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DEVELOPMENT OF PREPARING FEED MACHINES

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A R T I C L E I N F O	A B S T R A C T
	This article presents the results of the development of a device for the production of feed in devices based on real screw drums. The novelty lies in the manufacture of the working body of the device for the continuous preparation of feed from sections, the elements of which during installation are mounted at predetermined angles both to each other and to the axis of rotation. In this case, they work like shelves, capture portions of particles of feed components and direct them towards not only each other but also opposite walls of a rotating real screw drum. **Disciplinary**: Agricultural Machinery.

1. INTRODUCTION

At the enterprises of our country and abroad for the execution of feed production operations, the most widespread are various drum devices with mixing blades located inside.

However, the low intensity of the ongoing processes and their localization in a limited area leads to a long duration of the implementation of feed production processes and therefore, the implementation of these technological operations in drum devices is ineffective. An engineering and scientific search for innovative feed production technologies is constantly being carried out, ensuring an increase in their efficiency and productivity.

This problem can be solved with the help of machines, the working bodies of which are real screw drums, which due to the original geometry provide not only non-standard forms of particle movement of feed components with a large amplitude (10-1000 mm or more) but also a significant energy intensity of their interaction. The spatial form of relational screw drums was created by us due to the helical lines of the main and opposite directions formed along their perimeter.

Such original devices retain the positive characteristics of both drum devices - ease of manufacture, operation, insignificant losses in the transfer of energy from the engine to the masses of granular media, and vibration devices - not only the high speed of the feed preparation processes but

also highly specific productivity at relatively low energy costs, as well as significantly smaller, compared with other devices, dimensions. As a result of the creation of such devices for the continuous preparation of feed, a fundamental possibility of reducing production areas, vehicles, capital, and operating costs, that is, the creation of resource-saving machine-based innovative technologies opens up. A feature of such machines is the combination of technological and transport operations.

2. METHOD

The basis for the development was taken the device, which consists of a frame ①, welded from the corners. Four support bearings ② are fixed in pairs on the bed ①. Two shafts ③ and ④ are mounted in them with the possibility of rotation. Four support rollers ⑤ are rigidly mounted on the shafts, on which the rotary screw drum ⑦ is rotated with the possibility of rotation by means of rims ⑥.
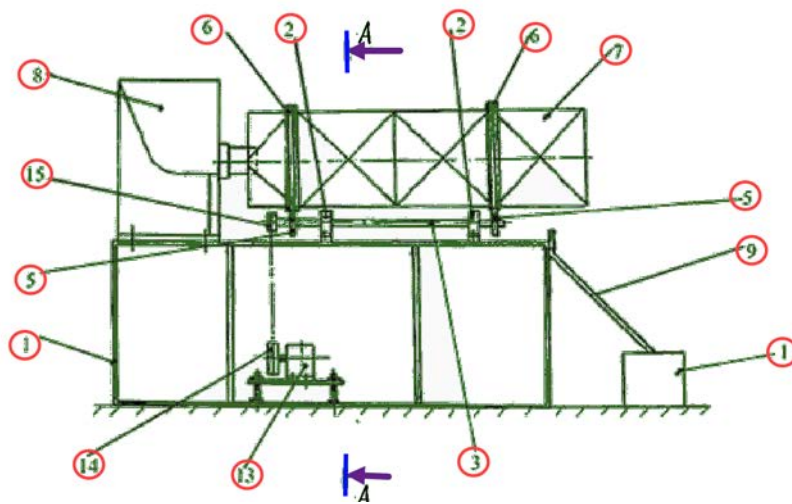

