

PROVIDING PROCESSES OF PREPARATION AND DISTRIBUTION OF FEED FOR CATTLE ON ANIMAL HUSBANDRY FARMS

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Abstract. World experience shows that family farms are the basis for the agricultural sector of countries with advanced market economies. The analysis of the components of the livestock ration provided an opportunity to identify the amount of feed mixture, which needs to be distributed to animals per day, depending on the livestock. Researches have shown that for preparation and distribution of feed on farms with livestock up to 10 cattles, it is advisable to use inefficient machinery with energy drive and partial execution of manual operations, 11-35 – self-feeders, mechanized lines using stationary machinery with energy drive and forklifts. For 36-50 cattles of livestock and at an average animal productivity of at least 6500 kg of milk per year, processes of preparation and distribution of feed can provide self-feeding and mobile combined feed making machines. Preparation and distribution of feed mixes for 51-400 heads of cattle – provide mobile combined feed making machines with delivery of the mixture on the feed tables. For livestock with more than 400 heads of cattles, it is advisable to use stationary robotic feed making facilities and distributors of feed mixtures or a mobile combined feed making machine. In the feed mixture preparation process, it was found that the multifunctional feed making machines with a vertically positioned conical auger in the hopper have a high power consumption of more than 35 kW. Power consumption, driven by the working bodies, is almost directly proportional to the speed of an auger. With increasing rotation frequency of an auger, the efficiency of grinding and mixing does not increase significantly; we have substantiated the rotation frequency of an auger $16-20 \text{ min}^{-1}$, with grinding rolls and packs and in the mode of mixing and dispensing $24-25 \text{ min}^{-1}$. However, in the process of dispensing the feed mixture, the existing auger does not clean itself from the feed.

Keywords: animal husbandry, machine, auger, feed mixture, farm.

Introduction

Recently, the development of family farms has become a very popular topic in Ukraine. They are part of the strategy for the development of the agricultural sector. The declared strategy has three main priorities. The first is the reform of the state support system, with a focus on small farmers [1]. The second is completion of the land reform and the third is the reform of state-owned enterprises. There are also five main areas: development of sales markets; organic production; niche cultures; rural development; irrigation and food safety [2]. The choice of such accents and priorities was based on a deep analysis of the situation on the world market. However, in individual farms and family farms in Ukraine, the means of mechanization of feeding in such farms are minimal and of low productivity. For preparation of feed components for feeding, machines are used that require use of manual operations (loading, removal of cooked feed, and sometimes dispensing) [3].

European agricultural producers have a legal status and are legal entities, whose actions are clearly regulated at the legislative level [4]. However, in the world practice between countries there are large disparities in the size of land holdings, for example, in the EU south – areas up to 5 ha are characteristic, but in the northwest – areas can exceed 100 hectares. In Israel, milk is produced on farms, with dairy farming one of the best in the world. The average cow productivity in the country is about 11500 liters of milk per year. The experience of 93 countries in the world shows that, from over 570 million farms, more than 500 million belong to families. Family farms account for at least 56 % of agricultural output [5].

Such farms cultivate a significant proportion of agricultural land in the world: 83 % – in North and Central America, 68 % – in Europe, 85 % – in Asia, 62 % – in Africa. In the USA, family farms cultivate 78 % of the country's farmland, producing 84 % of all agricultural output [6]. Therefore, it is clear that, in terms of technological level of development and share of own labor, family farms also differ very strongly. World experience shows that the traditional feed preparation unit for stirring is a vessel, preferably cylindrical in shape, equipped with a mixing device including components for torque transmission, shaft and mounted on the shaft inside the mixer hopper [7]. Rotating, the mixer transmits to the mixed mass the movement force from the gearbox and causes it to mix. When using paddle mixers, the front of the blades presses against the raw material and it flows around the blades. Blades cause a dilution that causes the liquid components to be sucked in from the surrounding

volume. Turbulent turbulence is created by the flow and suction near the blades, which with the increase of the size of the mixer and the speed of rotation extend to the entire volume of the liquid, ensuring its mixing [8]. The same actions occur when working a conical screw working body.

