INVESTIGATION OF ENERGY AND PERFORMANCE INDICATORS OF POTATO DIGGER WORK WITH EXPERIMENTAL DIGGING-SEPARATING OPERATING PART

Volodymyr Bulgakov[1], Semjons Ivanovs[2], Viktor Kornuchin[3], Zinoviy Ruzhylo[1], Yevhen Ihnatiev[4], Mykhailo Chernovol[5], Valentyna Kaminska[6]

[1]National University of Life and Environmental Sciences of Ukraine, Ukraine; [2]Latvia University of Life Sciences and Technologies, Latvia; [3]Institute of Mechanics and Automation of Agricultural Production of the National Academy of Agrarian Sciences of Ukraine, Ukraine; [4]Dmytro Motornyi Tavria State Agrotechnological University, Ukraine; [5]Central Ukrainian National Technical University, Ukraine; [6]National Scientific Center "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine", Ukraine

semjons@apollo.lv,

Abstract. Potato harvesting is the most labor-intensive technological process in the potato production, which accounts for 45...60% of the total labor costs. When working in difficult conditions, the potato harvesters have insufficiently high quality indicators, low reliability and high energy performance. The purpose of this work is to determine the energy and performance indicators of a two-row potato digger-loader KKN-2 with an experimental V-shaped heap distributor. The test conditions were typical for heavy soils, the soil hardness in the tuber layer was up to 3.0 MPa. The performance indicators were determined at operating speeds of 3.2...4.8 km·h^{-1}. The obtained dependences of the traction resistance upon the forward speed of the potato harvester for the basic and the modernized machines show that at the speeds above 3.55 km·h^{-1} the resistance of the modernized machine is lower. This can be explained by a better separation of the heap and, as a result, a decrease in its total mass, which is in the cleaning system. The use of the proposed combined digging-separating operating part in the technological scheme of the potato harvester provides higher operational and energy performance: it increases the productivity by 0.16 ha·h^{-1} and reduces the specific fuel consumption by 4.1 kg·ha^{-1}.

Key words: potatoes, harvesting, separation, resistance, tubers.

Introduction

Potatoes are an important agricultural crop that is widely distributed in many countries [1-2]. The peculiarity of potatoes, used for food purposes, is the relatively high possibility to damage the tubers during harvesting. On the other hand, the need for long-term storage (six months or more) requires that the damage to the tubers should be minimal [3-4].

Analysis of the labor costs in the technological process of the potato production shows that harvesting accounts for 45-60% of the total costs [5]. The significant labour intensity of harvesting potatoes is due to the fact that the tubers are in the soil layer and therefore can be harvested most reliably and completely only when using the harvesting principle, which is based on digging a potato bed with the subsequent separation of tubers from the soil impurities. This determines the complexity and high energy intensity of the process since, when digging a potato bed, into the potato harvester every second about 100 kg of the tuberous mass (1-1.5 thousand tons per each hectare) come from one linear meter of the bed. In this mass, the tubers make only 2-3%. However, the difficulty of obtaining tubers clean without the impurities of soil in the container is determined not only by the need to sift a significant amount of soil but also by some of its unfavorable properties that appear during harvesting.

The main indicators that characterize the quality of combine harvesters are damage to the tubers, the completeness of harvesting and the cleanliness of the tubers in the bunker (container) [6]. According to agricultural requirements [3] a modern potato harvester must collect at least 97% of the potato crop into the bunker, the losses of all kinds should not exceed 3% (but not more than 6 centn·ha^{-1}). The purity of the tubers in the bunker (container) must be at least 80%. Damage to the tubers due to the operation of the combine harvester on light, medium and stone-contaminated soils should not exceed 10%, and on waterlogged heavy soils – up to 5%. The efficiency of the modern potato harvesters should be at least 0.15 ha·h^{-1} per one row of the crop [7].

Separation of a layer of the dug-up heap is the main operation of the technological process of harvesting [5]. High-performance and high-quality operation of potato harvesters depends mainly on the solution of the problem how to increase the efficiency of the heap separation [1, 8]. Experimental studies [9] 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

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potato harvester. Therefore, the development and justification of machines, technical means and design solutions that improve the quality of the work of the separating tools of potato harvesters is an important technical and national economic task. The task of the potato digger-loader KKN-2, improved by us [9-10], was to raise the quality of harvesting without a significant increase in the energy consumption for its aggregation.