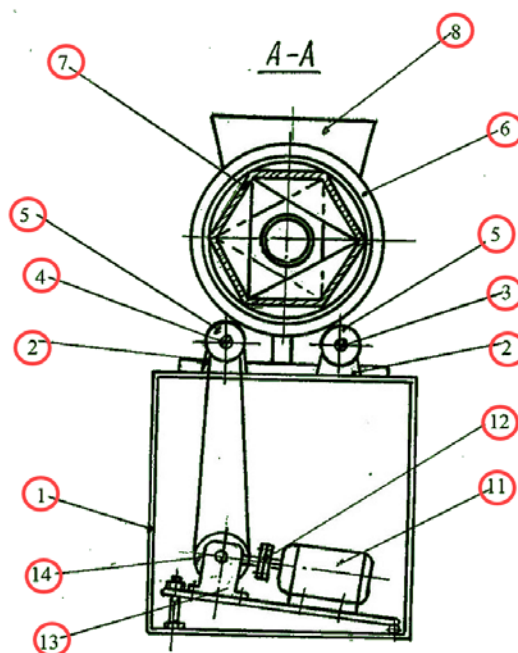**Figure 1:** Device for the continuous preparation of feed (front view).

Figure 2: Device for the continuous preparation of feed (section AA in Figure 1)

A loading device ⑧ is fixed on the bed ①, providing a continuous supply of particles of the components of the concentrated feed into the relational screw drum ⑦. On the opposite side of the relational screw drum ⑦, on the discharge side, a slip ⑨ is mounted on the bed ①, with which particles of the components of the concentrated feed after mixing from the inner cavity of the relational screw drum ⑦ is moved under the action of its own weight in the tank ①. The rotation of the relational screw drum ⑦ is communicated from the motor⑪. Through the clutch gear⑬and the belt drive, by means of interchangeable pulleys⑭and⑮ the rotation is communicated to the shaft ③. The shaft ③ rotates in the bearing bearings ② and by means of the support rollers 5 and the rims ⑥ transmits the rotation to the rotary screw drum ⑦. The angle of inclination of the axis of rotation the relational screw drum is adjustable by tilting the entire device.

3. RESULT AND DISCUSSION

The elements from which the rotating relational screw drum is assembled are different in area, size and configuration, therefore, the intensity of the feed preparation increases, since these elements, working as shelves, capture portions of feed different in volume and direct them towards each other, thus violating , the stationarity of their movement, increase the intensity of interaction, expand technological capabilities.

The execution of a relational screw drum from sections, the elements of which, when mounting the drum, are mounted at certain angles not only to each other, but also to the axis of rotation, and therefore, working like shelves, they capture portions of particles of feed components and direct them towards not only each other, but and opposite walls of the rotating drum. Therefore, the intensity of feed preparation increases, the technological capabilities of the device for continuous preparation of feeds increase. The area, shape and size of the bore of the relational screw drum along its length varies from loading to unloading, first to increase and then decrease, thereby intensifying the preparation of feed, not only the activity of the interaction of particles of the components of the feed with each other and with the walls of the drum increases , but also changes the frequency of their interaction and the amplitude of the movement relative to each other, resulting in increased technological capabilities of the device for the continuous preparation of feed. This constructive design of the relational screw drum along the perimeter with helical lines and screw surfaces allows not only to provide longitudinal cascade movement of feed components along the entire length of the drum, but also to increase the productivity of feed preparation and expand technological capabilities. The cross-sectional shape of the relational screw drum is a polygon, which in length changes not only the shape and dimensions of the sides of the polygon, but also their location relative to the axis, giving the particles of the feed components a waterfall mode of movement, which helps to increase productivity. Since the frequency of movement of particles of the components of the feed in the proposed design is determined not only by the rotational speed of the relational drum, but also by the number of flat elements along its perimeter, such a structural design of the drum by increasing the number of flat elements in each section around the perimeter increases the frequency of collisions for each revolution of the drum particles of feed components between each other and with the walls of the drum, increases the productivity of feed preparation, increases technological capabilities. The elements from which the

