CODEN [USA]: IAJPBB ISSN: 2349-7750

INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES

http://doi.org/10.5281/zenodo.2628865

Available online at: http://www.iajps.com Research Article

IMPROVING THE EFFICIENCY OF THE KUUSIK PREPARATION LINE FOR FEEDING, TAKING INTO ACCOUNT ITS DIMENSIONAL FEATURES

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Article Received: February 2019 **Accepted:** March 2019 **Published:** April 2019

Abstract:
On the basis of the adopted approaches, which take into account the peculiarities of the raw materials in the form of a Kuusik, a rational system of machines and its parameters are substantiated, ensuring an increase in the efficiency of the line for preparing and using this root crop in feeding animals.

Keywords: *efficiency increase, work, feedstock, processing of a Kuusik, feeder, cleaner, grinder, distributor, productivity, parameters, power.*

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Please cite this article in press Sergei Dotsenko et al., ***Improving The Efficiency Of The Kuusik Preparation Line For Feeding, Taking Into Account Its Dimensional Features.,*** *Indo Am. J. P. Sci, 2019; 06(04).*

INTRODUCTION:

It is known that the root crops in the fodder balance of the Russian Federation occupy a significant place and are fed to farm animals of all kinds. At the same time, the cultures belonging to this group of feed, with the observance of the appropriate agrotechnology, give more nutrients per unit area than grasses and grains combined (except for corn) [1].

Of particular interest, of this type of feed, is a hybrid of a Kuusiku swede variety, which yields a crop of 800–900 centners per hectare and 200–300 centners per hectare of green leaf [1].

However, due to the large dimensions of such roots, their mechanized preparation for feeding animals difficult. At the same time, the quality indicators for the processes of their supply, cleaning from soil impurities and grinding do not meet the requirements of zootechnical requirements.

In this regard, it is important to solve the problem of obtaining scientifically based data for designing and designing a machine system for the effective use of Kuusik type root crops in fodder production.

PURPOSE OF THE STUDY:

Improving the efficiency of machinery and equipment in the line of preparation of feed using Kuusiku.

RESEARCH TASKS:

- on the basis of the developed technological scheme for the preparation of fodder products using the Kuusik, to propose a set of interrelated technical parameters with respect to the parameters, ensuring the complex processing of Kuusik-type root crops;
- for the accepted set of interconnected by the parameters of technical means to justify their parameters;
- to offer an effective technological line for the implementation of these processes.

Based on the analysis performed (1), it was found that the most effective technological scheme for transforming feedstock in the form of a Kuusik into ready-made feed products is as follows:

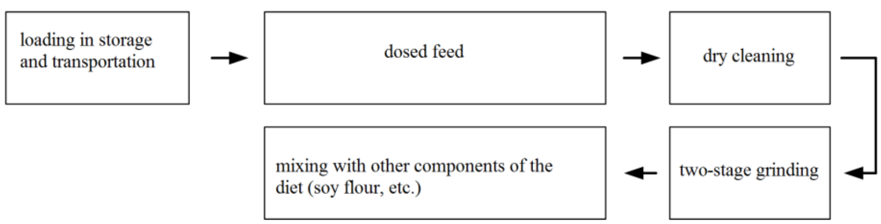

Figure 1: Flow chart for the preparation and feeding of a kuuzik for animals

A mobile feeder has been proposed as a device for feeding kouziku root crops - a feeder for which parameters are justified to ensure its efficient operation. In the proposed feeder [2] for the implementation of a uniform supply of root crops by the feeder it is necessary to choose the correct values of the parameters – H_1, H_2, H_3 (figure 2).

Their values were substantiated taking into account the dimensional characteristics of the fruits of a Kuusik of length - l and diameter - D.

Based on experimental studies, it has been established that these parameters vary within the following limits $l=0,2\text{-}0,45$ *m*, and $D=0,1\text{-}0,22$ *m*.

