EXPERIMENTAL RESEARCH OF QUALITY INDICATORS OF OPERATION OF NEW POTATO HARVESTER

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Abstract. Potato harvesting is a labor-intensive and energy-intensive operation in the production of this crop. Therefore, the development of new and improvement of the existing potato harvesters, which will have higher quality harvesting indicators, is an important task for agricultural production. We have developed a new 2-row potato harvester with an improved cleaning system from soil and vegetable admixtures. The purpose of this research was to determine a rational design and technological parameters of the potato harvester that ensure high quality indicators of potato harvesting. To determine rational parameters of the distributor, the influence of the parameters of the distributor upon the content of impurities in the potato heap with soil impurities was studied. The criterion for evaluating the impact of these parameters upon the quality of the machine was taken as the indicator of contamination of tubers with the soil and plant impurities, which is defined as the ratio of the mass of soil elements in the heap to the total mass of the heap at the outlet of the potato harvester. The established graphic dependencies also made it possible to choose rational design parameters of the V-shaped potato heap distributor. On the basis of experimental investigations a mathematical model of the influence of the design parameters of the distributor upon contamination of the tubers with the soil admixtures was obtained, and the area of rational values of the parameters of the distributor, which were determined theoretically, was confirmed. These parameters of the distributor reduce contamination of the heap on the sorting table of the potato harvester to 11.41%.

Key words: potatoes, harvesting, experiment, cleaning, quality.

Introduction

Potato is an important agricultural crop, used for food and industrial purposes. Harvesting potatoes is one of the most labor-intensive and energy-intensive operations in the technology of growing this valuable agricultural crop [1]. A lot of research has been devoted to the improvement of potato harvesters, but this topic is still relevant.This is because of different soil and climatic conditions for the cultivation of potatoes, different sizes of areas in farms, financial opportunities, etc.[2-4]. Despite the availability of perfect kinds of machines, most of the potatoes are harvested with relatively simple machines. In particular, under the conditions of Ukraine potato harvesters KKU-2A are widely used.

These serial machines have a number of shortcomings in the quality of harvesting and damage to the tubers. One of the most important components of the potato harvester that affects the quality of harvesting are the digging-separating mechanisms, which take on them a layer of soil with tubers, remove the soil admixtures, leaves and weeds, and separate clean tubers. The task of obtaining clean tubers with minimal damage on soils that are heavy by their mechanical composition is very urgent and can provide a significant economic effect. Experimental studies [3] have shown that the intensification of the separation process utilizing uniform distribution of the heap across the width of the elevator web can improve the quality of the results seen in the use of the potato harvester.

To solve the problem of improving the technological process of distributing heaps across the width of the conveyor, we have developed a new 2-row potato harvester with an improved system for separating soil and plant impurities [5-6].

The purpose of the research is to determine the optimal design and technological parameters of the potato harvester, providing the best indicators of the quality of the technological process.

Materials and methods

On the basis of theoretical investigations and analysis of previous experimental studies [6-7], a field experimental setup was created for further experimental study of the combined digging-separating

working body under the field conditions. The experimental setup for the research of a combined digging-separating working body for the field conditions was created on the basis of a KKU-2A potato harvester (Fig. 1).