relational screw drum is assembled are mounted at certain angles to each other, therefore the intensity of the interaction of the components of the feed increases, since these elements, working like shelves, capture portions of particles of the components of the feed, direct them towards each other and on the walls moving on the opposite side of the drum, violating, thus, not only the stationarity of their movement, but also expand technological capabilities. Figure 3 shows a prototype device for continuous preparation of feed.
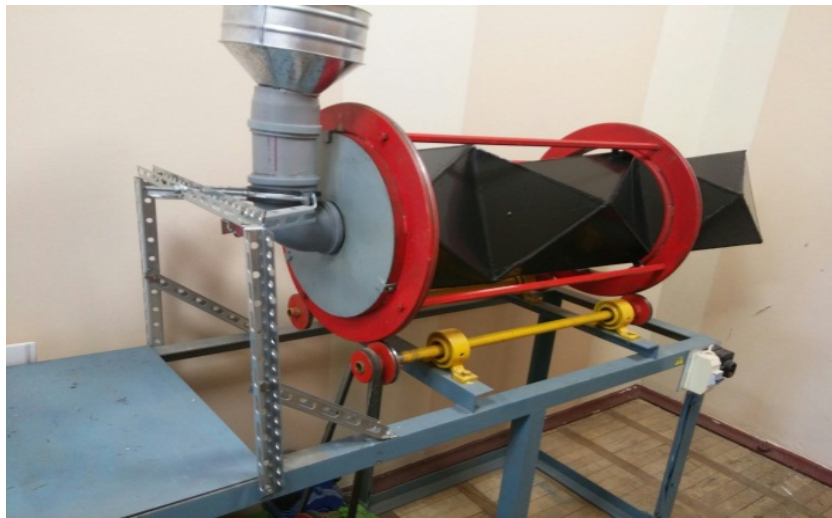

Figure 3: Device for the continuous preparation of feed (view from the loading side)

Table 1: Parameters of the device for continuous preparation of feed

Parameters	Values
Relative Screw Drum Length	1800
Diameter of a relational screw drum (conditional) (mm)	350
Drive power (kW)	1,5
Overall dimensions (mm)	3000×1000×2000
Productivity (kg/h)	1920

To determine the effectiveness of the feed preparation process on installation for continuous feed preparation, experimental studies were conducted.

- o Processing (mixing) time: 0.5 min.
- o The frequency of rotation of the relational screw drum RC 5.1.a: 64 rpm.
- o The total volume of the relational screw drum is 44 liters (44000 cm^3).

The experiment was carried out when loading 0.5 volume of a relational screw drum, i.e. with a volume of 22 liters (22000 cm^3) (KV = 0.5), namely: 5.5 liters (5500 cm3) of wheat, 5.5 liters (5500 cm^3) of corn, 5.5 liters (5500 cm^3) of alfalfa, 5 5 liters (5500 cm^3) oats.

A sample of 1.1 liters of the mixture (1100 cm^3), which are divided into fractions, was taken.

The results of experimental studies are presented in the form of nomograms (Figure 4, Figure 5) and show that for a RC 5.1 rotary screw drum, the optimal cooking time is 1.75 minutes.

Deviations in volume from the average value are:
- o for wheat + 4.7%;
- o for corn 0.0%;

o for alfalfa +3.2%;

o oats +2.9%.