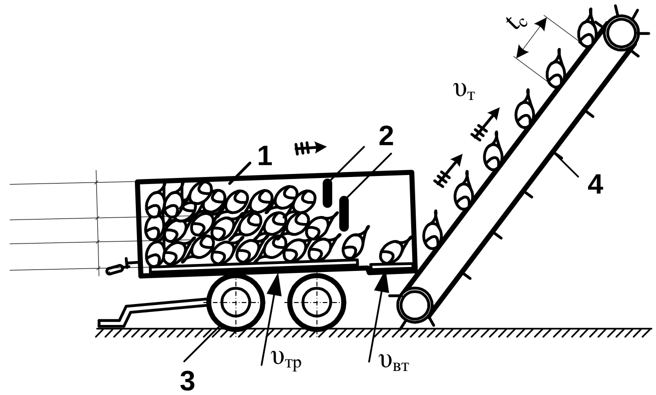

Figure 2: Constructive-technological scheme of a mobile feeder-dispenser of large-sized root and tuber crops
1- bunker; 2- dosing elements; 3- chassis; 4- scraper conveyor; $\upsilon_{Тр}$ - feed conveyor speed; $\upsilon_{ВТ}$ - unloading conveyor speed; υ_c - scraper conveyor speed; t_c - scrapers pitch.

Therefore, in view of the data obtained, it can be assumed that $H_1=H_2=H_3 \geq D_{max}$.
With these values of the feeder parameters, there is a tiered shift of the roots in the feeder hopper with the height of the tier not less than $H_1 \approx H_2$, which ensures the smooth passage of root crops in the gap size $H_3 \approx D_{max}$ and an interval of time equal to – t_{gr}, that, ultimately, will allow to obtain a feed stream with a uniform feed not lower than the required – [δ_n] ≤ ± *15%*.
To implement the process of dry cleaning the roots of the kouziku, an original method and technical device was proposed for its implementation [3] (Figure 3)

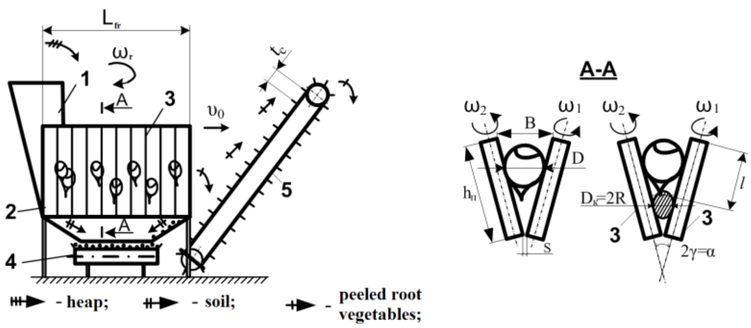

Figure 3: Constructive-technological scheme of the device for dry cleaning of tubers: a boot node; 2- V-shaped working body; 3- conveyor belt; 4- soil conveyor; 5- receiving and unloading scraper conveyor; ω_r - root angular velocity; ω_1 - angular velocity of the right conveyor; ω_2- angular velocity of the left conveyor; υ_o - linear velocity of the root.

MATERIALS AND METHODS:

The analysis found that the parameters of the cleaner with $V-$ figurative body, largely depend on the initial contamination of the pile - $\delta_c^н$, humidity - $w_в$ and the diameter of soil clumps $D_к = 2R,$ as well as a number of other less significant factors.

The principle of operation of the cleaner of this type is based on the possibility of giving the root and lumps of soil complex movement, including rotational around its axis - ω_c and progressive - υ_0.
For the quality of the process of cleaning root vegetables, it is necessary that the following condition be met [4]

$$\lambda_0 = \upsilon_2 / \upsilon_1 > 1, \quad (1)$$

where λ_0 - indicator of the kinematic mode of the cleaner;
υ_1 - speed of the right conveyor belt;
υ_2 - speed of movement of the canvas of the left conveyor;
At the same time, the duration of the destruction - t_p clump of soil radius R will make

$$t_p \leq 2\pi \cdot \left\{ \left[R_0 + \sum_{i=1}^{n} \left(R_i - \frac{h_l}{2 \cdot \pi} \right) \right] \right\} \cdot \frac{2 \cdot R}{\upsilon_0 \cdot S}, \quad (2)$$

where $R, R_i, R_0 -$ the initial, current and final radii of soil lumps, taking into account the soil layer removed from them - h_l ;

$n -$ the number of removed soil layers (taken as equal to the number of turns of the soil lump);

$S -$ the size of the lower gap between the conveyor belts (Figure 3).

