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# Substantiation Of The Method And Parameters Of The Process Of Grinding Root Crops For Lines For The Preparation Of Granulated Forages.

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**ABSTRACT**

The results of these studies are implemented in a designed line for the preparation and distribution of granulated feed mixtures for pigs. An innovative method for grinding large-sized root crops was developed, by removing chips from a product rotating around its axis using a 3-chamber disk chopper equipped with a diametrically installed partition. Obtained analytically and experimentally, the dependencies allowed us to determine the optimal values of the parameters of the innovative shredder, with a view to their subsequent use in the design and design of technical facilities for this purpose. The use of a root-binder in the production of root-grain granules will make it possible to obtain the pressed product with the required accuracy.

**Keywords:** root crop, chopper, product moisture, degree of grinding, irregularity of the granulate.

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## INTRODUCTION

The most important sources of carbohydrates, vitamins and minerals for animals, are root crops. They differ in good taste, readily eaten, have dietary properties, and therefore are of special feed value [1].

With the observance of appropriate agrotechnics, root crops can give more nutrients from a unit of area than grasses and cereals (except corn) [7-13]. Most often in the diet of animals used forage beets, carrots, sugar beet and semi sugar, Jerusalem artichoke, turnips, rutabaga and potatoes. Roots of variety kausika, and also a number of other root crops because of the big sizes and the form practically cannot be subjected to grinding by means of serially let out machines and, as a rule, are fed to an animal in unprepared kind and in small volumes that reduces efficiency of their use at feeding [2].

The aim of the research is to substantiate the method and parameters of the process of grinding root crops like kausika.

Research objectives:

- develop a functional-structural and constructive-technological scheme for grinding large-sized root crops;
- Analytically and experimentally obtain the dependencies of the criteria for optimizing the grinding process on the constructive-regime parameters;
- To offer an innovative technological solution using the obtained data.

Functional-structural and constructive-technological scheme of a 3-chamber chopper of disc-type root crops with diametrically-mounted disks in Figures 1a and 1b.

## MATERIALS AND METHODS

In accordance with the above diagrams, for the output parameters of the system, we can write the target functions in their general form:

$$-\lambda = f(PBX; D\frac{n}{k}; D\frac{k}{k}; \rho_1; \rho_2; W(t); F\frac{1}{crp}; F\frac{2}{crp}) \to opt \qquad (1)$$

$$\vartheta = f(\lambda) \to \min \qquad (2)$$

$$-N_s = f(\lambda; Q_i) \to \min \qquad (3)$$

Where $\lambda$ - degree of grinding;

$\vartheta$ - Heterogeneity of particle size distribution;

$D\frac{n}{k}; D\frac{k}{k}$ - Initial and final product diameters;

$\rho_1$, $\rho_2$ - density of root crops and particles;

W (t) - product humidity;

$F\frac{1}{crp}$ - A set of constructive-regime parameters of a disc working body with knives;

$F\frac{2}{crp}$ - A set of constructive-regime parameters of the finger working body.

## RESULTS AND DISCUSSION

According to the accepted grinding schemes of root crops with the help of the proposed chopper, the root crops are first destroyed by a certain number of particles in the form of chips, depending on the number of knives, and then on a certain number of particles of a product of finite size $d_i$.

This process of destruction occurs until the particles acquire a size smaller than (γ '+ γ) and leave the working area of the shredder. On the basis of the principle of preserving the volumes of the initial and final products

$$D^3 = \sum_{d_i=0}^{d_i=\gamma'+\gamma} \times C(d_i)\times d_i^3 + \sum_{d_i=\gamma'+\gamma}^{d_i=d_{\max}} \times C(d_i)\times d_i^3 \qquad (4)$$

Where $C(d_i)$ – number of particles with a diameter $d_i$;
$d_{max}$ – maximum size of the particle formed as a result of grinding.

