Selection and justification of the optimal multifunctional design of the unit for the preparation and distribution of liquid feed mixtures in animal husbandry

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Abstract. The article deals with the problem of using various installations for mixing and preparing liquid feed mixtures in animal husbandry. The analysis of domestic and foreign installations capable of performing this function is carried out. But during the review process, many shortcomings and problems were identified that needed to be solved by developing a new design that would eliminate all the identified problems. Therefore, the design of two installations in horizontal and vertical versions is proposed, while the values of their pressure-energy (hydraulically) characteristics are given. This allowed us to determine their further expansion of functionality. This is how the process of drinking and feeding was considered, using experimental installations. The parameters for each livestock room are analytically calculated, which shows the effectiveness of the use of experimental installations.

1 Introduction

Nowadays, there are many different designs of devices or installations for preparing mixtures. In general, they are called mixers, dispersants, homogenizers, but their final function and task is to mix two or more components that are needed to obtain the final product.

Choosing this or that technological process, it is necessary, to design and create such designs, so that they meet the quantitative and qualitative indicators for mixing the components. So the most common quantitative indicators are: the degree of homogeneity, the degree of mixing coefficient of variation, the rate of completeness of dissolution. To the qualitative indicators can be attributed such as complete stability and stability to coalescence.

For the needs of agriculture, fundamental, is the preparation of liquid feed mixtures for young animals, but also for some groups of animals. Thus it is necessary to create such technical means which will satisfy mainly zootechnical requirements on quality of a mix.

Analysis of the global market shows that the majority of foreign agricultural producers use substitutes for feeding, and whole milk is given for processing. A similar trend can also be seen in Russia.

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Thus, obtaining feed dairy mixtures based on whole milk substitutes with a composition adapted to the needs of animals and reducing costs when raising young animals is a very urgent task.

The aim of the work was to theoretically study the design of a mixing unit for the preparation of liquid lumpy mixtures (LCM), with subsequent confirmation of its main design parameters.

The object of the study were mixers based on vane pumps [1]. Choosing this or that technological process, it is necessary, to design and create such designs, so that they meet the quantitative and qualitative indicators for mixing the components. So, the most common quantitative indicators are: the degree of homogeneity, the degree of mixing coefficient of variation, the rate of completeness of dissolution. To the qualitative indicators can be attributed such as complete stability and stability to coalescence.

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2 Theoretical, methodological and empirical base

In order to analyze mixing plants and technical means, it is necessary to analyze domestic foreign manufacturers engaged in these developments.

The Swedish company Alfa Laval offers mixers (mixers) under such names as: Vortex mixing hopper, Vortex MixMate and S15 and M15 hybrid powder mixer.

The German company Forster-Technik offers a wide range of equipment for calves in the form of a feeder dispenser called Vario Smart and Vario Compact. These devices are mounted in the line of animal feeding.

Analysis shows that the bulk of the equipment on the market h

Tetra Pak, no less famous company, designs and produces mixing devices as Tetra Pak RJCI mixer, Tetra Pak module for production of finished products and Tetra Pak R370-1000D that are installed on technological lines with productivity in the range of 5000 ... 40000 l/h.

Among Russian manufacturers it is possible to mark out company "Agromoltechnika" (Novosibirsk) which produces installation UZHK-600/800 which works by principle of circulation through centrifugal pump, with high power consumption.

The largest producer of equipment "Molmash plant" (Moscow), is engaged in production of plants for reconstitution of dried milk or its substitutes brand P8-UVSM vertical and horizontal version, as well as disperser brand P8-ORD-M.

Among mobile means for preparation and distribution of liquid feed, one type stands out called "Milk Taxi", many companies ("Milk Technology", "Alfa Agro", LLC "BelAgroSystem", etc.) produce different designs, but in general they are similar, the only difference is the tank capacity and power consumption.

as a design with a paddle stirrer. The equipment works in portions, low intensity of mixing causes the need to increase the duration of the process, which increases the energy consumption for obtaining mixtures [2].

The analysis reveals the following main operational and technological requirements:
  – small dimensions (no mixing tank as part of the unit);
  – simultaneous dosing of liquid and dry components;
  – elimination of sticking or adhesion of dry components because of the separate input;
  – intensive mixing;
  – combination of the working process of the mixer and the transfer pump;
  – low energy costs.