Bandwidth Q_0 cleaner determined by parameter υ_0

$$Q_0 = 0,5 \cdot (B + S) \cdot h_n \cdot \upsilon_0 \cdot \cos\alpha \cdot \rho_h \cdot \psi, \quad (3)$$

where $B, S -$ the upper and lower bases of the trapezium, for which the cross section is taken $V -$ figurative working body;

$h_n -$ conveyor belt width;

$\alpha -$ installation angle of conveyor blades (figure 3);

$\rho_h -$ heap density;

$\psi -$ intertransporter space filling ratio.

Energy costs for the cleaner drive were determined taking into account the length of the conveyor cloths – L_{con} and indicator - λ_0 :

$$N_0 = \left\{ \frac{[\tau] \cdot A + L_{con} \cdot f \cdot P}{2 \cdot D_{\max} \cdot \sin\alpha} \right\} \cdot \upsilon_0 \cdot (1 + \lambda_0), \quad (4)$$

where $[\tau] -$ ultimate shear stress of soil shift from the surface of root crops and soil lumps;

$A -$ area from which the soil is shifted;

L_{con} - conveyor belt length;

$f -$ coefficient of friction of a pile of bars;

$P -$ mass of root crops and soil lumps in $V -$ shaped gap device.

For efficient grinding of this type of root vegetables, including frozen ones, a disk-type chopper is proposed [5] (Figure 4)

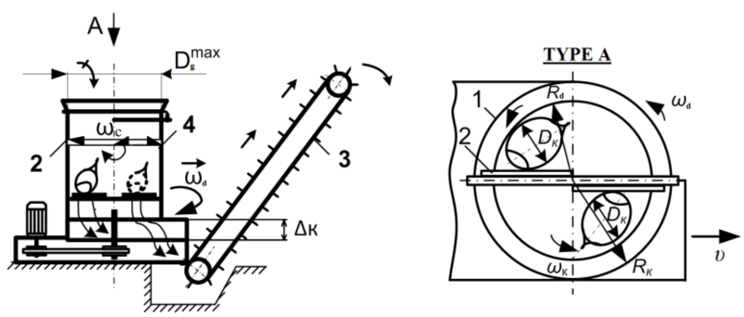

Figure 4: Constructive-technological scheme of a shredder for a kouziku: 1- disk shredder; 2- stop; 3- scraper conveyor.

According to the physical meaning of the indicator λ similar to the grinding degree then

$$\lambda = \frac{D_{kp}}{d_r} \leq [\lambda], \quad (5)$$

Where [λ] - – permissible degree of grinding.

The throughput capacity of a disk-type shredder, according to its first stage (Figure 4), depending on the size-mass and physico-mechanical characteristics of root crops can be represented as

$$Q_i = 2 \times V_{kp} \times \rho_1 \times \omega_d, \quad (6)$$

where V_{kp} - volume of root; ρ_1- плотность материала корнеплода;

ω_d - angular speed of the chopper disk (Figure 4).

At the same time, taking into account the removable form of chips in the form of a spherical belt, the throughput of the first stage of the chopper is equal to

$$Q_i = \frac{\lambda_1 \times h_{sh} \times (3 \times r_1^2 + 3 \times r_2^2 + h_{sh}^2) \times \rho_2}{t_{gr}^I}, \quad (7)$$

Where λ_1 - degree of grinding after the passage of the product of the first stage grinder;

h_{sh} - высота снимаемой с корнеплода, принятого за шар;

r_1 and r_2 - chip radii by its upper and lower sections corresponding to the parameter h_{sh}; t_{gr}^I - duration of the grinding of the first step of the root.