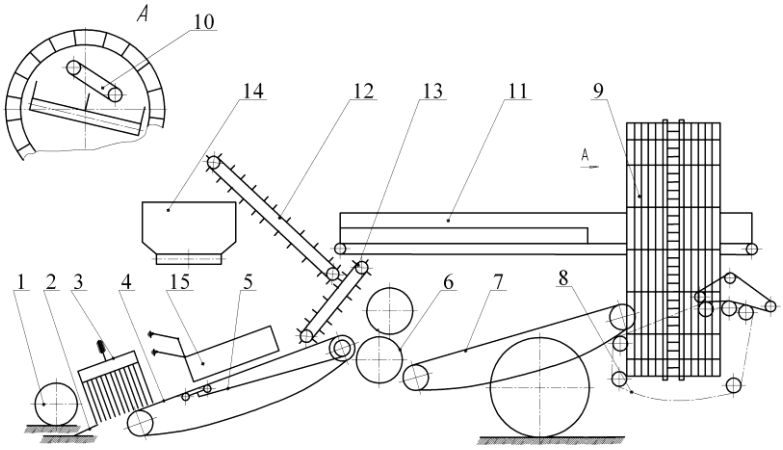

Fig. 1. **Scheme of the experimental setup, based on the KKU–2A potato harvester:** 1 – copy roller; 2 – plowshare; 3 – bar drum; 4 – first bar conveyor; 5 – shaking mechanism; 6 – balloon-clod crusher; 7 – the second bar conveyor; 8 – a rare bar conveyor; 9 – drum conveyor; 10 – slide; 11 – sorting table; 12 – loading conveyor; 13 – impurity transporter; 14 – bunker; 15 – V-shaped

The distributor (Fig. 2) consists of two wings 1, which are pivotally connected to each other by means of an axis, a parallelogram linkage mechanism 2, attached to the frame of the potato harvester, a bed 3, a restrictive chain 4, an adjusting bar 5, a spring 6. The distributor is attached to the bed using a square bar and fixed with clamps. The hinged connection of the wings made it possible to change the angle of the opening of the wings, which was fixed with the help of an adjusting bar. With the help of the restrictive chain the gap between the conveyor belt and the distributor is regulated. By means of a spring, the distributor has the ability to carry out smooth vertical movements when copying the vibrations of the conveyor surface, as well as to prevent breakage during overloads.

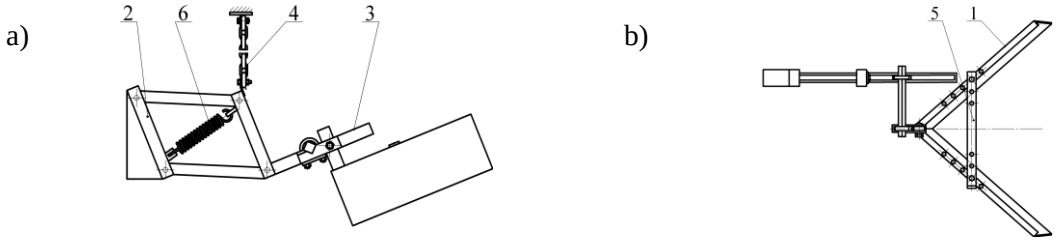

Fig. 2. **Distributor diagram:** a – side view; b - top view; 1 – wing; 2 – parallelogram mechanism; 3 – beds; 4 – restrictive chain; 5 – adjusting bar; 6 – spring

The main parameters of the distributor were adjusted as follows. The opening angle of the wings was adjusted using a bar which has a group of holes on each side, and similar ones are made on the flanging of the wings. By rearranging the bolts in the corresponding holes of the strap and flanging of the wings, it is possible to change the opening angle of the distributor wings to 5º. The gap between the distributor and the conveyor belt was changed by fixing the corresponding link of the chain, which at one end was attached to the parallelogram mechanism, and at the other end to the bracket on the machine frame by means of a bolted connection. Accordingly, the gap between the distributor and the conveyor can be changed in increments of 10 mm. The distance between the bar drums and the distributor was steplessly regulated by moving the clamp fastening of the distributor along the ridge of the parallelogram mechanism. The process work proceeds as follows. During the movement of the potato harvester (Fig. 1), the shares 2 dig into two adjacent rows of potatoes. The bar drums 3, rotating towards each other, with their bars grab a layer of potato beds, dug up by the plow shares, crush it in the gap between the drums. At the same time part of the soil is sifted between the fingers of the drums and falls under the combine, and the bulk of the heap is sent to the separating conveyor 4. The heap, moved by the conveyor, comes across the V-shaped distributor 15. In addition, the flow of the heap is distributed into two flows

that come into movement along the wings of the device; part of the heap will constantly pass under the distributor, since it is installed with a gap relative to the surface of the conveyor. Moving along the wings, the heap is distributed over the width of the conveyor, and, due to the presence of the gap, it is leveled in height. Further, the heap moves along the surfaces of the separating working bodies where the final separation of the soil and plant residues takes place, and the cleaned potato tubers fall into the hopper 14. The main parameters of the experimental setup are given in Table 1.

