, 8].

$$t_p \le z_p t_ц \le [t], \qquad (9)$$

where t_p – distribution time, c; z_P – quantity of runs of distributor; $t_ц$ – cycle time for preparation and distribution of fodder, s; [t] – time for distribution allowed by zoo technical requirements, s:

$$z_p = \frac{N \cdot g_{раз}}{G_{корм}}, \qquad (10)$$

where **N** – population of livestock; $g_{раз}$ – allocation of fodder per one animal, kg; $G_{корм}$ – mass of the fodder in bunker.

The main working factor of processing line is quality of mixture prepared, which is determined as a sum of identity of mixture components which is given along the whole processing line

$$\Theta_{см} = \Theta_{см}^{загр}(t_i) + \Theta_{см}^{тр}(t_i) + \Theta_{см}^{подач}(t_i) + \Theta_{см}^{изм+см}(t_i) + \Theta_{см}^{выгр}(t_i) \to max \qquad (11)$$

where $\Theta_{см}^{загр}$, $\Theta_{см}^{тр}$, $\Theta_{см}^{подач}$, $\Theta_{см}^{изм+см}$, $\Theta_{см}^{выгр}$ – accordingly, identity of particulate mixing of components of fodder mixture in contiguous layers by transportation to the place of distribution in a bunker by the moving of material to active work member by separating, crushing, mixing and distribution on the cross transfer (unloading conveyer), during the moving of the mass along the cross transfer (unloading conveyer).

To substantiate parameters of processing lines and hardware, the formula for the determination of reduced expenses should be given in following view:

$$\frac{(И_i + E_н K_i) \cdot Q_i[t_i]}{Nq_i} \to min, \qquad (12)$$

where $[t_i]$ – the work time allowed by zoo technical requirements for i-line (hardware), is 1,5-2 hours; N – quantity of animals; q_i – quantity of i-kind of fodder, which is for a single animal.

The product of $Q_i[t_i]$ in the formula defines the quantity of prepared or distributed fodder G_m, with a glance of reliability of functioning of hardware.

Subject to certain allowances it can be written:

$$Q_i[t_i] = G_{ni} = Nq_i, \qquad (13)$$

The second equality sign in formula (13) was given conditionally, because the preparation of fodder allows to raise their nutritive value [2, 5, 9].

The productivity of system Q_c subject to the time allowance for preparation (distribution) of fodder can be determined from the formula

$$Q_c = \frac{Nq_i}{[t_i]} \leq Q_i, \quad (14)$$

The first part of the system (8) is written in following view:

$$(И_i + E_н K_i) \cdot Q_i \cdot t_i \cdot K_э \leq N \cdot q \cdot K_э \cdot Ц, \quad (15)$$

where $К_э$ – the coefficient of transfer of nutrition value into production, Ц – price of production unit.

The limiting value of the quantity of animals [N] or their average productivity [q·$К_э$], by which the using of a variant of a system for preparation and distribution of fodder worked out or chosen, can be determined from this formula

$$[N] = \frac{(И_i + E_н K_i) \cdot Q_i [t_i]}{q \cdot K_э \cdot Ц}, \quad (16)$$

$$[q \cdot K_э] = \frac{(И_i + E_н K_i) \cdot Q_i [t_i]}{NЦ}, \quad (17)$$

So, economical and mathematical (8) connects material costs ($И_i$; K_i), technological (t_i;G_{ni}) and constructive parameters (Q_i), qualitative (γ_i) and energy indicators of the process and the parameters of the system of producing under consideration.

Technology of preparation for feeding and distribution of feed, may be implemented in accordance with the technological scheme (figure 2).

