CONSTRUCTION FEATURES OF POTATO HARVESTERS AND THEIR INFLUENCE ON DAMAGE TO POTATO TUBERS DURING HARVESTING

Vasyl Achkevych, Borys Onyshchenko, Iurii Gumeniuk, Oksana Achkevych
National University of Life and Environmental Sciences of Ukraine, Ukraine
achkevych@nubip.edu.ua, borysoniscenko@gmail.com, gumenyuk.yurii75@gmail.com, achkevych@gmail.com

Abstract. The article is devoted to the analysis of the design features of potato harvesting machines and their influence on the quality of potatoes during mechanized harvesting. Harvesting and processing potatoes can cause physical damage to the tubers and cause economic losses to producers. Damaged tubers increase the risk of diseases and crop loss during storage, increase labour costs for sorting, and reduce the quality and value of stored tubers. The design features of potato harvesters and their influence on the quality of the obtained crop are analysed. An algorithm for determining the critical points of potato damage when passing through a combine is proposed. It was established that parameters such as the soil moisture, ambient temperature, and potato variety have less influence on damage to potato tubers. It was established that the percentage of injury to potatoes largely depends on the settings of the potato harvester and the speed of the harvester. A comparison of potato harvesters GRIMME SE 150-60 and AVR Esprit showed that non-compliance with technological settings increases damage to potato tubers by up to 27%. Increasing the speed of the unit above the specified standards increases the percentage of injuries from 7 to 11%. After correction for the reduction of the rotation speed of the rollers and technical clearances, the injury rate decreased from 16% to 11% under the same conditions. Reducing the speed of the unit to the established standards minimizes the percentage of damage. In general, any potato harvester, with the correct technological settings and compliance with all requirements, can ensure the process of harvesting potatoes with minimal losses.

Keywords: potatoes damage, harvester, technological setting.

Introduction

Today in Ukraine there is a problem with providing the population with potatoes. According to statistics, 20-21 million tons of potatoes are grown in Ukraine. Most producers are small farmers. With the transfer of potato production to an industrial basis, i.e. to full mechanization of all processes from planting to harvesting and storage, the problem of preventing mechanical damage to tubers becomes especially urgent. A large percentage of potato tubers are injured when passing through the potato harvester and when falling from the unloading conveyor into the trailer. Potato damage is a major problem in potato production worldwide. Damaged potatoes sent for storage can cause damage to the entire crop. Potatoes damaged during handling will be rejected by processors looking for perfect material to produce perfect potato products.

It was established that damaged potatoes have a reduced shelf life, which leads to increased waste and greater losses during storage in potato warehouses. Mechanical damage, in turn, also contributes to the development of rot, and crumpled tubers cause blackening of the pulp during storage. In foreign and domestic practice, the main directions of solving the problem of reducing potato injuries by improving the working bodies of potato harvesting machines have been clearly outlined. In [1], a physical model of the collision of potato tubers was investigated, considering the deformation and the analysis of the deformation energy during the collision. The model showed that the degree of potato damage is correlated with the impact material, potato variety, potential energy, and the impact angle. The work [2] gives the results of field experiments and found that the level of injury depends on the speed of transporting potatoes. The work [3; 5] investigated the frequency of injuries when falling from a height of 30, 60, and 90 cm. It was established that the reduction of injuries is directly proportional to the height of the fall. The minimum percentage of damage is when the height of the fall is less than 20 cm. In [4], the degree of injury was assessed based on parameters describing a specific bruise, such as: depth and width of the bruise. It was found that the appearance of bruises was detected for the studied potato variety at an impact speed of 1 $m \cdot s^{-1}$. This corresponded to a drop height of 50 cm. In works [6; 7], the authors studied the design of a rotary potato harvester. The main task is to improve separation from lumps as much as possible and thereby reduce injury to potato tubers. In [8,9], based on experimental studies, a mathematical model of the design parameters of the separator for the soil impurity cleaner was developed. These parameters of the distributor reduce pile pollution on the sorting table of the potato harvester to 11.41%. In [10], the results of the influence of the speed of the potato harvester and the soil

DOI: 10.22616/ERDev.2024.23.TF164

moisture on the impact intensity and tuber damage are given. In wet soil conditions, the increased flow of soil in the machine due to the higher speed of movement reduces the intensity of the impact and the degree of damage. Harvesting in dry soil resulted in greater lesion intensity and tuber damage.