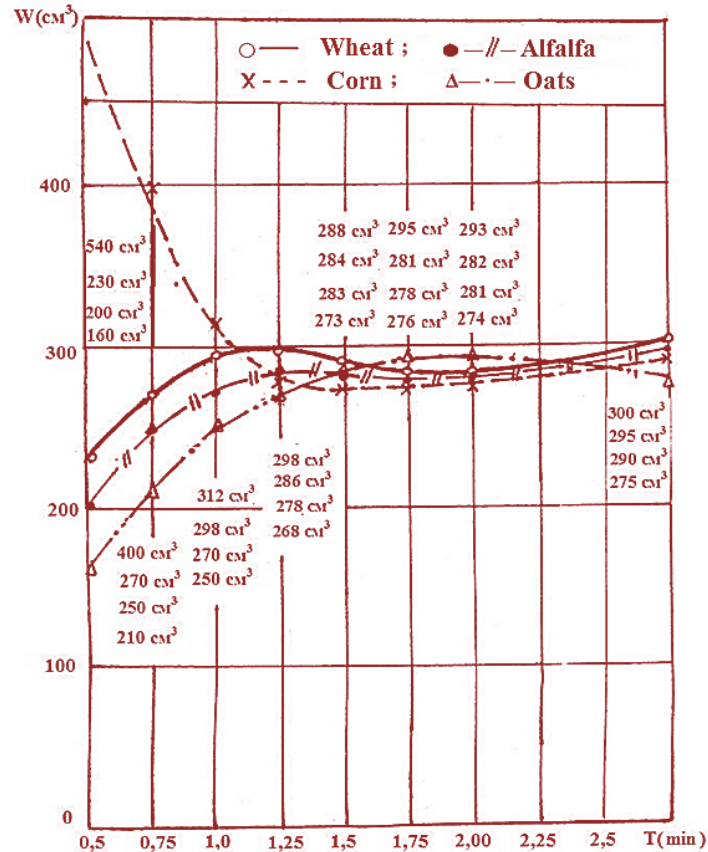That is, the maximum deviation is + 4.7% and the minimum is 0.0%.

Figure 4: Dependence of changes in the volume of feed particles in samples of the intake of the mixture from the time of their mixing.

With the continuation of the experimental study, there is a slight increase in deviations, for example:

o 1.75 minutes deviation is +7.3% .- 0.4%;

o 2.0 minutes the deviation is +6.5% .- 0.4%;

o 3.0 minutes the deviation is + 9% .0.0%.

Therefore, for high-quality mixing of particles of the components of the feed, you can take the duration of the process from 1.5 minutes to 1.75 minutes
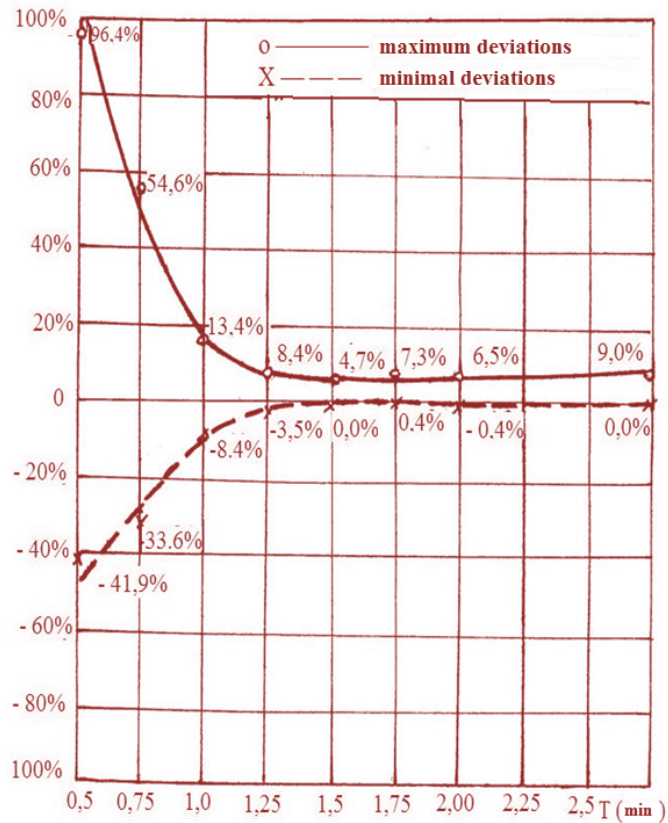
Figure 5: Dependences of deviations from 100% theoretically high-quality mixing of feed components in sampling samples from the time of mixing

Figures 6 and 7 show samples of a mixture of feed components with a volume of 1.1 liters (1100 cm3) taken after mixing the components of the mixture for 0.5-2.75 minutes.

Figure 6: Samples of the feed mixture after conducting research on the process of mixing them in the RC 5.1.a relational screw drum for 0.5-2.75 min.