When pre-selecting the type of the mixing device, environments with a coefficient of dynamic viscosity of less than 1 Pa·s in apparatus up to 10 m³ are conventionally considered to be slightly viscous [9]. During their mixing, the turbulent mode of motion is practically always realized with the regions of predominant macro- and micro-mixing. In environments with a higher dynamic viscosity ratio and in larger volume apparatus, the probability of laminar motion zones, where there is little mixing, is likely. In this case, devices of the types recommended for high viscosity and non-Newtonian fluids should be used [10].

When using mobile compound feed units, compromise solutions have to be applied that involve the high power required to drive (over 35 kW) their working bodies [11]. The power that drives the working bodies depends largely on the speed of the mixing device. Accordingly, it is advisable to reduce the screw speed. However, at low speeds, the auger with a perpendicular arrangement of the coil to the axis does not self-cleanse from the feed when unloaded. Self-cleaning the auger coils at a low speed of rotation can be ensured provided that the coils are not perpendicular, but inclined to the axis of the auger. Therefore, there is a need for analytical studies to determine the rational speed of the screw without changing the angle of inclination of its coils.

Feeding animals requires a balanced nutrient, with high homogeneity of mixing, feed mixture and no stagnant zones in the hopper [12]. Better mixing of feed components can be achieved by installing several mixing bodies both in height and in the horizontal section of the hopper of the feed unit [13]. Also, the multiplicity of feed distribution and its dosage delivery are significantly influenced by the productivity of animals [6]. For example, in Israel, for high-performance dairy animals, the feed mixture is distributed 4-5 times a day, at a well-regulated time, in addition, 4-5 times fed the feed [8]. Cattle in Germany and Switzerland also receive a feed mix 3-6 times a day [11], and when using a forage robot – the number of feed distribution can reach up to 10 times. In Ukraine, most farms that keep cattle feed the feed mixture three times a day.

The purpose of the research is to determine the amount of feed preparation, depending on the livestock population and to justify the means of mechanization of feed preparation and to determine the parameters of the auger working body of the feed preparation unit.

Materials and methods

The analysis of the components of the feed ration made it possible to identify the amount of feed mixture to be distributed to animals per day, depending on the livestock (Table 1). The daily rate of feed consumption K_{cum} is determined by the formula, kg:

$$K_{cum} = \sum_{j=1}^n g \cdot m, \quad (1)$$

where K_{cum} – daily feed consumption, kg;
 g – feed rate per head, kg;
 m – number of animals, in j group, head;
 n – number of groups of animals with the same feed rate.

Considering the productivity of the mechanization tools used in the farm, it is possible to determine how many times the daily feed rate will be prepared for all livestock.

The data obtained can serve as an indication of the multiplicity of feedstuff delivery n_{roz} to animals

$$n_{roz} = \frac{K_{cum}}{\rho \cdot V \cdot K}, \quad (2)$$

where n_{roz} – indicator of the multiplicity of feed mixture to animals;
 V – capacity of the hopper of the machine, m³;
 ρ – density of feed mixture, kg·m⁻³;
 K – fill factor of the hopper, $K = 0.9-0.95$.

Table 1

Feeding structure and daily number of feeds depending on livestock

Name of the feed component	Livestock herds, heads			
	10	35	50	400
Hay	4-7	4-7	4-5	3-4
Soilage	-	-	4-5	10-12
Other roughage	2-5	2-5	2-4	2-3
Corn silage	10-15	18-20	20-24	20-24
Pulp	5-8	3-8	-	-
Concentrated feed	2-5	2-4	2-4	2-3,5
Liquid nutrient solutions	-	1-1,5	1-1,5	1-1,5
swelling (liquid)	5-8	-	-	-
Just a head	28-48	30-46	33-44	38-48
Total per head, kg	280-480	1050-1610	1650-2200	15200-19200

Results and discussion

The analysis of Table 1 leads to the conclusion that preparation of the feed mixture requires the use of machine units that can grind and mix feed with each other (provided pre-shredded long-fiber components are sufficient to mix).

