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FEASIBILITY STUDY OF AN AUGER CONVEYOR PERFORMANCE OF THE HAULM REMOVING MODULE

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Summary. *Nowadays, the available haulm removing machines and mechanisms do not fully meet the agronomic requirements for the process of harvesting roots. In this paper, the need to design new haulm removers and improve the available ones is substantiated. The results of experimental and theoretical studies require a more detailed description and analysis on the basis of the obtained data during field tests of an advanced haulm removing machine. The technological process of the module operation for harvesting the tops of root crops is primarily regulated; it depends to a large extent on the technological feeding of the plant components cut off with knives of rotary haulm removers. Therefore, the results of experimental studies of the auger conveyor performance are given in this paper. Based on the obtained results, the efficiency of the developed analytical and applied model of the feed process of cut vegetable components to the auger conveyor of the haulm removing module is proved. The discrepancy in the experimental values of the auger conveyor performance (obtained in accordance with the regression equation) and the theoretical values of its performance (obtained at the analytical level according to the mathematical model) ranges from 5 to 10%. The rational parameters of the auger conveyor of the haulm removing module are defined: auger diameter – 0,35 m; auger rotational frequency – 350 rpm.*

Key words: *tops, roots, cutting, auger conveyor, process, knife.*

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Statement of the problem. The need to develop new designs of haulm removing machines and improve the available ones is stipulated by the difficult and changing conditions of their functional operation, as well as the inefficient adaptation of the available designs of cutting tools to these changes. Therefore, the constant top agronomic results of implementing the technological process in general cannot be achieved [1].

Analysis of recent researches and publications. The results of experimental and theoretical studies, which require a more detailed description and analysis on the basis of data obtained during field tests of an advanced haulm removing machine, are presented in the papers [2, 3, 4].

The objective of the paper is to analyze and compare the experimentally obtained data of the advanced haulm removing machine in accordance with the research program as well as to verify the adequacy of theoretical positions of the developed mathematical model, which characterizes the dependence of the change in the second feed $\dot{\Pi}_{ke}$ of the plant components on the auger conveyor of the haulm removing module.

Statement of the task. To verify the adequacy of the developed mathematical model [5, 6], which at the analytical level defines the functional change in the auger conveyor performance Q_k of the haulm removing module due to its structural and kinematic parameters, the field experimental studies were conducted.

Research results. The design scheme of the experimental installation is shown in Figure 1. The diameter of the auger is $D = 0{,}35\ m$, the step of the first auger sheave is $S_1 = 0{,}15\ m$, the interval of increasing the auger step is $\Delta S = 0{,}005\ m$, and the number of auger steps is $z = 1$.

The first and subsequent experiments were conducted according to the numbered order of the randomized plan matrix of the planned multi factorial experiment.

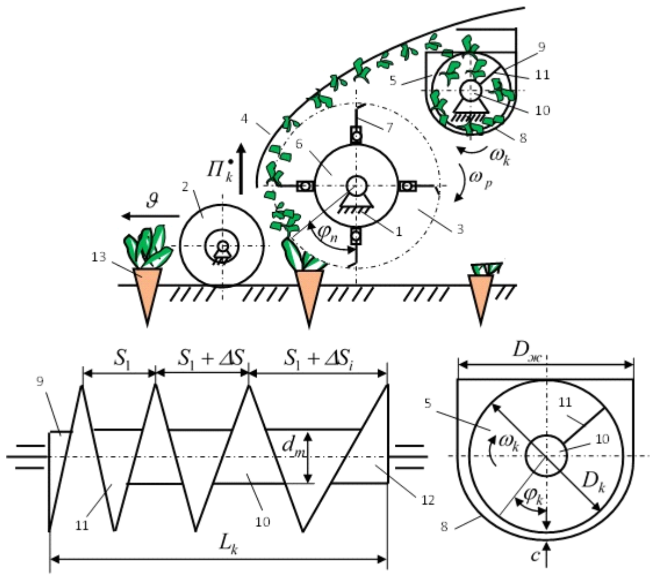

Figure 1. Design scheme of the experimental installation: 1 – frame; 2 – supporting wheel; 3 – rotor haul cutter; 4 – guiding jacket; 5 – screw conveyer; 6, 10 – drum; 7 – knife; 8 – trough; 9 – hector; 11 – turn; 13 – beet root

The assessment results of the determined factors and the value of their variation levels, which are obtained in accordance with the results of the theoretical studies of the auger performance, are given in Table 1.

