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MANUFACTURING ENGINEERING AND AUTOMATED PROCESSES

МАШИНОБУДУВАННЯ, АВТОМАТИЗАЦІЯ ВИРОБНИЦТВА ТА ПРОЦЕСИ МЕХАНІЧНОЇ ОБРОБКИ

UDC 631.361.8

EXPERIMENTAL INVESTIGATIONS OF THE HOMOGENEITY COEFFICIENT OF ROOT CROPS CRUSHED PARTICLES

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Summary. *In the general structure of livestock products manufacturing up to 50 ... 70% of all costs are accounted for the share of preparation of various juicy forages from root crops. Screw conveyors are widely used in the agrarian production sector for moving, mixing, dosing products, etc. Improvement of the existing structures of screw conveyors and substantiation of their rational parameters and operating modes are important scientific tasks. The objective of the investigation is to increase (expand) the functional abilities of technological operations of screw conveyors by developing the combination of operating elements that ensure the simultaneous shredding and movement of roots in the process of their preparation and processing on juicy feed. The main objectives of the research, which ensure the implementation of the stated goal, is to prove the parameters of the combined working body screw conveyor-shredder, which is used in the processing lines of roots. The research results are the further steps in developing the methodology for justifying the parameters of operatiing bodies and modes of screw mechanisms operation.*

Key words: *working body, Г-shaped knife, spiral turn, plan-matrix, diameter, rotational frequency.*

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Statement of the problem. The development of high-efficiency technological processes of simultaneous grinding and moving, both single lump and bulk products of agricultural production requires an integrated scientific approach to solving the engineering problem of increasing the technological performance and expanding the technological capabilities of screw conveyors-shredders [1–3]. The screw conveyors perform various technological tasks: mixing, crushing, dosing of products during the preparation and distribution of feed; material etching; crop and livestock products movement, etc. [7–9].

The set tasks are solved on the basis of the development of methodology and methodology for the substantiation of the technological process and the calculation of technological parameters and design-kinematic parameters and modes of screw conveyers.

Improving the productivity of screw mechanisms and production lines of any manufacturing complexes in general, including agricultural processing machines, depends largely on the throughput of loading bins and the screw conveyor functioning not only as operating bodies for product movement, but also those capable of performing various operations of grinding, mixing, dispensing and the like.

Screw transport mechanisms and screw conveyors, as a separate engineering element of transport mechanisms, are widely used in the construction of agricultural machines – grain harvesters and beet harvesters, fertilizer machines, crushers, seed etchers, etc. [10], as well as in overhaul machines designs for materials loading and transportation due to their simplicity of construction, maintenance and the ability of complete or partial material unload at any point of tecological line [11].

The combination of performing one or more technological operations, along with the materials transportation peculiar for combined screw conveyors, is their defining feature.

Therefore, the development of advanced designs of screw conveyors, which ensure the simultaneous grinding and transportation of materials and substantiation of the rational parameters of the transport mechanisms operating elements, is an important scientific task.

According to [4], the specifi gravity of screw conveyors in loading-unloading operations is 40–45%. Analysis of the current state of screw transport mechanisms operation [12–14] showed that there are significant suppositions for further research aimed at the development and use of energy-efficient, high-tech combined screw conveyors that provide efficient performance of related functional operations, as well as transportation and simultaneous grinding of raw materials from agricultural products manufacturing while processing.

The objective of the paper is to improve the technological parameters of the process of simultaneous grinding and transportation of root crops by developing and substantiating the parameters of the conveyer-shredder operating elements.

Statement of the problem. Improvement of economic indicators and technological efficiency of processing enterprises functioning is achieved by the development and implementation into production the energy-saving technologies and technical means intended for preparation and processing of raw materials of the agro-industrial sector.

Improvement of existing designs of screw transport mechanisms and substantiation of their rational parameters and operation modes enables to increase significantly productivity and reliability of technological operations.

Therefore, during their design should take into account the specific technical requirements and functional and operational characteristics of machines for relevant work performance, as well as the features of transport-technological processes, agrobiological and physical-mechanical properties of products to be transported shoul be taken into account.