The most promising are units that have the design of a centrifugal-blade mixer, which has the shape of an impeller in the form of a turbine stirrer, which can stir liquids with very high viscosity, which is the most rational and as a consequence is universal for mixing various media.

Among all the variety of blending units on the market, the problem of mixing dry components with liquid has not been definitively solved and requires further research and study. In general, there is a tendency to use devices for injecting the dry component directly into the flow.

The most common units use a vertical feed of powdered or crystalline products connected to the horizontal flow of the dissolving liquid (Figure 1) and mixed with it in the suction branch of the pump. At the same time, such scheme of material supply does not exclude the possibility of hang-up and its subsequent heating due to friction and clumping, which in turn causes a decrease in service life, as well as possible unexpected breakdowns, which can lead to injuries for the operating personnel [3].
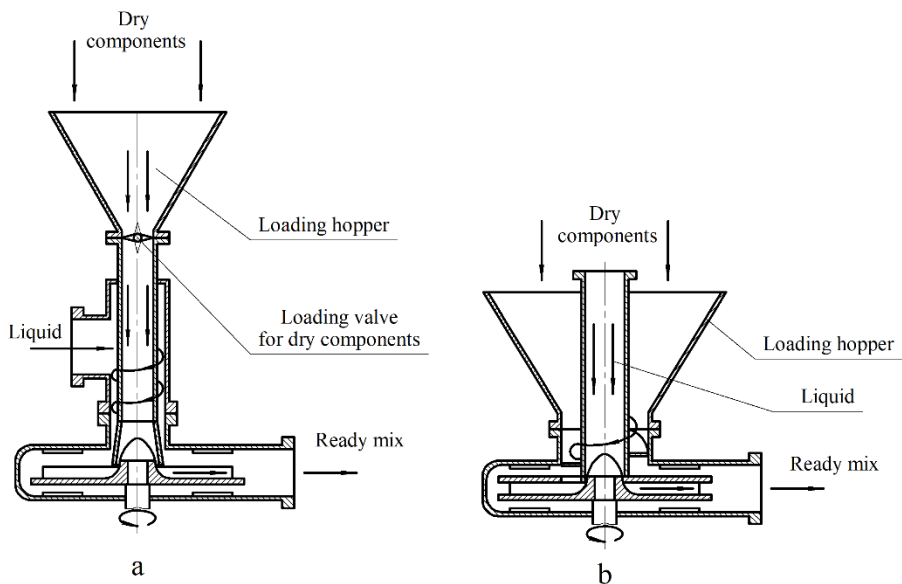

Fig. 1. Scheme of devices (a) with horizontal and (b) with vertical fluid supply.

The proposed scheme of the installation (Figure 1 b) eliminates disadvantages in operation due to the special design of the wheel. Also, this installation combines three devices: pump, dispenser and mixer, which eliminates cluttering of the process line and reduces the safety requirements for its operation.