Table 1

Results of coding the factors and the levels of their variation during the planned factor experiments such as PFE 3^3 and PFE 3^2

Factors	Notation		Intervals of variation.	Level of variation natural/coded		
	Natural	Coded				
Speed of module m/s	ϑ_M	x_1	0,3	1,6/-1	1,9/0	2,2/+1
Density of plantings the root crops, ths./ha	Γ_{kc}	x_2	20	80/-1	100/0	120/+1
Interval of changes in yields of root crops, c/ha	$\pm\Delta U_{г}$	x_3	2	3/-1	5/0	7/+1
Auger rotational velocity, rpm	n_k	x_3	100	250/-1	350/0	450/+1

The results of implementing the plan-matrix of experimental studies concerning the determination of the mass of the collected tops $M_{Qг}$ at the corresponding length of the roll are given in Table 2.

The approximating response function, or the optimization parameter, that is, the performance of the auger conveyor of the haulm removing module, determined experimentally, was deduced in the form of a mathematical model of the logarithmic function

$$Q_{ke} = b_0 + b_1 \ln x_1 + b_4 \ln x_4 , \tag{1}$$

where b_0, b_1, b_4 – free member and coefficients of the corresponding values x_1 i x_4; x_1, x_4 – corresponding coded factors.

Table 2

The results of experimental studies of the mass of the collected tops $M_{Qг}$ at the corresponding length of the roll are given

№ of experiment	Factors		$M_{Qг}$, kg	
	ϑ_M, m/s	n_k, rpm	Repeatability $M_{1Qг}$	$M_{c.Qг}$
1	1,6	250	12,4	62,0
2	1,9	250	16,3	81,5
3	2,2	250	21,6	108,0
4	1,6	350	17,1	85,5
5	1,9	350	22,9	92,5
6	2,2	350	27,2	136
7	1,6	450	22,5	112,5
8	1,9	450	29,4	147,0
9	2,2	450	33,3	166,5

The natural values of the coefficients b_i of the regression equation for changing the auger conveyor performance Q_{ke} are given in Table 3.

Table 3

The natural values of the coefficients b_i of the regression equation for changing the auger conveyor performance Q_{ke}

Notation	The natural values of the coefficients of the regression equation		
	b_0	b_1	b_4
$Q_{ke} = f_Q(\vartheta_M; n_k)$	– 99,66	31,31	17,48

After evaluating the statistical significance of the regression equation coefficients and verifying the adequacy of the empirical model and the transition from coded notation of factors to natural quantities, a regression equation that characterizes the change in the auger conveyor performance Q_{ke} in natural factors is deduced

$$Q_{ke} = -99{,}66 + 31{,}31\ln(\vartheta_M) + 17{,}48\ln(n_k) \quad (2)$$

The obtained regression dependence or the empirical model (2) can be used to determine the auger conveyor performance Q_{ke} of the haulm removing module according to the approximating model $Q_{ke} = f_Q(\vartheta_M; n_k)$ within the range of values of the input factors: the speed of the haulm removing module is $1{,}6 \le \vartheta_M \le 2{,}2$ *m/s*; auger rotational velocity is $250 \le n_k \le 450$ *rpm*.

Therefore, the operating parameters and modes of the haulm removing module can be calculated during the development and design of its working bodies.