Table 1

Technical characteristics of the experimental setup

Indicator	Unit of measurement	Value of the indicator
Speed of the movement of the machine	$m \cdot s^{-1}$	0.7-1.5
Speed of the movement of the bar conveyor	$m \cdot s^{-1}$	1.85
Length of the distributor wing	mm	480
Height of the distributor wing	mm	150
Opening angle of the distributor wing	°	10-55
Gap between the conveyor belt and the distributor	mm	0-250
Distance between the bar drums and the distributor	mm	150-700
Rotation speed of the drums	$m\ s^{-1}$	2.5
Dameter of the bar drum	mm	580
Installation step of the bars on the drum	mm	80

Before each experiment the experimental setup was adjusted, which consisted of setting the opening angle of the distributor wings, the gap between the conveyor belt and the distributor, the distance between the bar drums and the distributor to the appropriate values of the factors.

The heap samples were taken from the sorting table as follows [8-10]. After setting up the device it began to perform the technological process of harvesting potatoes (Fig. 3); after reaching a stable operating mode the device was stopped. The heap that was on the sorting table was collected in a container. The moment of sampling is shown in Fig. 4. Then the heap was divided into fractions and weighed. The results of weighing were entered into in appropriate columns of the table.

Infestation of the tubers with the soil impurities was determined according to the expression [9]:

$$Z = \frac{m_d}{m_z} \cdot 100, \quad (1)$$

where Z – infestation of the tubers with the soil impurities, %;
m_d – mass of soil impurities in a heap sample, kg;
m_z – total mass of the heap sample, kg.

In a similar way there was determined damage to the tubers. After experimental investigations the results were processed to obtain a regression equation that characterizes the influence of the factors and their interactions in the separation process of the soil impurities [11-14].

Fig. 3. **General view of the distributor during the experimental investigations**

Fig. 4. **Sampling from the bulkhead table of the experimental setup**

Results and discussion

On the basis of theoretical analysis it has been established that the main factors that most significantly affect the quality of the technological process of the heap distribution across the width of the conveyor, and therefore affect the completeness of separation, are the following parameters of the distributor:

- the angle of opening of the distributor wings – 2α;
- the distance between the bar drums and the distributor – L;
- the gap between the conveyor and the distributor – Δ.

They were variables during the investigations. The length and the height of the wings of the distributor during the experiment were not changed.

The evaluation criterion was contamination of the potato heap with the soil impurities, which was determined as the ratio of the mass of the soil elements in the heap to the total mass of the heap. The research was carried out in the field during the potato harvesting season on the territory of the Vasilkovsky district, Kiev region, the soil type - chernozem, the soil moisture – 21-23%. The results of the data processing are presented in the form of a regression equation, which is a mathematical model of the technological process of the distributor, connecting the parameters of the working body with the indicator of the quality of its work.

On the basis of statistical processing of the results of experiments we received a regression equation in the form of a polynomial of the second degree (probability level $P = 0.80$, $t\alpha\text{-}crit = 1.302$):

$$Z = 39.4 + 3.74L\text{-}0.24\alpha\text{-}13.78\Delta\text{-}0.05L^2 + 0.84\Delta^2, \quad (2)$$

where Z – infestation of the tubers with the soil impurities, %;
L – distance from the drums to the distributor, cm;
α – opening angle of the distributor wing, deg;
Δ – gap between the conveyor and the distributor, cm.