Studies have shown (Fig. 1) that for preparation and distribution of feed on farms with livestock up to 10 heads of cattle, it is advisable to use low-productive machinery energy-driven and partial execution of manual operations, 11-35 heads – mechanized lines using stationary power-driven machinery and forklifts. For 36-50 heads of livestock and with an average animal productivity of at least 6500 kg of milk per year, feed preparation and distribution processes can provide self-feeding and mobile combined feed units.

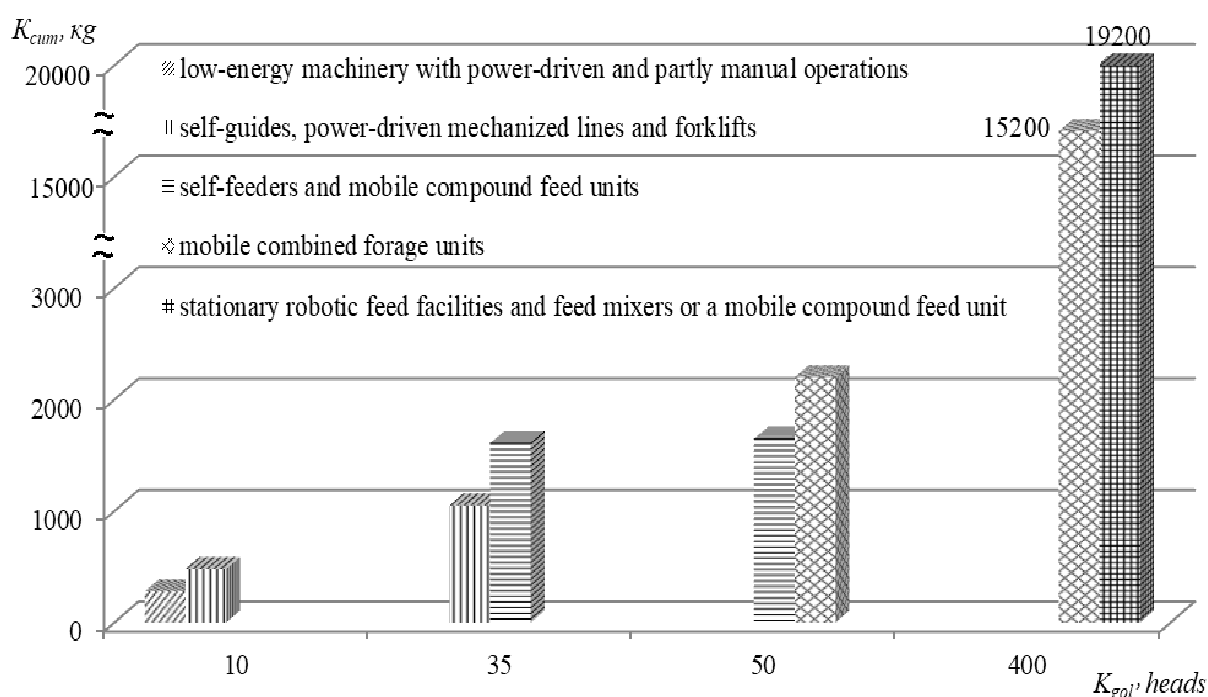


Fig. 1. Means of mechanization, depending on the daily amount of feed K_{cum} and livestock K_{gol}

Preparation and distribution of feed mixes for 51-400 heads provide mobile combined feed preparation units with delivery of the mixture on the feed tables. For livestock with more than 400 heads, it is advisable to use stationary robotic feed facilities and feed mixers or a mobile compound feed unit. In the feed preparation process, it was found that multifunctional feed units with a vertically positioned conical auger in the hopper have high power consumption (more than 35 kW).

Power consumption, driven by the working bodies, is almost directly proportional to the screw speed. When the screw speed is increased, the efficiency of grinding and mixing does not increase significantly. However, in the process of distributing the feed mixture, the existing auger does not self-purify itself from the feed (Fig. 2).