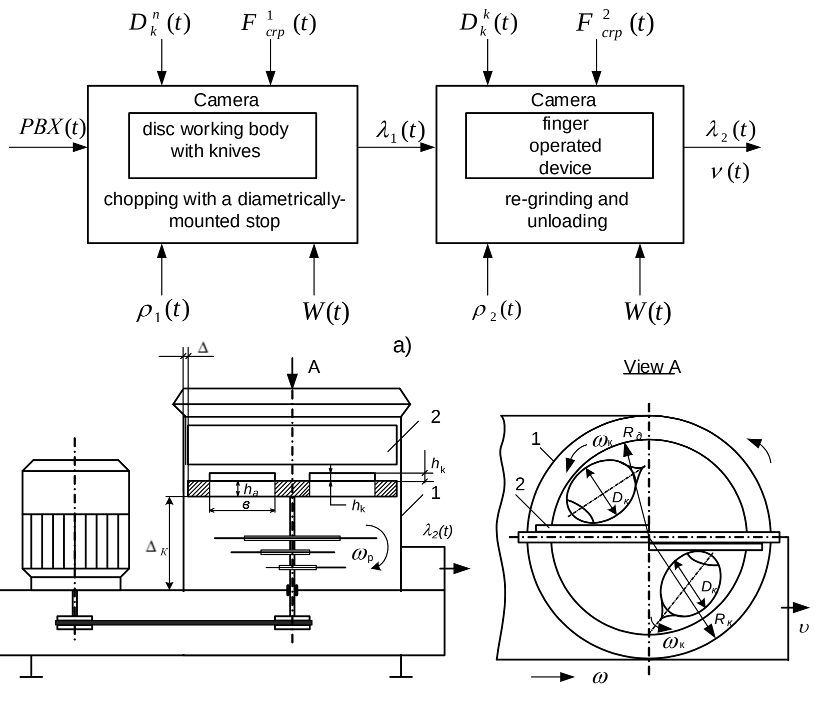


**Figure 1: Functional-structural (a) and constructive-technological (b) scheme of grinding of root crops: 1-chamber; 2 - the emphasis; 3 - finger working element**

The first term of this sum takes into account the total volume of particles whose diameters are smaller (γ '+ γ), the second term takes into account the particle volume whose diameters are larger (γ' + γ). It is most likely to be assumed that the second part of the particles will have less ability to average the moisture content through the diffusion process of its transfer, the second component with less moisture in the process of obtaining a two-component mixture.

As a result of the analysis, it is assumed that the diffusion capacity of a particle of diameter $d_i$ is proportional to its size in the power of *Z*

$$k_d(d_i) = \xi \times d_i^z \qquad (5)$$

where $\xi$ - coefficient of proportionality.

Then the diffusion capacity for averaging the moisture in the two-component mixture of all obtained as a result of the destruction of the root crop particles will be

$$k_d(\sum_{i=1}^{n} d_i) = \xi \times \sum_{d_i=(\gamma'+\gamma)}^{d_i=d_{\max}} C(d_i) \times d_i^z \qquad (6)$$

The mathematical expectation of the average size (diameter) of the particles formed as a result of the first grinding of the root crop

$$\overline{d_1} = \frac{\sum_{d_i=0}^{d_i=d_{\max}} C(d_i) \times d_i}{\sum_{d_i=0}^{d_i=d_{\max}} C(d_i)} \qquad (7)$$

In this expression, the numerator is the total number of particles formed as a result of the first grinding (the first stage of destruction).

We denote it by $n_1$ and then it follows from expressions (4) and (7) that $D^3 = d_i^3 \times n_1$, so

$$\overline{d_1} = D \big/ (n_1)^{1/3} \qquad (8)$$

Denoting $d_i$ as the probability of comparing this averaged dimensional characteristic $\overline{d_1}$ with size (γ '+ γ) at $\overline{d_1} > (\gamma'+\gamma) \times d_1 = 1$ at $\overline{d_1} < (\gamma'+\gamma) \times d_1 = 0$, but in all intermediate cases $0<d_1<1$, then from expressions (6) and (8) we obtain

$$k_d(d_1) = \xi \times d_i \times n_1 \times (\frac{D}{(n_1)^{1/3}})^Z = \xi \times d_i \times n_1^{1-\frac{Z}{3}} \times D^Z \qquad (9)$$

For the case when newly formed particles with an average diameter *$d_1$* are again destroyed by $n_2$ particles of medium diameter $\overline{d_2}$, by analogy we find that

$$\overline{d_2} = D \big/ (n_2^{1/3} \times n_1^{1/3}) \qquad (10)$$

Then for the particles formed as a result of the *i-th* destruction we have

$$\overline{d_i} = D \big/ P_{i=1}^{i} \times n_i^{1/3} \qquad (11)$$

$$k_d(d_i) = \xi \times P_{i=1}^{i} d_i \times n_i^{1-\frac{Z}{3}} \times D^Z \qquad (12)$$

For the subsequent realization of the mixing process, the total diffusion capacity of all particles of diameter D and all of its newly formed, as a result of m fractures, is

$$k_d(D) = \sum_{i=0}^{i=m} k_d(d_i) \qquad (13)$$

Taking into account expressions (8) - (10), we obtain

$$k_d(D) = \xi \times D^Z \times \sum_{i=0}^{i=m} P_{i=0}^{i} d_1 \times n_i^{1-\frac{Z}{3}} \qquad (14)$$

Component for $\xi \times D^Z$ by physical essence is the degree of grinding of root crops

$$\lambda' = \sum_{i=0}^{i=m} P \frac{i}{i=0} d_1 \times n_i^{1-\frac{Z}{3}} \qquad (15)$$

This index also takes into account the number of times the diffusion capacity of the obtained particles increases to averaged moisture in the two-component mixture when mixed with a component of lower humidity by the time of their final production.