This scheme with the vertical version (Figure 1 b), also has a horizontal version (Figure 2), which is also versatile in its characteristics.
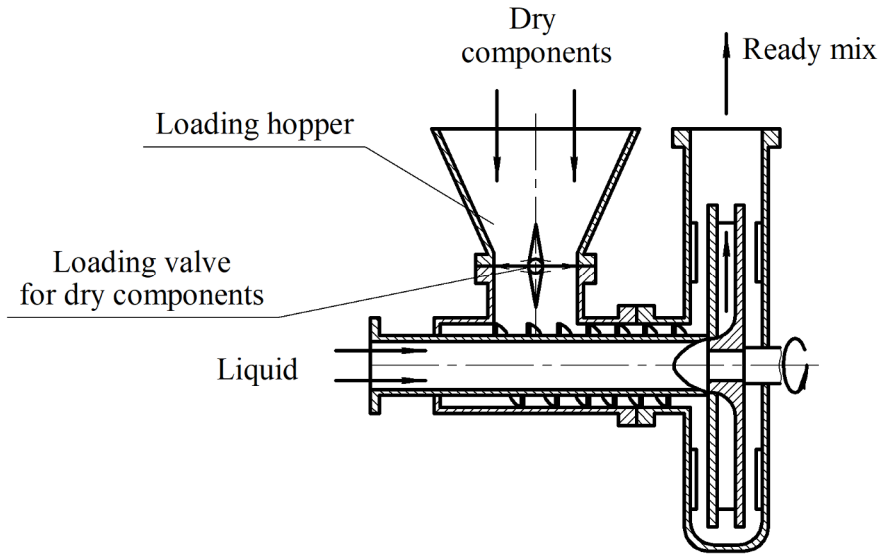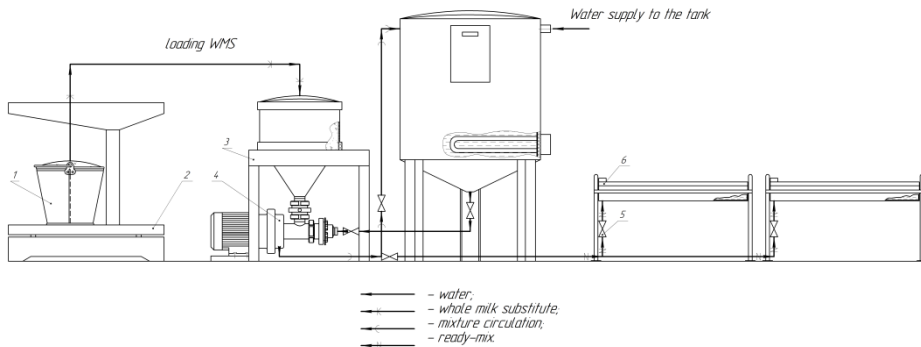
Fig. 2. Scheme of the installation for the preparation of liquid feed mixtures in a horizontal design.

To implement the process of feeding young animals using a whole milk substitute, an installation is proposed that can be used in the production line (Figure 3).

1 - container for dry components; 2 - scales; 3 - installation for the preparation of liquid feed mixtures; 4 – mixer pump; 5 - ball valve; 6 – group drinker

Fig. 3 Technological scheme for the preparation (mixing) of liquid feed.

When considering the use of the installation in the animal watering line, it is necessary to consider possible use schemes for young animals: pigs and cattle, taking into account possible design parameters of the premises[4,5].

Since basically the largest part of the drinking systems has either a dead-end type or a closed trunk, each of them has its advantages and disadvantages. At the same time, as for the dead-end circuit, there is a problem of flushing the system, and in the main system, an additional pump is always needed.

It is worth remembering that to calculate the need for water or a whole milk substitute, you can use a formula that will take into account the required performance of the installation as a whole:

$$Q_{water(WMS)} = q_{i(j)} \cdot m_k \qquad (1)$$

where $q_{i(j)}$ - need per day of i – water, j – WMS;

m_k - the number of animals in the room by age, heads.

At the same time, the need for water and whole milk substitutes is presented in Table 1.

Table 1 - Norms of water consumption and consumption of liquid feed per day.

Animal species	Norms of water consumption per animal, l / day.	Norms of consumption of whole milk substitute (liquid feed) per animal, l / day.
Cattle - young animals up to two years old	30	5
Young and fattening pigs	15	0.6

The unevenness of the daily water consumption of water and whole milk substitute can be expressed:

$$Q_{\max\left(\frac{water}{WMS}\right)} = Q_{water(WMS)} \cdot K_1 \tag{2}$$

where K_1 - the coefficient of daily unevenness, $K_1 = 1.3...1.5$.

The hourly consumption can be defined as the expression:

$$Q_{h.\max\left(\frac{water}{WMS}\right)} = \frac{Q_{\max\left(\frac{water}{WMS}\right)} \cdot K_2}{24} \tag{3}$$

where K_2 - the coefficient of hourly unevenness, $K_2 = 2.5$ – for farms equipped with automatic drinkers.

At the same time, it should be borne in mind that some of the premises have different capacities for livestock [6,7,8].