In order to increase the efficiency screw mechanisms operation, we proposed on the basis of invention the combined root crops screw conveyor-shredder [17], which allows to expand the screw mechanisms functionality, Fig. 1.

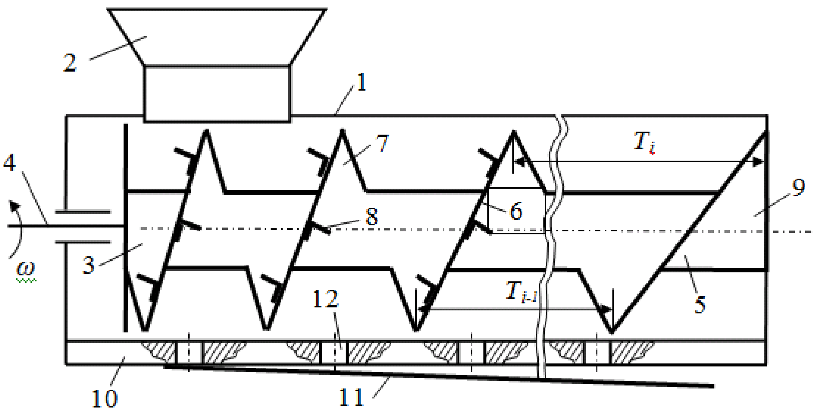

Figure 1. Design-layout scheme of the screw conveyor-shredder with combined operating element: 1 – casing; 2 – bunker; 3 – screw; 4 – drive shaft; 5 – drum; 6 – screw line; 7 – spiral turn; 8 – Г-shaped knife-shredder; 9 – unloading part; 10 – bottom part; 11 – guide tray; 12 – holes

The screw conveyor-shredder consists of acasing 1, on top of which a loading bunker 2 is attached. In the casing, which can be placed at angle to the horizon, a screw 3 is mounted. The screw 3 is made in the form of the drive shaft 4 on which the drum 5 is mounted. The drive shaft 4 rotates with angular velocity ω.

The drive shaft drum along the screw line 6 spiral turns 7 are fixed. On the inner and outer sides of the spiral turns relatively to the roots movement direction the plate Γ-shaped knife-shredders 8 are mounted radially. The screw line is made with variable step, in this case step T of the spiral turns increases with constant angle of the helical line elevation toward the unloading part 9 of the guide tube.

A guide tray 11, which covers the lower casing part, is mounted below the lower part of the guide tube at a certain angle to the horizon. The lower part of the casing, which is aligned with the guide tray, has through-holes 12 made along and across the lower part of the casing.

The screw conveyor-shredder operates in the following way.

Root crops are fed into the bunker 1, which is then moved into the casing 2 to the screw 3, or to the plate Γ-shaped knife-shredders 8. During the drive shaft 4 rotation and, relatively, the drum 5 and the Γ-shaped knife-shredders, the root crops are grounded and simultaneous movement of the crushed particles by spiral turns 7 towards the unloading part 8 of the casing is performed.

Simultaneously with the grinding and moving of the root particles, there is a significant release and accumulation of juicy liquid formed during the processed products grinding. In this case, the accumulated juicy liquid through the through holes 12 flows to the guide tray 11, and then – to its destination.

To solve the problem of optimization of the rational parameters of the combined screw conveyor-shredder operating elements, it is necessary to carry out experimental investigations of the quality of root crops shredding, the coefficient of uniformity of root crops shredded parts is determining.

Statement of the basic material. Outline of the main material. The objective of the experimental investigation of the uniformity of root grinding $\lambda_к$ was to develop or determine the empirical approximation model (regression equation) characterizing the regularities of the coefficient $\lambda_к$ change depending on the number $z_н$ installed Γ-shaped knife-shredders on one turn, the rotation frequency $n_ш$ of the screw and the operating screw length L_p, while implementing the planned three-factor experiment of PFE 3^3 type. The structural diagram of the model planned three-factor experiment of PFE 3^3 type is shown in Fig. 2, construction diagram of the laboratory installation – in Fig. 3, the general view of the mock-up sample of the screw conveyor-shredder experimental installation – in Fig. 4.