Expression (7) is an analytical model characterizing the process of grinding a conditionally “spherical” fruit.

Equating the right sides of expressions (6) and (7) and solving the resulting equality with respect to t_{gr}^I we get

$$t_{gr}^I = \frac{6 \times \lambda_1 \times h_{sh} \times (3 \times r_1^2 + 3 \times r_2^2 + h_{sh}^2) \times \rho_2}{\pi \times D_{kp}^3 \times \rho_1 \times \omega_d} \quad (8)$$

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

$$t_{gr}^{II} \approx t_{gr}^{II} = \frac{0,523\times\lambda_1\times\lambda_2\times d_r^3\times\rho_3}{D_{kp}^3\times\rho_1\times\omega_d} \qquad (9)$$

Expression (9) is an analytical model of the grinding process of root crop particles, which interconnects the technological and design-mode parameters of a 2-chamber chopper.

This relationship gives a complete picture of the laws governing the process of chopping a root crop with a disk chopper of the proposed type.
At the same time, for the second grinding stage, it can be written that

$$Q_i = \frac{14,4\times R_k\times L_k\times\Delta_k\times\rho_3'\times\mu_1'\times\nu^{1/(1-\nu)\times(\lg k_1-\lg k_2)}}{k_1-k_2} \qquad (10)$$

where R_k - shredder camera radius;
L_k - circumference of the camera radius;
Δ_k- height of the shredder chamber of the secondary grinding apparatus (air product layer);
μ_1 - mass fraction of particles in the volume of the chamber disk grinder;
k_1 and k_2 - grinding intensity constants;
υ - heterogeneity of the particle size distribution of the final product.

On the basis of the approaches adopted, the authors of the article have developed a technological line for the preparation and distribution of feed mixtures (wet masses) to pigs (Figure 5).

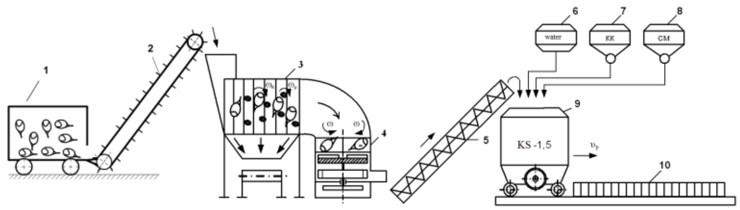

Figure 5: Constructive-technological scheme of the line for the preparation and distribution of complete feed mixtures, using Kuusiku, for pigs

According to the developed scheme, the root crops, subjected to dosing and dry cleaning, with the help of devices -1, -3, are fed into a two-section chamber of a disk shredder -4. Further, the crushed mass of root vegetables is fed into the bunker - 9 distributor KS-1.5, where it is mixed with the end feed and soy flour. The quality of the prepared feed mixture depends on the degree of grinding of root crops, which is associated with the efficiency of the redistribution of moisture between the components of the dry and wet physical form.

Diffusion ability $R_d(D)$ process of redistribution of moisture between the particles of the components identified as

$$R_d(D) = \xi\cdot D^z\cdot\sum_{l=0}^{l=m}\prod_{i=0}^{l}\alpha_i\cdot n_l^{1-\left(\frac{z}{3}\right)}, \qquad (11)$$

Where $D^z -$ total particle diameter;
$m-$ crushing number;
$\xi-$ coefficient of proportionality;
$\alpha_i -$ probability of getting particles by $i-$th size;
$n-$ total number of particles.
Component at $\xi\cdot D^z$ on the physical essence there is a degree of grinding root vegetables:

$$\lambda = \sum_{l=0}^{l=m}\prod_{i=0}^{l}\alpha_i\cdot n_l^{1-\left(\frac{z}{3}\right)}, \qquad (12)$$

RESULTS AND DISCUSSION:

Taking into account this approach, experimentally, mathematical models for evaluating the process of grinding the Kuusik root crops were obtained and the optimal parameters of the proposed shredder were substantiated.