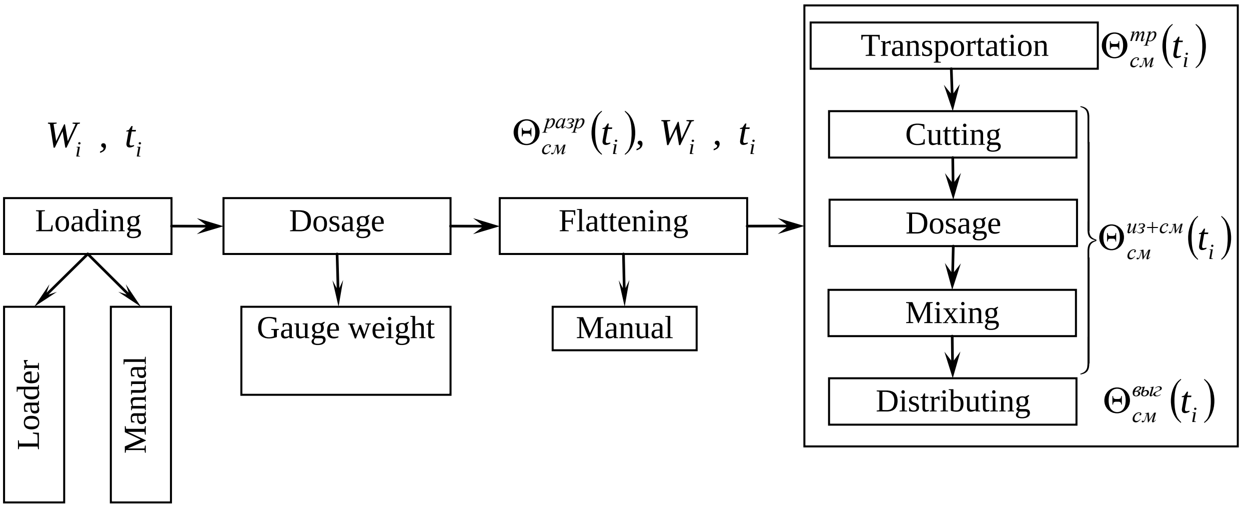

Figure 2: Structural and technological scheme of the line of distribution of fodder mixtures at small farms.

The analysis of the model (8) and the scheme (the picture 2) shows, that reduce of material costs for purchasing of the additional equipment for the preparation and distributing of fodder at small farms is possible at the expense of raising of qualitative factors of processes of reducing of energy parameters of machines worked out, containing several working processes with different constructions of working members and using multifunctional machines in concomitant processing lines at farms [2].

To determine the influence of factors and their interaction to the stability of the process of the simultaneous cutting and mixing, a plan of the whole factorial experiment 2^3 was realized, data processing was carried out and statistical mathematical model full-scaled was made.

– for the granularity of the mixture:

$$\delta = 8825{,}429 - 9{,}99114W_c + 163{,}358S + 10{,}8383Z_1 + 9{,}9232\upsilon_n - 440{,}854W_cS - 0{,}2492W_c\upsilon_n - 57{,}2SZ_1 - 2070{,}4684S\upsilon_n - 7{,}37567Z_1\upsilon_n + 1{,}6793W_c^2 - 400{,}868S^2 - 1{,}16967Z_1^2 - 1{,}372\upsilon_n^2 \quad (18)$$

– for the homogeneity of granulometric compound:

$$\lambda = 357{,}201 + 23{,}7612W_c - 425{,}984S + 10{,}164Z_1 - 37{,}31\upsilon_n + 18{,}512W_cS - 39{,}16W_cZ_1 - 62{,}88562W_c\upsilon_n - 286{,}1SZ_1 + 251{,}382S\upsilon_n - 9{,}65765Z_1\upsilon_n - 4{,}0872W_c^2 + 1047{,}8S^2 - 1{,}02487Z_1^2 + 5{,}0901\upsilon_n^2 \quad (19)$$

– for the power:

$$N = 1777{,}107 + 4{,}07086W_c - 41{,}8262S + 0{,}3773Z_1 - 1{,}95678\upsilon_n - 78{,}676W_cS - 1{,}52635W_c\upsilon_n + 32{,}604SZ_1 + 94{,}64S\upsilon_n - 0{,}76692Z_1\upsilon_n - 0{,}6865W_c^2 + 101{,}4S^2 - 0{,}040293Z_1^2 + 0{,}26786\upsilon_n^2 \quad (20)$$

By the optimization W, S, Z_1 and υ_n the method of multicriterion evaluation of rational factors was used, that is principle of dedication a single main criterion (the granularity of the mixture), and the others (the homogeneity of the granulometric compound and the power) as a limit in the range of variation. The method of nonlinear programming was used – the method of limited scanning.

On the ground of the analysis carried out the programs for search of required rational parameters, which allow to get the following values: the moisture of roughage W_c = 17 %; the helix lead of the screw conveyer S = 0,2 m; the quantity of segments on one wind of the screw conveyer Z_1 = 8 ones; linear velocity of input transporter υ_n = 0,005 m/s.

By the rational parameters found, finished fodder corresponds to zoo technical requirements: the granularity of the mixture is δ = 9,7 %; homogeneity of the granulometric compound is λ = 89,26 %; the power is N = 7,8 kilowatt.

CONCLUSION

The realization of the working process of preparation and distribution of fodder at small farms with introduction of distributor-mixer with replaceable working members suggested allow to reduce steel-intensity, power-intensity, and, as a consequence, operating costs at the expense of combination of several technological operation in one machine.

The scientific significance of the economical and mathematical model is, that it allows to consider expenses, factors and parameters in a coordinated fashion and carry out the analysis and point the way of raising of the efficiency of livestock production.

The evaluation of the efficiency of using of technologies and hardware for the preparation and distribution of fodder at small farms in accordance with the economical and mathematical model (1) suggested, allows to substantiate quantitative and qualitative factors of the realization of the working process in the stage of project.

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