The approximating function describing the character of the variation in the root shredder ing uniformity $\lambda_к$ by screw conveyor-shredder, was determined as mathematical model of the logarithmic function with the largest value of the multiple determination coefficient D_μ = 0,965

$$\lambda_k = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_3 \ln x_3 , \qquad (1)$$

where b_0 , b_1 , b_2 , b_3 – are coefficients of values x_i; x_1 , x_2 , x_3 are coded factors.

The natural numerical values of the coefficients b_0 , b_1 , b_2 , b_3 of the regression equation, which is given in the form functional dependence $\lambda_k = f_\lambda (z_н ; n_ш ; L_p)$ are as follows: $b_0 =$-50, 79; $b_1 =$52, 9; $b_2 =$4, 4; $b_3 =$ 12, 75.

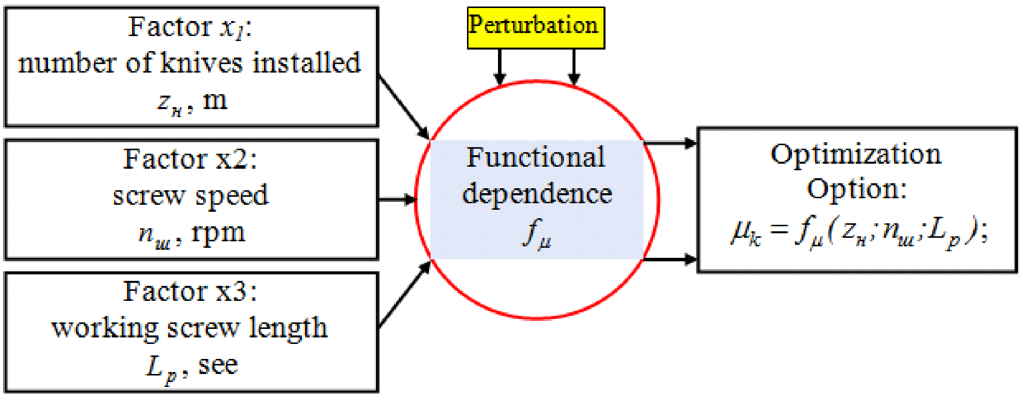

Figure 2. Scheme of the model of planned three-factor experiment of PFE 33 type

The statistical significance of b_1, b_2, b_3 coefficients of the regression equation (1) was performed using t – Student test. It was found that all the calculated values of b_1, b_2, b_3 coefficients of the regression equation, which were determined according to the standard methodology, are significant.

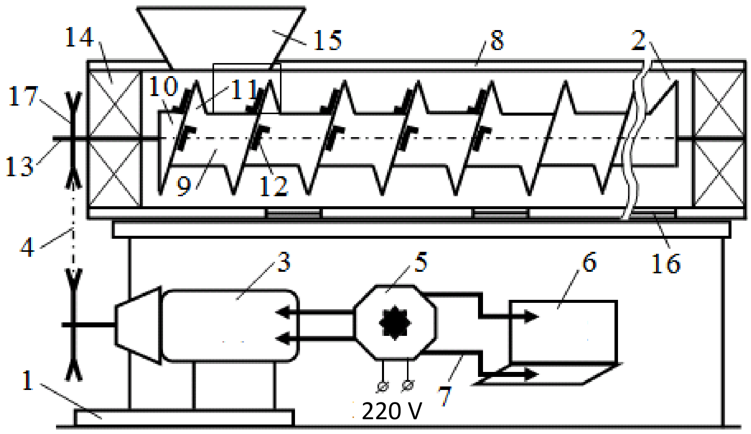

Figure 3. Constructive scheme of the laboratory installation: 1 – main frame; 2 – screw conveyor-shredder; 3 – electric motor; 4 – V-belt drive; 5 – Altivar 71 device; 6 – personal computer; 7 – switching connection; 8 – casing; 9 – screw; 10 – drum; 11 – spiral turn; 12 – Г-shaped knife-shredder; 13 – shaft; 14 – bearing housing; 15 – bunker; 16 – damper 17 – pulley

The verification of the empirical model, that is, the correspondence of the obtained theoretical distribution of random values, determined by the regression equation and the corresponding values of the real experimental data array, was performed according to F – Fisher criterion, the table value of which was determined under $F_T(0{,}05; f_{ag}; f_u)$ condition.