Scientists are developing different methods to assess potato tuber injuries during harvest. The latest developments are Smart Spud and TuberLog. These are electronic potatoes that detect and record shocks while moving with real potatoes during harvesting and processing. Impacts are instantly transmitted via Bluetooth, so the operator can immediately locate the source of the impact and adjust machine settings to reduce impact and minimize bruising. The advantages of using electronic potatoes become obvious for producers and processors due to the rapid response to injury sites.

The disadvantage of using an electronic potato is the cost of the electronic potato itself and the imperfection of obtaining results. The electronic potato does not give a complete result of damage along the entire plane of the conveyor. Another drawback is only the determination of the impact force of electronic potatoes, which does not always indicate the appearance of bruises or mechanical injury. After all, injury depends on the potato variety, air and soil temperature, humidity, and many other factors.

Materials and methods

The research was conducted in the Zhytomyr region of Ukraine. Two potato harvesters Grimme SE 150-60 and AVR ESPRIT were studied. The combine Grimme SE 150-60 – 2-row with side undercut and with a storage hopper up to 7.5 t. The AVR ESPRIT combine - with direct undercut without a storage hopper. It works according to the technology of direct unloading into the trailer.

The studies were conducted in the same climatic zone and in the same harvest period at 60 km from each other. The soils on both studied sites are the same – sandy soil. The Grimme SE 150-60 combine was tested at: air temperature 25 ºC; potato temperature – 16 ºC; productivity - 35 t·ha^{-1}; percentage of potato dry matter – 21.4%; injuries – 16%. The AVR ESPRIT combine - at an air temperature of – 22 ºC; potato temperature – 14 ºC, productivity – 50 t·ha^{-1}; dry substances 22.3%; injury of tubers – 10%. Damage to potatoes was determined by the method presented in [11].

The research methodology consisted of the following.

1. 1. The harvester stops anywhere in the field. The main condition is that all conveyors are filled with potatoes. We take samples in designated places. Such places are Fig 1, 2: the transition of the flow of potatoes from the plow to the transport conveyor, the movement of the flow along the main conveyor and the lump crusher, the rise of the potatoes into the hopper-accumulator and the fall of the flow of potatoes into the hopper or the vehicle. From each research point 10 potatoes are selected along the width of the conveyor.

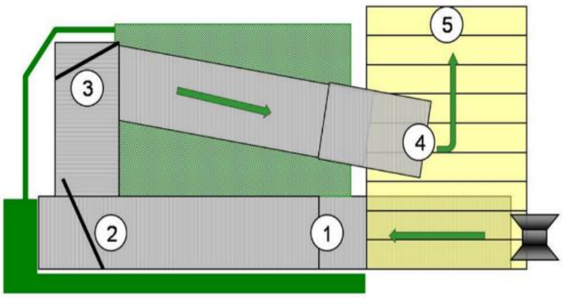

Fig. 1. **Sampling points Grimme SE 150-60:** 1 – digging shovel; 2 – transition from the first to the second conveyor; 3 – transition to the third conveyor; 4 – sorting table; 5 –hopper

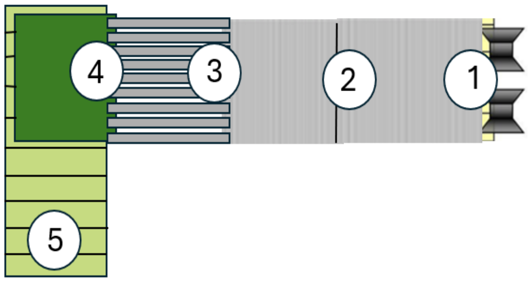

Fig. 2. **Sampling points AVR ESPRIT:** 1 – digging shovel; 2 – transition from the first to the second conveyor; 3 – transition to separation rollers; 4 – sorting table; 5 – transport conveyor

2. Determination the percentage of dry matter of potatoes. Potatoes consist of 70-75% water and 20-30% dry matter. The dry matter content is important for the percentage of damage. The higher the percentage, from 25 to 28%, the greater the probability of damage when the potatoes pass through the potato harvester. The content of dry matter in potatoes was determined using the device in Fig. 3. To do this, you need to collect 3 kg of potato tubers and place them in a container with water. The

scale of the device will show the percentage of dry matter. According to the received data, it is necessary to adjust the operating mode of the potato harvester.