The purpose of this work was to investigate the energy and operational indicators of a potato harvester, equipped with an experimental V-like potato heap distributor.

Materials and methods

The experimental potato digger-loader KKN-2 is designed for digging two rows of potatoes, separating tubers from the soil, the tops and other plant impurities, loading potatoes into a vehicle that moves nearby [8-9]. A general view of the machine is shown in Fig. 1, where the technological process of the potato digger with a distributor in a working position can be seen.

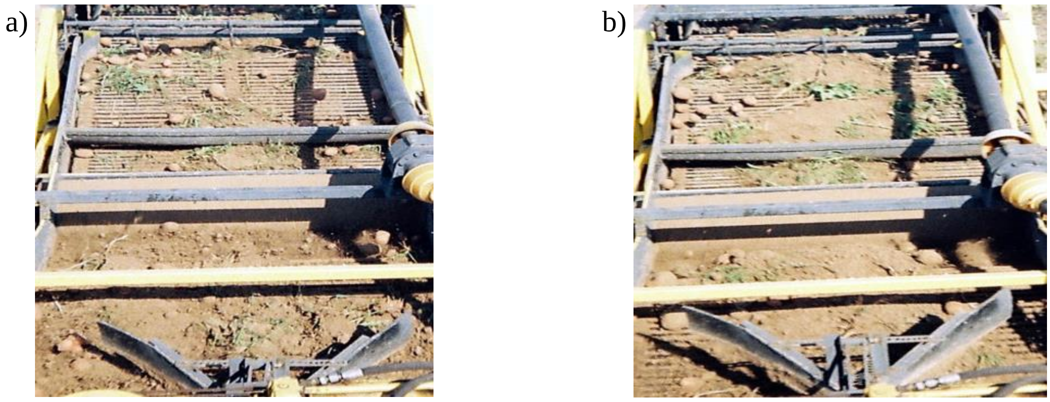

Fig. 1. **General view of the KKN-2 potato digger-loader in operation:** a – distributor in a working position; b – distributor in a non-working position

A peculiar feature of the design of the experimental potato digger-loader is the presence of a combined digging-separating operating tool (Fig. 2), which contains bar drums (Fig. 3a) and a distributor (Fig. 3b), which significantly improves the quality indicators of the technological process of potato harvesting.

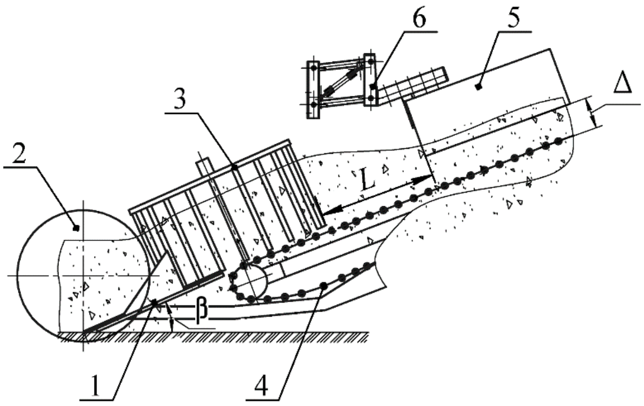

Fig. 2. **Layout scheme of the combined digging-separating operating tool of the potato harvester:** 1 – ploughshare; 2 – cutting disc; 3 – bar drum; 4 – bar separating conveyor; 5 – V-shaped heap distributor; 6 –distributor suspension

The working process of the experimental combined digging-separating operating tool of the potato harvester (Fig. 2) begins with a supply of the dug heap to the ploughshare 1. The angle of inclination of the ploughshare 1 is set to the maximum possible, taking into account the fact that the movement of the dug layer is provided at an angle of not more than 24°. In order to prevent collapse of the dug layer to the sides, as well as to limit the intake of the compacted layer of soil from the row spacing, passive cutting disks 2 are installed on the sides of the outside ploughshares. The bar drums are installed in the zone of transition of the dug heap from the shares 1 to the separating conveyor 4, and the axis of rotation of the drums is perpendicular to the surface of the shares 1. The length of the wing *l* of the distributor 5 is selected, based on the condition of the qualitative distribution of the heap on the width of the conveyor 4. The opening angle of the distributor wing 5 provides for regulation in various soil and climatic conditions. The gap between the distributor wing and the conveyor plane depends on the size of the potatoes, the type and condition of the soil, and therefore this parameter is regulated. Since the conveyor belt 4 can perform oscillatory movements with a rather significant amplitude, the distributor 5 is installed with a possibility to provide a constant predetermined gap size by means of a parallelogram device 6. The distance between the drums 3 and the toe of the distributor 5 must ensure free passage of the heap.