To assess the quality of mixing the components of the feed-in relational screw drums, studies were conducted. As a controlled component (indicator) we use black rapeseed. The average weight of 1 grain of rapeseed is 0.0043 g. For research, 12 samples were taken from the stream, each weighing up to 30 g. The degree of mixing of two or more components is estimated using the coefficient of

variation in the quantity in the samples of the controlled component (included in the mixture in a lower dose). The numerical value of this indicator depends on many variables:

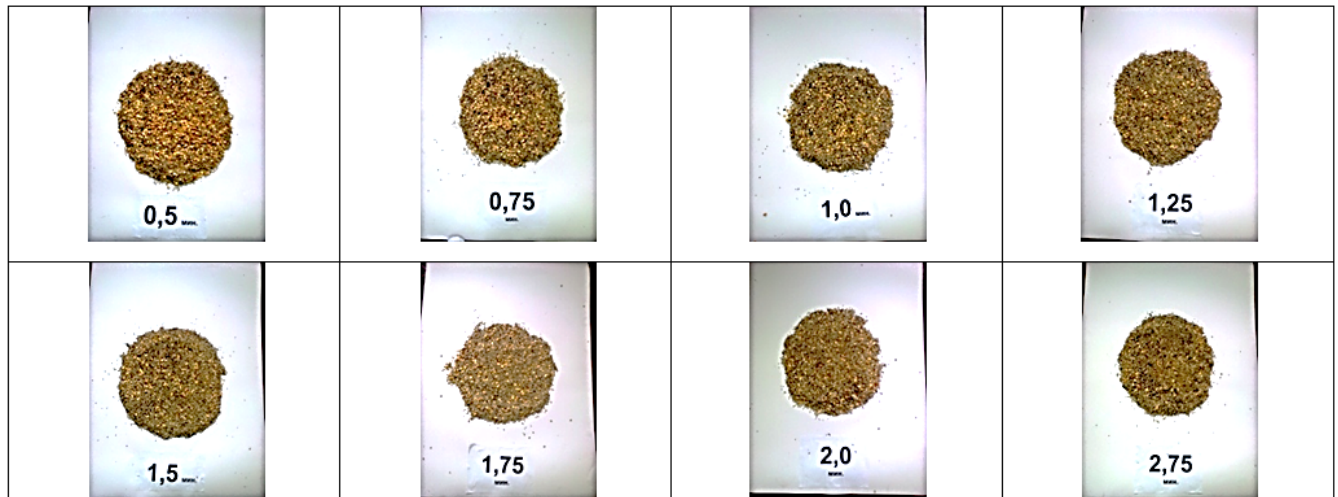$$\upsilon = f\left(d, l, y_y, t_c, \eta, g_{\Pi}\right) \tag{1}.$$

Figure 7: Samples of the mixture of feed components taken after researching the process of mixing them in the RC rotary screw drum for 0.5-2.75 min.

To determine the amount, the content of beet seeds was chosen manually (using sieves):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n-1}} \tag{2},$$

$$v = \frac{\sigma}{\overline{X}} 100\% \tag{3},$$

where X_i – concentration of the component in the samples;

       $\overline{X}$ – the arithmetic mean concentration in samples;

       n – number of samples.

Then mixing uniformity

$$\delta = 100 - v \tag{4}.$$

To determine the component X_i, we used the well-known dependence:

$$\overline{X_i} = \frac{W_2 g_{ni} - g_{bi}}{W_2 - W_1} \tag{5},$$

where W_2 – moisture content of one component;

       W_1 – moisture content of the second component;

       q_{ni} – mass of the mixture, g;

       q_{bi} – mass in water sample, g

Recalculate x_i to the accepted mass of the sample:

$$X_{in} = \frac{X_i \cdot g_n}{g_{\phi i}}$$

(6),

where $\quad$ X_i, X_n – mass of the component in the samples, actual and reduced to q_n

$q_n = 30$ g;

q_{phi} – mass of the sample, in fact.