Fig. 3. **Device for measuring dry matter**

3. The selected samples are placed in a thermal cabinet. The conditions and time of exposure of experimental samples accelerate the processes occurring in potatoes during long-term storage in potato warehouses.

The warming cabinet is designed to accelerate this reaction by creating warm and moist conditions that promote faster bruising. Optimal development of bruises is at a temperature of 30 ºC and a relative humidity of 97% within 12 hours. When the hot box bruising testing is used in conjunction with an electronic potato chute, the shocks measured by the electronic potato during harvest or sorting can be effectively calibrated by relating them to the level of bruising that occurs in the hot box. This allows to take measures earlier, which leads to a decrease in the number of bruises and damage to potatoes.

Fig. 4. **Thermal cabinet, thermal relay and heater**

Results and discussion

Analysis of the Grimme SE 150-60 harvesters showed that of the 16% damage, 11% was mechanical damage such as peeling, punctures and cracks, and 5% was bruising, i.e. potatoes falling from a height. A study of the operation of the AVR ESPRIT potato harvester showed that the percentage of damage is only 9%, Fig. 4-9. These are mainly mechanical injuries such as punctures, cracks, and cuts.

Based on the conducted research, a graph of the dependence in Fig. 11 shows the damage to potato tubers from a change in the speed of the potato harvester. Both combines had the lowest injury percentage at a minimum speed of 2 km·h^{-1}. This is explained by the low speed of movement of potatoes along the conveyors of the combine.

Fig. 5. **Ploughshare**

Fig. 6. **First web**

Fig. 7. **Second web**

Fig. 8. **Picking table**

Fig. 9. **Hopper**

Fig. 10. **Trailer**

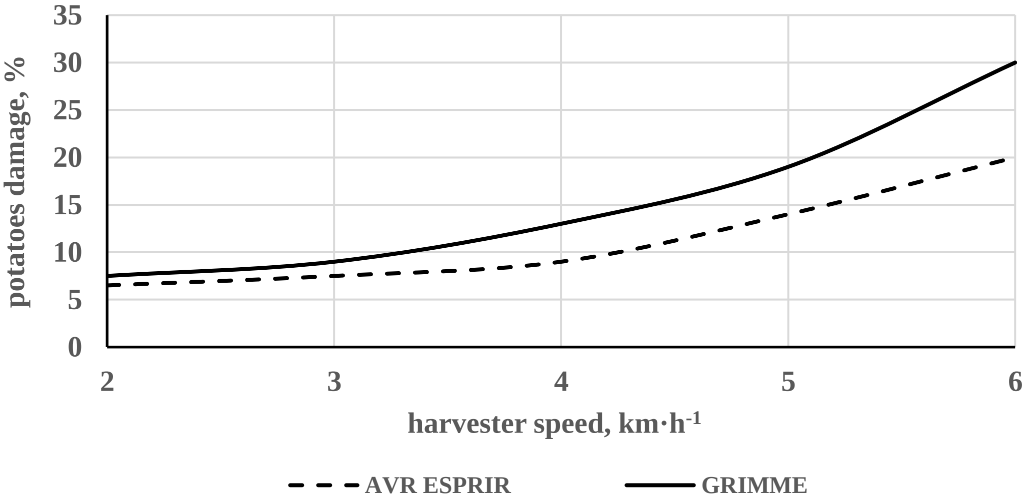

Fig. 11. **Dependence of potato damage on the speed of the potato harvester**

When the speed of movement increases to 4 km h^{-1}, the percentage of damage also increases, but not significantly. In the GRIMME potato harvester, the percentage of damage increased from 7 to 13%, in the AVR ESPRIT combine from 5 to 9%. With a further increase in the movement speed of the unit, there is a significant increase in the injury rate of potato tubers in both harvesters. At a maximum speed of 6 km·h^{-1}, the percentage of damage reaches 20 and 30%, respectively. This is explained by the large supply of potato piles to the conveyors of the combine. The entire pile does not have time to sift through and damage occurs with lumps and residues. A large percentage of damage in the GRIMME harvester is due to many potatoes that simply cannot pass from the unloading conveyor to the inspection table (bottle principle).