a)

b)

Fig. 3. **Main structural elements of the digging-separating operating tool that affect the quality indicators:** a – bar drums, b – V-shaped distributor

In the experimental investigations standard methods were used to determine the main energy and operational indicators [11-13]. The conditions for conducting the research of the KKN-2 potato digger-loader are presented in Table 1. The performance quality indicators were determined at the operating speeds of 3.2-4.8 km·h^{-1}. Comparative investigations were carried out for the base machine and the experimental machine, equipped with an additional digging-separating operating tool. Performance indicators that characterize the efficiency of the use of the digging-separating operating tool were determined according to a generally accepted method [12; 13]. Characteristics of the crop in the laboratory and the field research are given in Table 2. The results of the experimental investigations were processed according to the well-known method of statistical processing of research data.

Table 1

Conditions for conducting research of the KKN-2 potato digger-loader

Indicator	Value or characteristic of the indicator
Type of the soil	Loamy chernozem
Soil hardness, MPa:	
0-5 cm	1.35
5-10 cm	2.35
10-15 cm	2.9
15-20 cm	3.0
Soil moisture, % in soil layers:	
0-5 cm	16.1
5-10 cm	18.0
10-15 cm	17.8
15-20 cm	17.0
Number of weeds per 1 m^2, pcs.	6
Mass of weeds and leaves of tops, t·ha^{-1}	1.56

Table 2

Characteristics of the crop in laboratory and field research

Indicator	Value of the indicator
Potato variety	Nevsky
Planting method	in ridges
Row spacing, cm	70
Biological yield of potatoes, $t \cdot ha^{-1}$	24.3
Bed height, cm	19.2
Number of bushes, thousand $units \cdot ha^{-1}$	39.1
Nest characteristic:	
- width, cm	22
- depth of the lower tuber, cm	18.2
Size-mass characteristics of the tubers:	
– length, mm	68.8
– width, mm	50.8
– thickness, mm	35.2
– average tuber weight, g	88.6
Composition of the tubers, % by weight, g:	
-up to 50	52.9
– 50-80	17.6
– more than 80	29.5

Results and discussion

During the testing period, 10 hectares of potatoes were harvested by the experimental potato digger-loader KKN-2, as well as operational assessment was performed (Table 3). The potato digger-loader ensures potato harvesting in accordance with the established requirements - the completeness of harvesting, the purity of potatoes meet the agrotechnical requirements. The V-like heap distributor showed high efficiency – the purity of the tubers in the container reached 97.4%; without the distributor the purity of potatoes in the container was 85.8%. The use of the distributor increases such an important indicator of the operation of the potato harvester as the purity of the tubers in the container by more than 10% and reduces the clogging of the tubers with the soil impurities from 14.2% to 2.7%, that is, by 5.2 times. At the same time, when the combine harvester is operating without a distributor, the speed of the aggregate must be reduced to ensure satisfactory separation of the heap.

Table 3

Performance indicators of the potato harvester with the experimental combined digging-separating operating tool

Indicator	Basic machine	Experimental machine
Efficiency, $ha \cdot h^{-1}$	0.36	0.52
Specific fuel consumption, $kg \cdot ha^{-1}$	30.4	26.3
Working width of the machine, m	1.4	1.4
Operating speed of the machine, $km \cdot h^{-1}$	3.24	4.68
Completeness of harvesting tubers, %	99.0	99.0
Tuber damage, %	4.6	4.6
Purity of tubers in containers, %	85.8	97.4

The obtained dependences of the traction resistance upon the forward speed of the potato harvester for the basic and the modernized machines (Fig. 4) show that at the speeds above 3.55 $km \cdot h^{-1}$ the resistance of the modernized machine is lower. This can be explained by a better separation of the heap and, as a result, a decrease in its total mass, which is in the cleaning system.The traction resistance increases with the growth of the forward and reaches the maximum value of about 12.6 kN at the speed of 4.7 km·h^{-1}.