Based on the analysis of the obtained regression equation (2) and the response surface (Fig. 2) as a function $Q_{ke} = f_Q(\vartheta_M; n_k)$, the functional change in the auger conveyor performance Q_{ke} in dependence with the input variable factors possesses directly proportional characteristics. That is, providing the increase of the speed ϑ_M of the haulm removing module and the auger rotational velocity n_k, the auger conveyor performance increases as well. The main approximated experimental values of the auger conveyor performance range from *11* to *34 kg/s*. Based on the developed dependencies, the results of functional change in the auger conveyor performance Q_{ke} are shown in Fig. 3.

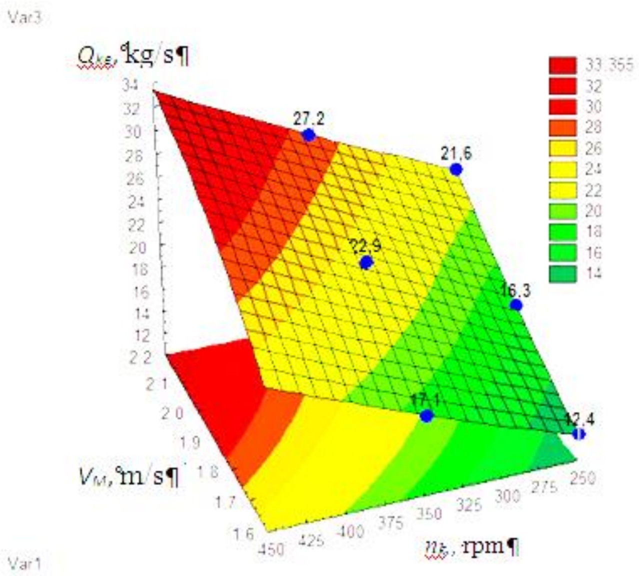

Figure 2. Response surface of the functional dependence of the change in the auger conveyor performance $Q_{k.e}$ on the speed ϑ_M of the haulm removing module and the auger rotational frequency n_k

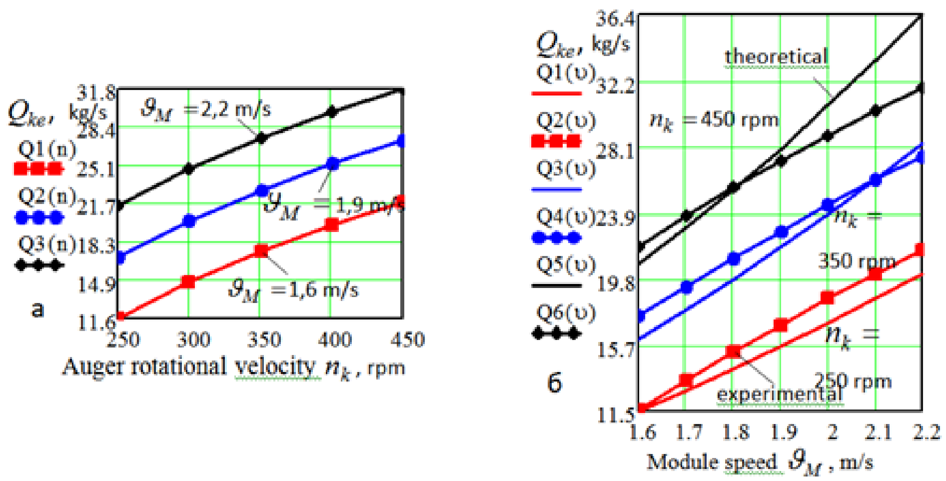

Figure 3. Dependence of change in auger conveyor performance Q_{ke} as a function:

a – $Q_{ke} = f_Q(n_k)$; b – $Q_{ke} = f_Q(\vartheta_M)$

The dominant factors, which improve the auger conveyor performance Q_{ke}, are concidered the all operating factors, such as the speed of the haulm removing module ϑ_M, and the auger rotational frequency n_k.