According to the results of carried out PFE 3^3, the final form of the regression equation for the change of the root crops shreddering homogeneity coefficient $\lambda_к$ by the screw conveyor-shredder, depending on the number $z_н$ installed Г-shaped knife-shredders, rotation frequency $n_ш$ of the screw and screw operation length L_p in natural values as function $\lambda_k = f_\mu(z_н; n_ш; L_p)$ was derived.

$$\lambda_k = -50{,}79 + 52{,}9\,ln(z_н) + 4{,}4\,ln(n_ш) + 12{,}75\,ln(L_p). \quad (2)$$

Analysis of the constructed response surfaces and their two-dimensional sections of the root crops shreddering uniformity coefficient $\lambda_к$ by the screw conveyor-shredder as a function $\lambda_k = f_\mu(z_н; n_ш)$, Fig. 5a, $\lambda_k = f_\mu(z_н; L_p)$, Fig. 5b, $\lambda_k = f_\mu(n_ш; L_p)$, Fig. 6 shows that the main array of approximated values of the root crops shreddering uniformity coefficient $\lambda_к$ is from 36 to 85%.

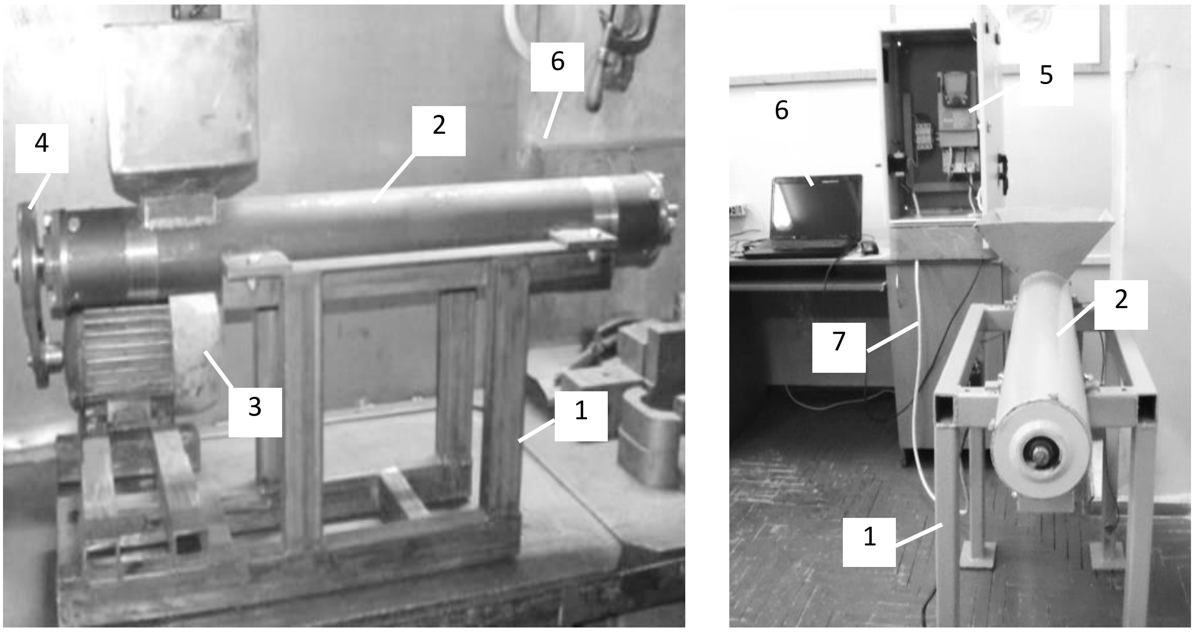

Figure 4. General view of the experimental installation: 1 – main frame; 2 – screw conveyor-shredder; 3 – electric motor; 4 – V-belt drive; 5 – Altivar 71 control unit; 6 – personal computer; 7 – switching connection