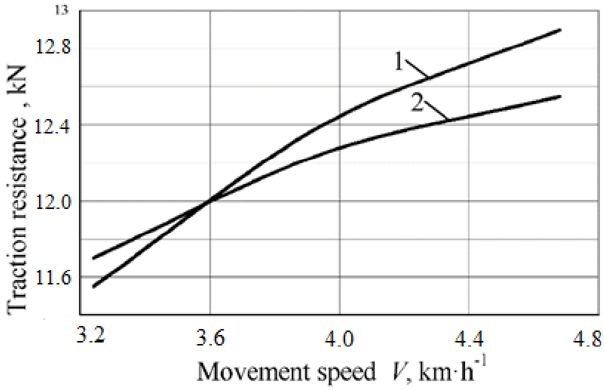

Fig. 4. **Dependence of the traction resistance of the potato harvester on the speed of its forward movement:** 1 – basic machine; 2–- experimental machine

The power to drive the operating parts of the modernized machine (Fig. 5) is 9-11% lower over the entire range of the movement speed despite the presence of additional active operating parts, which also indicates the high efficiency of the new digging-separating operating part and a decrease in the load on the cleaning system of the heap of the potato harvester.

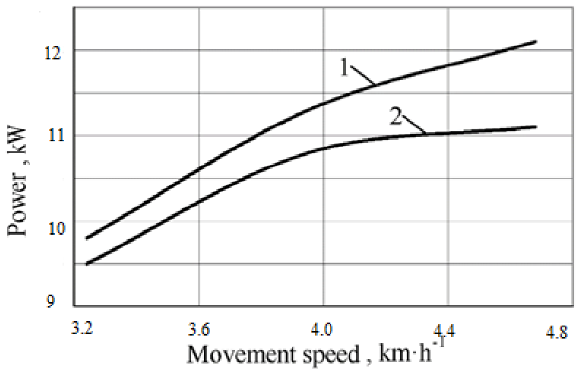

Fig. 5. **Dependence of the power on the drive of the operating tool of the potato harvester on the speed of its forward movement:** 1 – basic machine; 2 – experimental machine

The results of the research in the energy performance of the experimental machine are presented in Table 4.

Table 4

Energy assessment of operation of the experimental potato digger-loader KKN-2

Indicator	Value of the indicator		
Movemend speed, km·h^{-1}	3.24	3.95	4.68
Efficiency, ha·h^{-1}	0.45	0.55	0.65
Traction resistance, kN	11.7	12.3	12.6
Torque, Nm	185	210	216
Power on the tractor PTO (on the digger drive), kW	9.5	10.8	11.1
Used power, kW	19.8	24.7	26.5
Tractor engine load factor	0.315	0.411	0.441
Specific fuel consumption per hour of the main work, kg·h^{-1}	13.68	15.42	17.09

The results obtained confirm the efficiency of the proposed combined digging-separating operating tool in the technological scheme of the potato harvester and its high performance.

Conclusions

1. The use of the proposed combined digging-separating operating tool in the technological scheme of the potato harvester provides higher operational and energy performance: it increases the efficiency by 0.16 $ha \cdot h^{-1}$ and reduces the specific fuel consumption by 4.1 $kg \cdot ha^{-1}$.
2. The obtained dependences of the traction resistance on the forward speed of the potato harvester for the basic and the modernized machines show that at speeds above 3.55 $km \cdot h^{-1}$ the resistance of the modernized machine is lower. This can be explained by a better separation of the heap and, as a result, a decrease in its total mass, which is in the cleaning system. The traction resistance increases to the maximum value of about 12.6 kN at the speed of 4.7 $km \cdot h^{-1}$.

Author contributions

Conceptualization, V.B.; methodology, S.I. and V.K.; software, Z.R. and M.C.; validation, Y.I. and V.K.; formal analysis, V.B, S.I. and Z.R.; investigation, V.B., S.I., V.N. and Z.R.; data curation, Z.R., V.B. an V.K.; writing—original draft preparation, V.B.; writing—review and editing, Y.I. and Z.R.; visualization, Y.I..; project administration, V.B.; funding acquisition, S.I. All authors have read and agreed to the published version of the manuscript.

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