Having used the method of two-dimensional sections of the response surface, we determined the parameters of the distributor, at which the minimum and maximum values of the contamination of the tubers are reached. Accordingly, the minimum weediness value was $Z = 11.41\%$ at the values of the variables: $L = 0.60$ m, $\alpha = 45°$, $\Delta = 0.08$ m, and the maximum weediness value was $Z = 86.56\%$ at – $L = 0.35$ m, $\alpha = 15°$, $\Delta = 0.15$ m. As it is evident, the parameters of the distributor significantly affect the intensity of the separation process of the soil impurities from the potato heap since, when varying the variable parameters, the weediness value changes 7.6 times. With rational parameters of the distributor, the heap is evenly distributed over the width of the conveyor belt, which leads to an increase in the efficiency of the separation process. This indicates high efficiency of the distributor and the expediency of its use in a potato harvester.

The results of the experimental research are presented in the form of graphs in Fig. 5-7, which show the influence of the main parameters of the distributor upon the indicator of contamination of the tubers with the soil admixtures. The gap between the conveyor and the distributor Δ, and the distance between the drums and the distributor L have the most significant effect upon the technological process. As evident from the graphs in Figs. 5-8, the dependence of the contamination of tubers upon these factors has a parabolic character; respectively, with steeply increasing curves for the dependence of contamination upon the gap between the conveyor and the distributor Δ (Fig. 6, 7), and steeply falling curves for the dependence of contamination upon the distance between the drums and the distributor L (Fig. 7, 8).

As evident from Figs. 5, 6, the range of rational values of the gap Δ lies within 0.07-0.09 m (the minimum value of contamination is achieved at a gap $\Delta = 0.08$ m). Note that the workflow of the distributor is sensitive to this parameter, since going beyond the boundaries of the area of rational values leads to a significant deterioration in the efficiency of the heap distribution process - the contamination of tubers increases sharply. This is because with the increase in the gap Δ, the distribution of the heap across the width of the conveyor worsens, since the main part of the heap flow begins to pass between the distributor and the conveyor, and the heap flow to the sides decreases, which leads to a decrease in the separation efficiency. When the gap is reduced, the heap is excessively distributed on the sides of

the conveyor; that is, it is distributed over the width of the conveyor in an uneven layer in height, which also leads to a decrease in the separation efficiency.

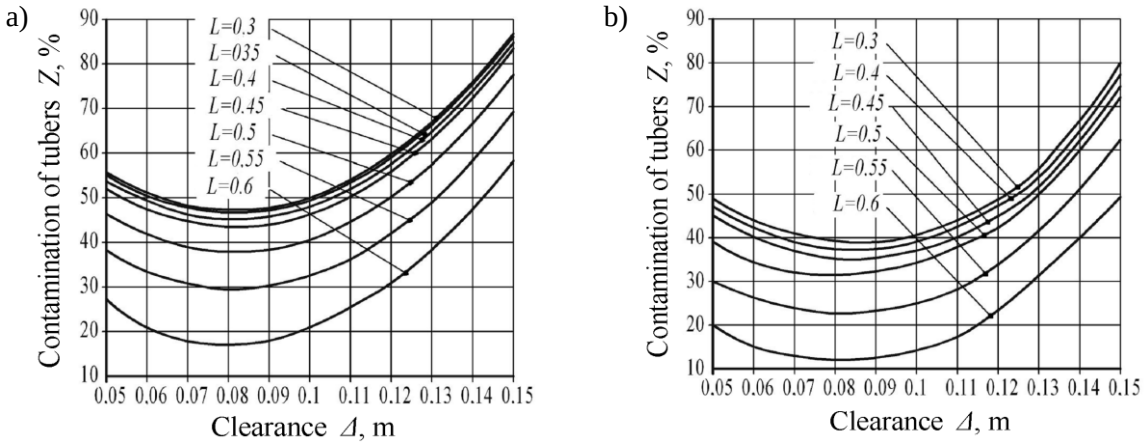

Fig.5. **Dependence of contamnation of the tubers with impurities upon the gap between the conveyor and the distributor Δ, and the distance between the drums and the distributor *L*:**
a, b – the opening angle of the distributor wing *α*, respectively, 15° and 45°.