The value $\lambda'$ depends on the number of newly formed particles *n* after removing the chips from the root crop and the number of destructions - *m*. The value of $d_i$ decreases rapidly, since the soft particles of the root crops are easily destroyed by a large number of small ones, and consequently the series (15) converges rapidly.

The structure of this series is such that for its evaluation it is necessary to know only the wide variations of *n, α, m* and not their specific values.

Analysis of expression (15) also shows that $\lambda'$ it depends on the physical and mechanical properties of root crops, the way they are destroyed by a disk chopper, and also its design-regime parameters, which can be determined by further theoretical analysis and experimental studies.

Since the physical meaning of the indicator $\lambda'$ is similar to the degree of refinement, then

$$\lambda' = \frac{D_{kp}}{d_r} \leq [\lambda] \qquad (16)$$

The throughput of a disc type grinder, according to its first stage (Fig. 1), depending on the size-mass and physico-mechanical characteristics of root crops, can be represented as

$$Q_g = 2 \times V_{kp} \times \rho_1 \times \omega_d \qquad (17)$$

where $V_{kp}$ - root volume;

$\rho_1$ - root material density;

$\omega_d$ - angular velocity of the disc shredder.

At the same time, taking into account the removed shape of the shavings, in the form of a ball belt, the throughput of the first stage of the shredder is

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$$Q_g = \frac{\lambda_1 \times h \times (3 \times r_1^2 + 3 \times r_2^2 + h^2) \times \rho_2}{t_g^I} \qquad (18)$$

where $\lambda_1$ - degree of grinding after the product passes through the first stage of the shredder;

*h* - height removed from the root, taken for a ball, chips;

*r₁* and *r₂* - radius of the shavings along its upper and lower sections corresponding to the parameter *h*;

$t_g^I$ - length of the grinding of the root crop by the first step;

Equating the right-hand sides of expressions (17) and (18) and solving the resulting equality with respect to $t_g^1$ we get

$$t_g^I = \frac{6 \times \lambda_1 \times h \times (3 \times r_1^2 + 3 \times r_2^2 + h^2) \times \rho_2}{\pi \times D_{kp}^3 \times \rho_1 \times \omega_d} \qquad (19)$$

For the stage of passing the second stage product, we have

$$t_g^I \approx t_g^{II} = \frac{0.523 \times \lambda_1 \times \lambda_2 \times d_r^3 \times \rho_3}{D_{kp}^3 \times \rho_1 \times \omega_d} \qquad (20)$$

This dependence gives a complete picture of the regularities of the process of grinding the root crop by a disk chopper of the proposed type.

At the same time, for the second stage of grinding, we can write down that

$$Q_g = \frac{14.4 \times R_k \times L_k \times \Delta_k \times \rho_3^{'} \times \mu_1^{'} \times \upsilon^{1/(1-\vartheta)\times(\lg k_1 - \lg k_2)}}{k_1 - k_2} \qquad (21)$$

where $R_k$ - radius of chopper chamber;

$L_k$ - circumference along the radius of the chamber;

$\Delta_k$ - height of the chopper chamber of the secondary grinding apparatus (air-product layer);

$\mu_1^{'}$ - mass fraction of particles in the volume of the disk chopper chamber;

$k_1$ and $k_2$ - values of the intensity constants of grinding;

$\upsilon$ - heterogeneity of the granulometric composition of the final product.

The energy intensity of the process of obtaining root particles of the desired final size with the help of a two-stage disc type grinder - $N_E$, and taking into account the achievable grinding ratio, will be determined as

$$N_E = {N_g}/{Q_g} \times \sum_{i=0}^{i=m} P_{i=0}^{i=l} d_i \times n_i^{1-(Z/3)} \qquad (22)$$

In the same time

$$N_g = Q_g \times A_g \qquad (23)$$

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where $A_g = C_1 \times \lg \lambda^3 + C_2 \times (\lambda - 1)$, according to the data of professor Melnikov S.V.

The total power required for the drive of the disk chopper of root crops of the proposed construction is

$$N = (1.15 - 1.20) \times N_g \qquad (24)$$

On the basis of a priori ranking of the factors, the main ones are identified, which have the greatest impact on quality indicators, such as the heterogeneity of the fractional composition of the crushed product - $\upsilon$% and degree of grinding $\lambda_n$. In addition, the dependence of the unit power consumption on the selected factors, $N_E, \frac{\text{kWh}}{t}$.

The main factors identified are the following:

$\omega_k, s^{-1}$ - angular rotation speed of a blade with knives;
γ, *deg*. - cutting edge angle;
$h_k$, *mm* - knife setting height relative to the disk surface.