Fig. 2. Screw after feed mixture is dispensed

Self-cleaning of the auger coils at low rotational speed can be ensured, if the coil is not perpendicular, but inclined to the axis of the auger. For this purpose, analytical studies were conducted to determine the desired angle of inclination of the coil, depending on the speed of rotation of the auger. The hypothesis was that the inclination of the forming coil of the auger, relative to the horizontal, will intensify the process of convergence of the feed mass from the coils of the auger.

The justification of the complex shape of the auger requires fundamentally new approaches to determining its parameters. The diameter of the auger is determined based on the efficiency of the feed preparation process and the provision of zootechnical requirements pertaining to forage machines. First and foremost, elimination of congestion. Accordingly, the diameter of the lower base of the auger should be equal to the value of the lower base of the cone, with the exception of the technological gap, $D_x = 2R - 2\Delta l$, (R – auger radius). With respect to the top base, its parameters are determined based on the performance of the auger, taking into account the specified parameters of the hopper. The rotor speed was determined from the conditions of motion of the feed components on its surface. The feed on the entire surface of the auger acts as: the gravity $F_{IT} = mg$, the centrifugal inertia force $F_c = mR\omega^2$, the normal response of the screw N , the friction force on the screw coil $F_{TP} = fmg$, the Coriolis force $F_K = 2m\omega v$ and friction from it $F_{KT} = 2f\omega v$.

$$mR\omega^2 > fmg + 2f\omega v. \quad (3)$$

The movement of the feed components towards the outer surface of the auger is possible, if the inertia force is greater than the friction force resulting from the force of gravity.

Cleaning the auger from the feed mixture is achieved under the following conditions:

$$\begin{cases} F_{ky} = N + F_c \sin \beta \cdot \sin \alpha - F_{IT} \cos \beta \cdot \cos \alpha + F_K \sin \beta \cdot \sin \alpha - F_{KT} \sin \beta \cdot \sin \alpha = 0, \\ F_{kx} = F_c \cos \beta \cdot \cos \alpha + F_{IT} \sin \beta \cdot \sin \alpha - F_{TP} + F_K \cos \beta \cdot \cos \alpha - F_{KT} \cos \beta \cdot \cos \alpha = 0. \end{cases} \quad (4)$$

at the inclination of the forming screw (Fig. 3).

$$\operatorname{tg} \beta = \frac{fg - \omega^2 R - 2\omega v + 2f\omega v}{\frac{S}{2\pi R} (f\omega^2 R + 2f\omega v - 2f^2\omega v + g)}, \quad (5)$$

where S – step of the auger screw, m.

$$\beta = \arctg \frac{2\pi R (fg - \omega^2 R - 2\omega v + 2f\omega v)}{S (f\omega^2 R + 2f\omega v - 2f^2\omega v + g)}. \quad (6)$$

From (Fig. 4) it is seen that self-cleaning of the coils, with their perpendicular placement to the vertical axis of the auger, is ensured at a rotational speed of at least 25 min^{-1} . The angle of inclination of the auger coil turn to the horizon, at a rotation speed of 20 min^{-1} and a distance to the axis of

rotation of 0.3 m, is within 29 degrees, and the horizontal position relative to the bottom of MCPA is at 0.48 m.