Then, formula (2) becomes

$$\nu = \frac{100}{\overline{\overline{X}}_{in}} \sqrt{\frac{\sum_{i=1}^{n}\left(X_{in} - \overline{X}_{in}\right)^2}{n-1}},$$

(7),

where X_{in} is the average component, with

$$X_{in} = \frac{\sum_{i=1}^{n} X_{in}}{n}$$

(8),

where n is the number of samples (30 samples were taken).

Factors and their levels are determined. The most significant of them are presented in Table 2.

Table 2: Most significant factors determining the optimization parameters

Factors	Designation	Dimension	Level of variation		
			-1	0	+1
Humidity components, Wcomp.	X_1	%	8	10	12
The angle of the relational screw drum, α	X_2	degrees	4	7	10
The number of calls winding, S	X_3	PCS.	1	5	9
Diameter of relational screw drum, D1	X_4	m	0.4	0.5	0.6
The frequency of rotation of the relational screw drum, ω	X_5	s-1	1	5	9
Granulometric composition of components, σcomp.	X_6	mm	0.3	0.5	0.7
The duration of the mixing process, T	X_7	min	0.5	1.75	3.0
Duty factor, Kv	X_8		0.2	0.5	0.8
The length of the relational screw drum, l dr.	X_9	m	1.5	2.0	2.5

Investigations of the feed preparation process were carried out by a screening experiment according to the Plackett-Berman plan.

Having identified the significant factors influencing the optimization criterion from the degree of significance of the factors (δ is the heterogeneity of the mixture, is the homogeneity of the particle size distribution, N_{sp} is the specific power), we determine the operational parameters of the relational cylindrical screw drums. Various studies of the process of preparing feed (mixing the components of the feed) show that the optimal process condition is described by a second-order polynomial.

$$Y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} b_{ii} x_i^2 + \sum_{i=j}^{n} b_{ij} x_i x_j$$

$$(9).$$

Taking into account (9)

$$\frac{Y_{\delta j} - \overline{Y}_j}{\sigma_j} \geq t$$

$$(10),$$

$$b_i \rangle t_{\text{кр}} S_{bi},$$

$$(11).$$

To verify the adequacy of the obtained mathematical model of the process, the Fisher F-test was calculated.

To calculate the economic efficiency of the proposed feed preparation machine as a base, to compare the proposed feed preparation machine based on a relational screw drum, the existing technology for mixing feeds with a VKS-3M mixer is adopted. Technical and operational characteristics of the compared feed preparation machines are presented in table 3. Using standard calculation methods, the economic efficiency of the proposed technology and feed preparation machines was evaluated.

Table 3: Comparison of economic efficiency of the proposed and control feed preparation machines.

№	Indicators	KMRC5.1.a proposed	VKS-3M base	% to the base case
1	Book value of equipment, rubles	589480	609090	96.7
2	Operating expenses per year, rubles	403625.8	410347.4	98.4
3	Costs per 1 ton of feed, RUB / t	10.6	10.6	100
4	Specific capital investments, rubles/t	7859.7	8121.2	96.8
5	Presented costs, rub./t	6560.5	6689.5	98.0
6	Annual savings in operating costs rub.	6727.5	-	-
7	Economic effect, in a year rub/t.	129	-	-

According to the results, the annual economic effect of the proposed feed mixer was 129 rubles / t, and its payback period was 1.1 years. The competitiveness assessment results showed that the competitiveness level of the new feed preparation machine based on the RC5.1.a relational screw drum (KMRC5.1.a ND) is quite high and amounted to 1.38. Evaluation of economic efficiency showed the advantage of the developed device over the closest analog.

4. CONCLUSION

As a result, a device for the preparation of feed was developed, the design of which provides for the presence of a rotating relational screw drum. This allows for consistent compaction and discharge of the feed component streams, their movement from loading to unloading, which expands technological capabilities and increases the efficiency of feed preparation.

5. AVAILABILITY OF DATA AND MATERIAL
Data can be made available by contacting the corresponding authors

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