Taking into account the technological scheme (Figure 3), a design scheme for livestock premises is proposed, taking into account the fact that all animals are evenly arranged in rows (Figure 4), according to these assumptions we will find pressure losses.
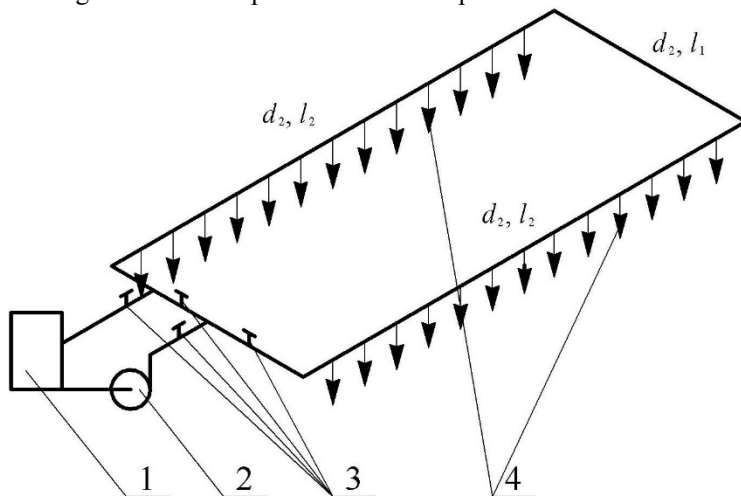

Fig. 4. Calculation scheme for determining pressure losses. 1 - a container with water; 2 – experimental mixing plant; 3 - two-way ball valves; 4 – consumer.

We believe that the movement of the liquid will occur sequentially in one circle, then the total pressure losses add up:

$$H = h_{w1} + h_{w2} + \cdots + h_{wi} \tag{4}$$

where $h_{w1}, h_{w2}, ..., h_{wi}$ - losses at various sites, m.

Losses will be determined by the following formula:

$$h_w = h_m + h_l \qquad (5)$$

where h_m and h_l - accordingly, local and linear losses, m.

$$h_m = \xi \cdot \frac{U^2}{2g}; \qquad h_l = \lambda \cdot \frac{l}{d} \cdot \frac{U^2}{2g} \qquad (6)$$

where λ - coefficient of linear hydraulic resistances;

$\quad l$ - length of the section between sections, m;

$\quad d$ - pipeline diameter, m.

3 Results and discussion

Preliminary (parametric) tests of installations with vertical and horizontal execution obtained the following dependences of their operation as a pump, the data obtained are summarized in Table 2.

Table 2. Results of parametric tests of experimental setups.

Indicators	Numeric values of options	
	vertical version	horizontal design
Throughput, Q m^3/h	8	16
Installed power, P kW	0.75	1.5
Head N, m	8	16
Efficiency η, %	12.3	25.4

Table 3. The results of the calculation of water requirements and WMS for different livestock premises.

The name of a room	Number of animals in the room	Consumption per day		Maximum daily consumption		Maximum hourly consumption	
		Q_{water}, m^3/day	Q_{WMS}, m^3/day	Q_{water}, m^3/day	Q_{WMS}, m^3/day	Q_{water}, m^3/hour	Q_{WMS}, m^3/ hour
Pigsty-fatter	500	7.5	0.3	11.25	0.45	1.17	0.05
	600	9	0.36	13.5	0.54	1.41	0.06
	1250	18.75	0.75	28.12	1.12	2.93	0.12
Calf house	100	3	0.5	4.5	0.75	0.47	0.08
	200	6	1	9	1.5	0.94	0.16
	350	10.5	1.75	15.75	2.62	1.64	0.27
	600	18	3	27	4.5	2.81	0.47

Table 4. Head loss calculation results (local losses are assumed to be approximately 10% of linear losses).

The name of a room	Dimensions, m		Head loss, m
	length	width	
Pigsty-fatter	72	12	7.65
	72	21	7.65
	87	12	9.24
Calf house	30	12	3.19
	60	12	6.37
	100	18	10.62
	120	24	12.74

4 Conclusions

The analysis of installations for mixing solid and liquid components of domestic and foreign production allowed us to identify the main disadvantages of these structures, which allowed us to create fundamentally new designs that exclude all of the above disadvantages.

The possibility of using the developed experimental facilities for watering and feeding animals indoors has been revealed. A theoretical calculation was carried out to determine the required hourly water supply and WMS, and approximate pressure losses were determined. As the results of calculations have shown, the obtained hydraulic characteristics of horizontal and vertical installations fully meet the requirements that are necessary for a particular type of livestock premises.

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