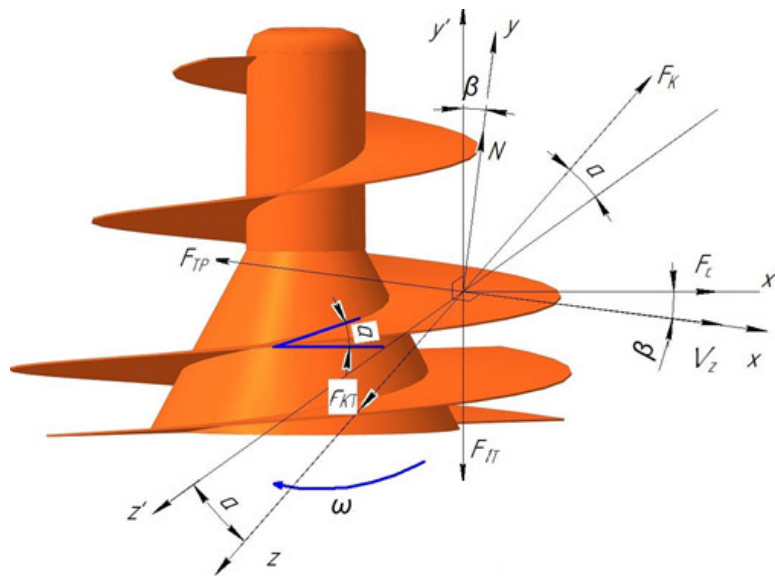


Fig. 3. Before determining the angle of inclination of the auger

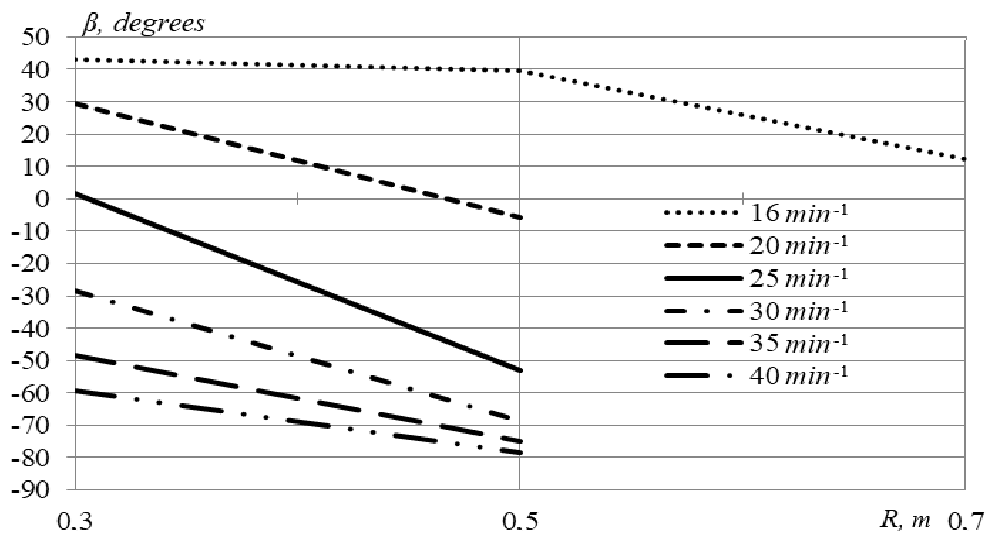


Fig. 4. Dependence of the required angle β of location of the screw auger to the horizon on distance to the axis of the auger at different frequencies of rotation, provided self-cleaning

Therefore, the analysis (Fig. 4) makes it possible to conclude that at a speed of 16-20 min^{-1} it is better to grind coarse feeds that are in rolls and packs, and to mix with the next component after coarse feeds. In this case, it is possible to completely destroy large parts of the roll or pack. For feed preparation units having two-speed gearboxes designed for a screw speed of 16 and 25 min^{-1} or 20 and 25 min^{-1} , it is recommended that the feed mixture is mixed and dispensed at a screw speed of at least 25 min^{-1} .

Conclusions

1. The use of a stationary feed mixer with a hopper volume, for example, 2.2 m^3 , is advisable in family farms for maximum of 60 heads of live flock with livestock, provided that the feed mixture is distributed three times.
2. Increasing the profitability of family farms by increasing livestock requires the use of versatile tools that can combine several operations, such as loading, transporting, grinding, mixing feed components and feed. Such machines prepare more than one feed at a time and significantly reduce the time spent on feeding animals while feeding and reduce labor costs.

3. The movement of the feed mixture on the surface of the auger is determined by the magnitude of the centrifugal force, as well as the coefficient of friction f , the value of which depends on the moisture content of the feed components.
4. Use for mixing the feed components of the screw working body with the installation of a forming coil perpendicular to the vertical axis of the screw, provided self-cleaning, is possible at a screw speed of not less than 25 min^{-1} .

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