The resulting models are as follows:
- for the heterogeneity of the resulting particles:

$$\nu = -2585 + 23,536\cdot\omega_d + 8,155\cdot\gamma + 67,985\cdot h_n + 0,350\cdot\omega_d\cdot\gamma - 0,325\cdot\omega_d\cdot h_n + 0,450\cdot\gamma\cdot h_n - 0,059\cdot\omega_d^2 - 0,183\cdot\gamma^2 - 2,904\cdot h_n^2 \to \max; \qquad (13)$$

- for the degree of grinding:

$$\lambda_n = -17219 + 147,18\cdot\omega_d + 114,17\cdot\gamma + 164,18\cdot h_n - 0,367\cdot\omega_d^2 - 1,268\cdot\gamma^2 - 21,554\cdot h_n^2 \to opt \qquad (14)$$

- for energy intensity:

$$N_{sp} = 27,239 - 0,226\cdot\omega_d - 0,102\cdot\gamma + 0,198\cdot h_n - 0,00037\cdot\omega_d\cdot\gamma - 0,00043\cdot\omega_d\cdot h_n + 0,0019\cdot\gamma^2 + 0,0821\cdot h_n^2 \to \min, \qquad (15)$$

The angular velocity of the disk rotation of the chopper is equal to $\omega_d = 200s^{-1}$;

The angle of the cutting edge of the knife is γ=45-46º.

The installation height of the knife above the disk is equal to $h_n = 3{,}8 - 4{,}1mm$, at which $\nu = 97{,}2\%$, $\lambda_n = 380 - 400$ and $N_{sp} = 2{,}53\text{kW / h}$.

For the process of obtaining the feed mixture, based on shredded root vegetables Kuusiku, soy flour and concentrated feed, taking into account the duration of mixing – t ,calculated dependence of the batch mixer performance is obtained:

$$\theta_{mix} = \frac{M_{mix} \times \alpha_k + M_{mix} \times \alpha_{mix} + M_{mix} \times \alpha_{kk}}{t_{opt}} = \frac{E \times \sum M_{mix} \times \alpha_i}{\ln(i_{o/\gamma})}$$

(16)

where M_{mix} – weight of the mixture by diet;

α_i – mass fraction i –th component;

E - parameter characterizing the slowing down of the mixing process;

i_0 – parameter characterizing the slowing down of the mixing process; i –th component in the mixture.

For the process of mixing components by the distributor-mixer KS-1.5, the homogeneity of the mixture, depending on its parameters, can be estimated according to the following mathematical model

$$\theta_{mix} = 3710{,}6 + 14{,}186 \cdot \omega_{sc} + 18{,}713 \cdot \lambda_n + 7{,}245 \cdot t_{mix} - 0{,}840 \cdot \omega_{sc}^2 - 0{,}023 \cdot \lambda_n^2 - -0{,}671 \cdot t_{mix}^2 \to \max,$$

(17)

and energy intensity

$$N_{sp} = 11{,}722 + 0{,}003 \cdot \omega_{sc} - 0{,}005 \cdot \lambda_n - 0{,}002 \cdot t_{mix} - 0{,}0002 \cdot \omega_{sc} \cdot \lambda_n + +0{,}004\omega_{sc}^2 + 0{,}00007 \cdot \lambda_n^2 + 0{,}0002 \cdot t_{mix}^2 \to \min;$$

(18)

where the angular velocity of the vertical auger is equal to $\omega_{sc} = 7{,}7 - 8{,}5s^{-1}$;

degree of grinding of root vegetables, equal $\lambda_n = 398 - 404$;

mixing time equal to $t_{opt} = 4{,}7 - 5{,}4\,\text{min},$ at which $\theta_{mix} = 98{,}9\%$, and $N_{sp} = 0{,}158\,\text{kW / h}/t$.

CONCLUSION:

As a result of the research, data were obtained that allowed the design and development of technology to implement the process of mechanized feeding of pigs using Kuusiku root vegetables.

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