The dominant factor that significantly influences the quantitative indicator of the change in the root crops shreddering uniformity coefficient $\lambda_к$ by the screw conveyor- shredder is number $z_н$ of the installed Г-shaped knife-shredders on the single spiral screw turn and tscrew operating length L_p. In the case of changes in the number $z_н$ of the installed Г-shaped knife-shredders from 4 to 8 pcs. (Fig. 5) the root crops shreddering uniformity coefficient $\lambda_к$ by the screw conveyor-shredder increases by in average by 2 times, which is also characteristic to the dependencies shown in Fig. 6: for the screw operating length $L_p = 0{,}6$ m – from 36 to 76%; for the screw operating length $L_p = 0{,}9$ m – from 41 to 81%; for the screw operating length $L_p = 1{,}2$ m – from 45 to 85%.

Changing the screw operating length L_p from 0,6 to 1,2 m (Fig. 6), the root crops shreddering uniformity coefficient $\lambda_к$ by the screw conveyor-shredder increases in average by 1.2 times the constant number $z_н$ of the installed Г-shaped knife-shredders on the single screw turn is 4, 6 and 8 pcs.

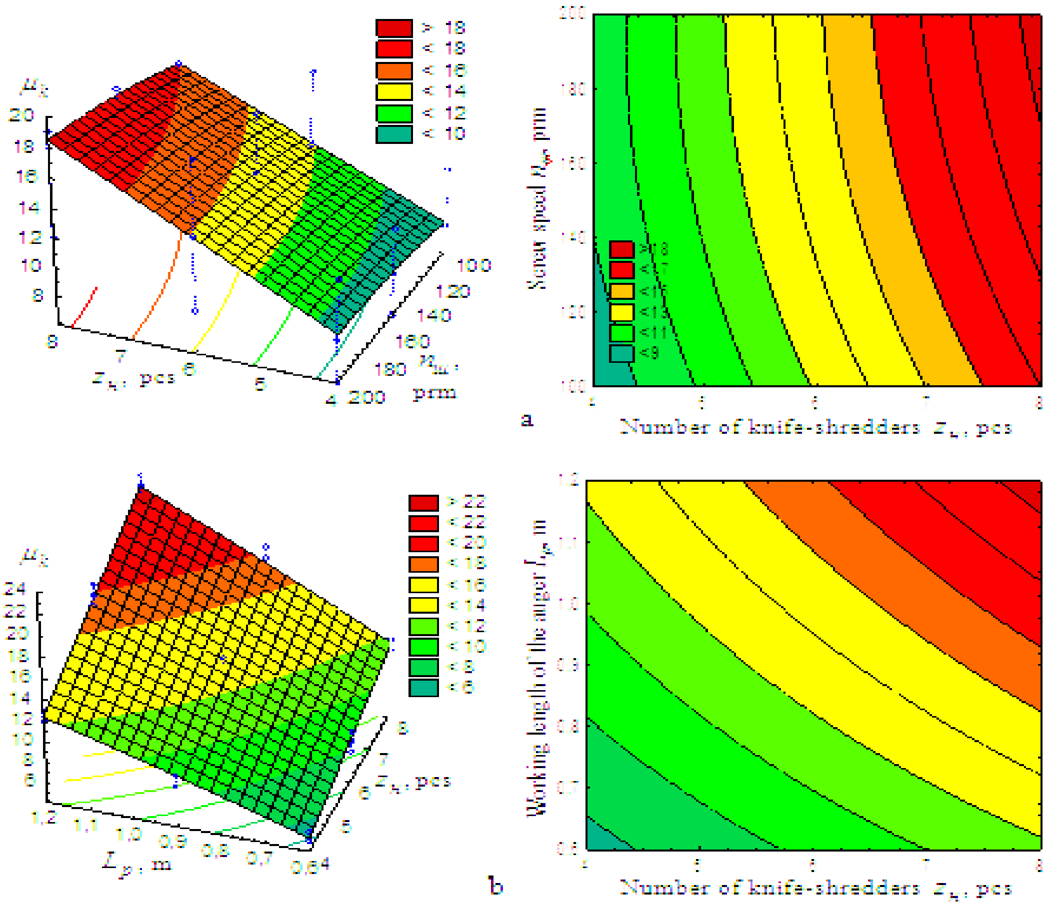

Figure 5. The response surface and the two-dimensional cross-section of the response surface of the functional dependence of the change the root crops shreddering uniformity coefficient $\lambda_к$ as a function: a – $\lambda_k = f_\lambda(z_н; n_ш)$; b – $\lambda_k = f_\lambda(z_н; L_p)$

The screw rotation frequency $n_ш$ has insignificant influence on functional change of the root crops shreddering uniformity coefficient $\lambda_к$ – within the change limit $100 \le n_ш \le 200$ rpm the root crops shreddering uniformity coefficient $\lambda_к$ increases in average by 2,5…3,0 %, Fig. 6, Fig. 7.

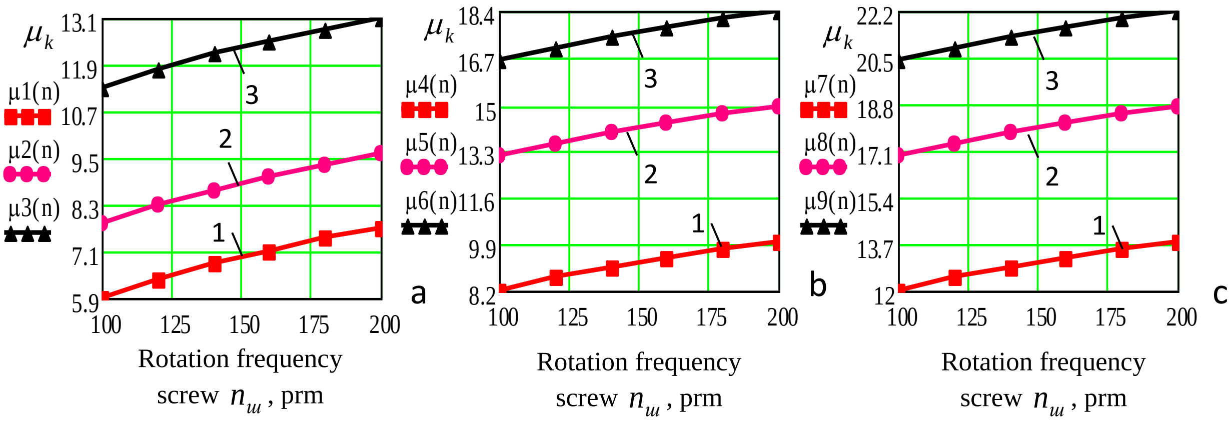

Figure 6. Dependence of the change of the root crops shreddering uniformity coefficient $\lambda_к$ as a function $\lambda_k = f_\lambda(n_ш)$: a, b, c – respectively at $L_p = 0.6$; 0.9; 1.2 m; 1, 2, 3 –, $z_н = 4$, 6 and 8 pcs