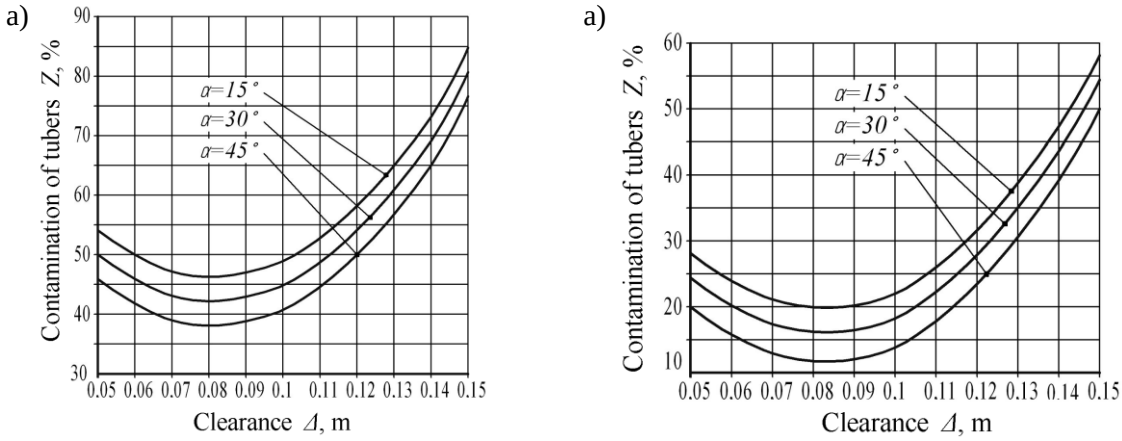

Fig. 6. **Dependence of contamnation of the tubers with impurities upon the gap between the conveyor and the distributor Δ, and the opening angle of the wing of the distributor *α*:**
a, b – the distance between the drums and the distributor *L*, respectively, 0.3 m and 0.6 m

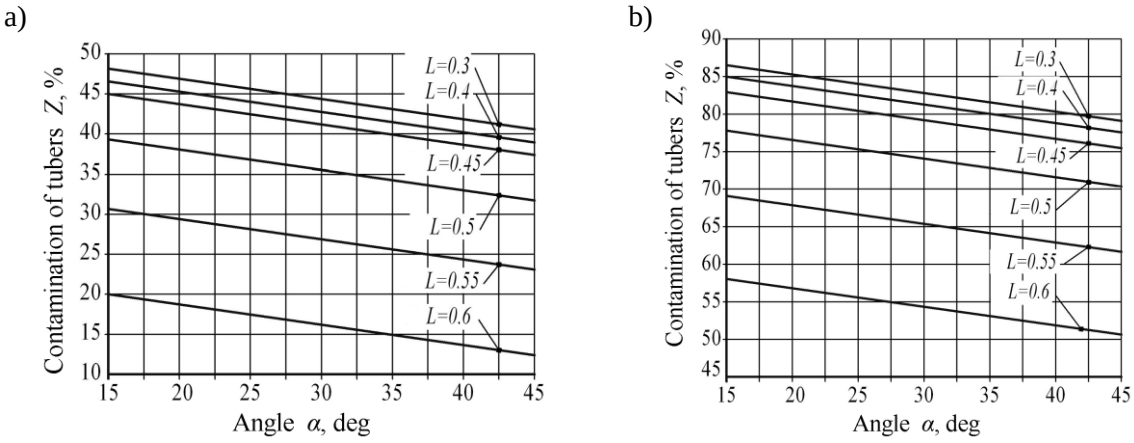

Fig. 7. **Dependence of contamination of the tubers with admixtures upon the opening angle of the distributor wing *α* and the distance between the drums and the distributor *L*:**
a, b – the gap between the conveyor and the distributor Δ, respectively, 0.08 m and 0.15 m