Thus, the performance improvement Q_{ke} within the variation of each input variable factor ϑ_M and n_k (Fig. 3), respectively, from $1{,}6 \le \vartheta_M \le 2{,}2$ *m/s* and $250 \le n_k \le 450$ *rpm* is approximately the same and range from *10* to *12 kg/s*.

Therefore, to ensure the rational operation of the screw conveyor or the movement of the plant components by means of an auger without their «download» on the auger working surfaces, the auger conveyor performance Q_{ke} must be not less than the range of change in the second feed of the plant components $\Pi^{\bullet}_{ke}$ to the auger conveyor of the haulm removing module.

According to the graphics (Fig. 2, 3), the second feed of plant components $\Pi^{\bullet}_{ke}$ to the auger conveyor ranges from *9* to *30 kg/s*.

Then, based on the analysis of the graphics shown in Fig. 2, 3, the condition $Q_{ke} \ge \Pi^{\bullet}_{ke}$ is proved to fulfil at all values of factors variation:

- the speed ϑ_M of the haulm removing module ranges from *1,6* to *2,2 m/s*;

- the auger rotational frequency n_k ranges from *250* to *450 rpm*.

In this case, the auger diameter is equal to $D_k = 0{,}35$ *m*; the first step of the auger sheave is $S_1 = 0{,}15$ *m*; the step change interval is $\Delta S = 0{,}005$ *m*.

The discrepancy in the experimental values of the auger conveyor performance Q_{ke} obtained according to the regression equation (2) (curves Q2 (n), Q4 (n), Q6 (n)) and the theoretical performance values of the auger conveyor performance (straight lines Q1 (n), Q3 (n), Q5 (n)) obtained at the analytical level according to the mathematical model [5, 6] ranges from 5 to 10% (Fig. 3 b).

Conclusions. The advanced haulm removing module performance was experimentally studied and analyzed. The developed theoretical model [5, 6] describes functionally the change in the auger conveyor performance Q_k in dependence with the auger structural and kinematic parameters. Therefore, the above model is proved to describe adequately the process under study.

Thus, based on the analytical and empirical analysis of the auger conveyor performance Q_k, the rational parameters of the auger conveyor of the haulm removing module are found: the auger diameter is $D = 0{,}35$ *m*; the auger rotational velocity is $n_k =$ *350 rpm*.

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РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ПРОДУКТИВНОСТІ РОБОТИ ШНЕКОВОГО КОНВЕЄРА ГИЧКОЗБИРАЛЬНОГО МОДУЛЯ

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Резюме. *Досліджено проблему, що полягає в необхідності вдосконалення існуючих та розробленні принципово нових гичкозбиральних механізмів і машин, оскільки наявні не повністю задовольняють агротехнічні вимоги до процесу збирання коренеплодів. Наведено результати експериментальних і теоретичних досліджень, що потребують детальнішого опису та аналізу на основі отриманих даних при проведенні натурних випробувань удосконаленої гичкозбиральної машини. Технологічний процес роботи модуля для збирання гички коренеплодів значно залежить від подавання зрізаних ножами роторного гичкоріза рослинних компонентів. Отримано результати експериментальних досліджень продуктивності роботи шнекового конвеєра, які підтверджують розроблену аналітично-прикладну модель процесу подавання зрізаних рослинних компонентів до гвинтового конвеєра гичкозбирального модуля. Розбіжність експериментальних значень продуктивності шнекового конвеєра, які отримано згідно з рівнянням регресії, й теоретичних значень його продуктивності, які отримано аналітично. Згідно з математичною моделлю вони знаходяться у межах 5…10%. Раціональні параметри шнекового конвеєра гичкозбирального модуля: діаметр шнека – 0,35 м; частота обертання шнека – 350 об/хв.*

Ключові слова: *гичка, коренеплоди, різання, гвинтовий конвеєр, технологічний процес, ніж.*

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