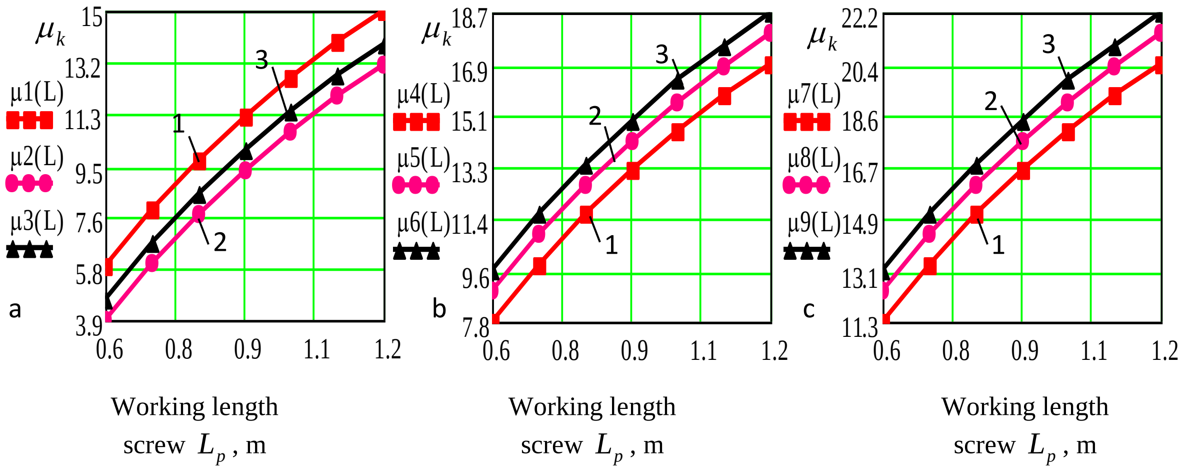

Figure 7. Dependence of the change of the root crops shreddering uniformity coefficient λ_K as a function $\lambda_k = f_\lambda(L_p)$: a, b, c – respectively, at z_H = 4; 6; 8 pcs .; 1, 2, 3 – 100, 150 and 200 rpm

Conclusions. The obtained dependence (2) is the empirical model which makes it possible to substantiate and determine the required design and kinematic parameters of the screw mechanisms at the stage of design and development of the operating elements of the combined screw conveyors-shredders.

In the future, the results of the investigations will be used in the development of methods and techniques for substantiation the rational parameters and operation modes for operating elements of the root crops screw conveyors-shredders.

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ КОЕФІЦІЄНТА ОДНОРІДНОСТІ ПОДРІБНЕНИХ ЧАСТИН КОРЕНЕПЛОДІВ

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Резюме. *У загальній структурі виробництва продукції тваринництва до 50…70% усіх витрат припадає на дольову частку приготування різнопланових соковитих кормів з коренеплодів. Шнекові транспортери широко застосовуються в аграрній сфері виробництва для переміщення, змішування, дозування продуктів тощо. Удосконалення існуючих конструкцій шнекових транспортерів і обгрунтування їх раціональних параметрів і режимів роботи є актуальним науковим завданням. Метою дослідження є підвищення (розширення) функціональних можливостей технологічних операцій шнекових транспортерів шляхом розробки комбінованих робочих органів, які забезпечують одночасне подрібнення та переміщення коренеплодів у процесі їх підготовки та переробки на соковиті корми. Основними задачами дослідження, які забезпечують реалізацію сформульованої мети, є обгрунтування параметрів комбінованого робочого органу шнекового транспортера-подрібнювача, який застосовується у технологічних лініях переробки коренеплодів. За результатами проведених експериментальних досліджень отримано рівняння регресії коефіцієнта однорідності подрібнених частин коренеплодів комбінованим шнековим транспортером-подрібнювачем, яке характеризує характер зміни параметра оптимізації залежно від кількості установлених Г-подібни х ножів-подрібнювачів на одному спіральному витку шнека, частоти обертання шнека та робочої довжини шнека. На основі аналізу побудованих поверхонь відгуку та їх двомірних перерізів зміни коефіцієнта однорідності подрібнення коренеплодів шнековим транспортером-подрібнювачем встановлено, що основний масив апроксимованих значень коефіцієнта однорідності подрібнення коренеплодів знаходиться від 36 до 85%. Результати досліджень є подальшим кроком із розроблення методології обгрунтування параметрів робочих органів і режимів роботи шнекових механізмів.*

Ключові слова: *робочий орган, Г-подібний ніж, спіральний виток, план-матриця, діаметр, частота обертання.*

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