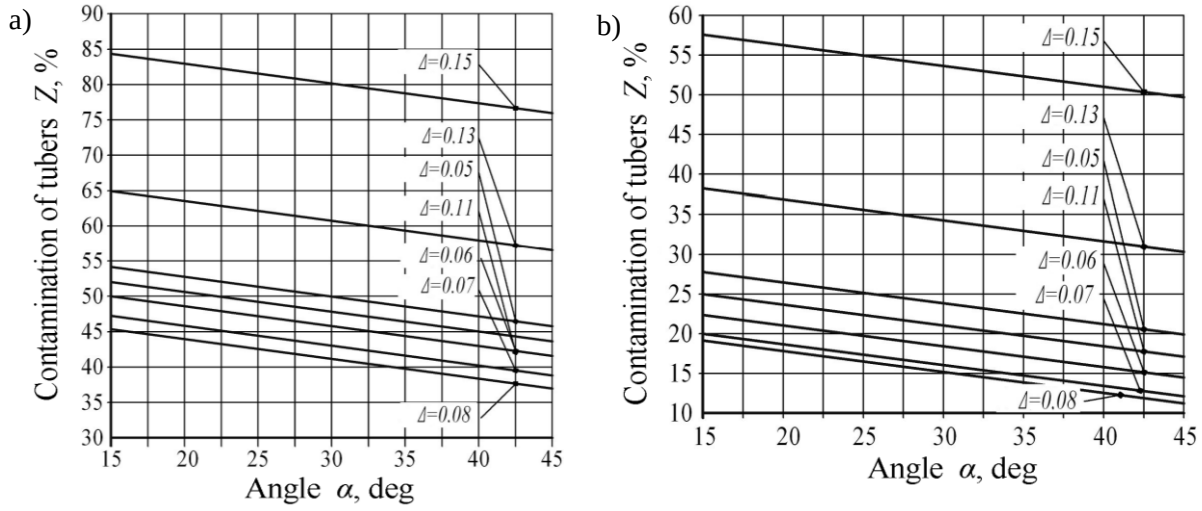

Fig. 8. **Dependence of contamination of the tubers with admixtures upon the opening angle of the wing of the distributor *α* and the gap between the conveyor and the distributor Δ:**
a, b – distance between the drums and the distributor *L*, respectively, 0.3 m and 0.6 m

As evident from Figs. 7, 8, the wing opening angle *α* creates a less effect upon the heap distribution process since the dependence of contamination upon the spreader wing opening angle *α* has a character close to rectilinear, and the curve is rather flat. Such an effect of the opening angle of the wings is explained by the fact that even at small angles *α* (*α* = 15-20°), the distribution process of the heap across the width of the conveyor belt occurs satisfactorily. With an increase in the angle *α*, the contamination decreases. The smallest contamination will be at *α* = 45°. This value of the parameter in the experiment was the limit because, due to the large angles, there is a violation of the technological process, the heap is unloaded on the wings of the distributor, which leads to the stop of the movement of the heap along the distributor. Therefore, the range of rational values of this parameter is taken within *α* = 40° - 45°.

Conclusions

1. As a result of the investigations of the interaction process of the potato heap with the developed V-shaped distributor, rational values of the parameters of the distributor were established: the angle of the distributor wing opening is *α* = 40-45°, the gap between the distributor and the conveyor is $\Delta \geq 0.08$ m, the distance between the bar drums and the distributor is $L \geq 0.54$ m.
2. On the basis of the experimental investigations a mathematical model of the influence of the design parameters of the distributor upon contamination of the tubers with the soil admixtures was obtained, and the area of rational values of the parameters of the distributor, which were determined theoretically, was confirmed. These parameters of the distributor reduce contamination of the heap on the sorting table of the potato harvester to 11.41%.

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