Thus, it was necessary to establish functional dependencies in their general form:

$$\left.\begin{aligned} \vartheta &= f(\omega_d; \gamma; h_k) \to \min \ ; \\ \lambda_n &= f(\omega_d; \alpha_2; h_k) \to opt \ ; \\ N_E &= f(\omega_d; \alpha; h_k) \to opt \ ; \end{aligned}\right\} \qquad (25)$$

Based on the results of the analysis, mathematical models are obtained in their decoded form:

$$\begin{gathered} \vartheta = -2585 + 25.536 \times \omega_d + 8.155 \times \gamma + 67.985 \times h_k + 0.350 \times \omega_d \times \gamma - \\ -0.325 \times \omega_d \times h_k + 0.450 \times \gamma \times h_k - 0.059 \times \omega_d^2 - 0.183 \times \gamma^2 - 2.904 \times h_k^2 \to \max \end{gathered} \qquad (26)$$

$$\begin{gathered} \lambda_n = -17219 + 147.18 \times \omega_d + 114.17 \times \gamma + 164.18 \times h_k - \\ -0.367 \times \omega_d^2 - 1.268 \times \gamma^2 - 21.554 \times h_k^2 \to opt \end{gathered} \qquad (27)$$

$$\begin{gathered} N_E = 27.239 - 0.226 \times \omega_d - 0.102 \times \gamma + 0.198 \times h_k - 0.00037 \times \omega_d \times \gamma - \\ -0.00043 \times \omega_d \times h_k + 0.00065 \times \omega_d^2 + 0.019 \times \gamma^2 + 0.0821 \times h_k^2 \to opt \end{gathered} \qquad (28)$$

The analysis establishes the optimal values of parameters of the process of grinding of root crops: the angular velocity of rotation of the disk - $\omega_d = 200 s^{-1}$, cutting edge angle - $\gamma = 45 - 46^\circ$, and blade height above the disc - $h_k = 3.8 - 4.1$ mm, under which $\vartheta = 97.2\%, \lambda_n = 380.2, N_E = 2.53 \frac{\text{kWh}}{t}$

The results of these studies are implemented in a projected line for the preparation and distribution of granulated fodder mixtures to pigs (Figure 2) [3].

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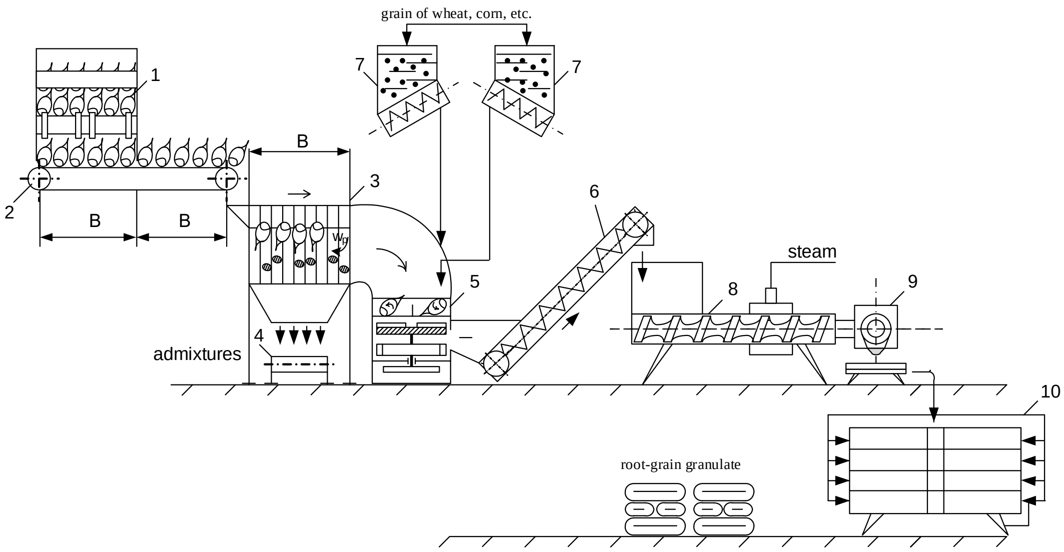


**Figure 2: Structural and technological scheme for the preparation of innovative products based on root-grain crops.**

1 - feeder of root crops; 2 - transverse conveyor; 3 - cleaner; 4 - conveyor for the removal of impurities; 5 - chopper; 6 - receiving conveyor; 7 - grain dispensers; 8 - feeder; 9 - press granulator for carrot extract; 10 - drying plant "ESPIS-4" Universal.

## CONCLUSION

An innovative method for grinding large-sized root crops was developed, by removing chips from a product rotating around its axis using a 3-chamber disk chopper equipped with a diametrically installed partition.

Obtained analytically and experimentally, the dependencies allowed us to determine the optimal values of the parameters of the innovative shredder, with a view to their subsequent use in the design and design of technical facilities for this purpose.

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