Also, the problem of damage to potato tubers is the discrepancy between the speed of the conveyors and the speed of the potato harvesting unit. Fig. 12 presents a graph of the dependence of damage to potato tubers on the change in the conveyor speed at the combine speed of 4 km·h^{-1}.

Analysis of Fig. 12 indicates that the minimum damage to potato tubers will be at the same speed of movement of the harvester and conveyors. At a significantly lower speed of the conveyors, in relation to the speed of the harvester, the percentage of injuries in both cases is quite significant. In the AVR ESPRIT combine, it decreases from 20% at a speed of 2 km·h^{-1} to 7% at a speed of 4 km·h^{-1}. In the GRIMME harvester, the percentage of damage is reduced from 17% to 10%. This is explained by the large amount of potato piles on the first conveyors. Also, when the speed of the conveyors increases, the percentage of damage increases significantly. This is the result of the lack of potatoes on the conveyors. Potatoes pass through the conveyors very quickly and bounce off. In some cases, they even roll back.

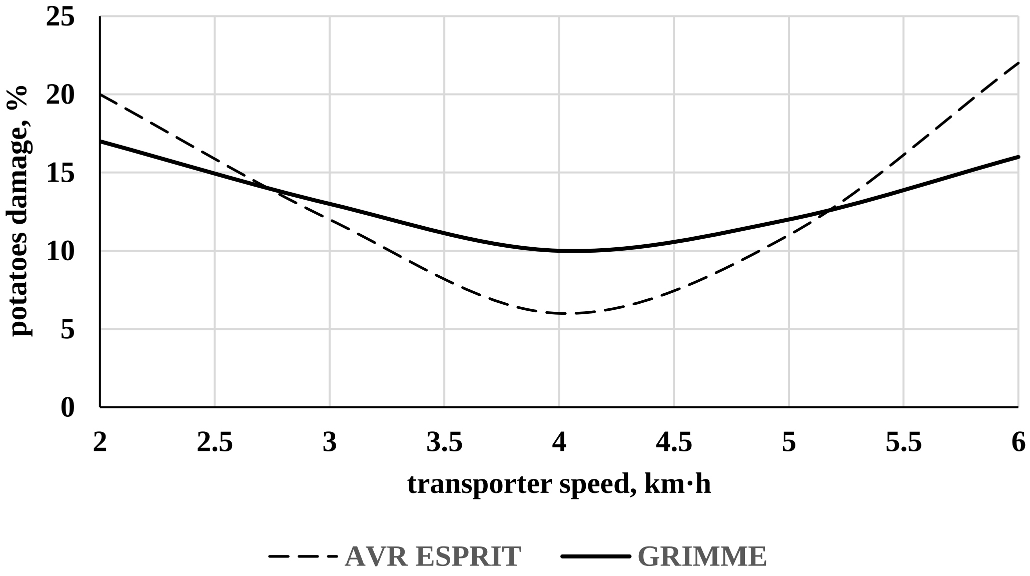

Fig. 12. **Dependence of potato damage on the speed of conveyors at the combine speed of 4 km· h^{-1}**

Conclusions

1. The study of the effect of potato harvesters of various designs on potato injury was carried out. It has been established that factors such as the soil moisture, ambient temperature, potato variety have less influence on damage to potato tubers.
2. The method of conducting a study to determine the effect of a potato harvester on the percentage of damage to potato tubers is presented. This technique can be used in different farms and is a cheaper option.
3. Both harvesters had the lowest injury percentage at a minimum speed of 2 to 4 km·h^{-1}. This is explained by the low speed of movement of potatoes along the conveyors of the combine. At the maximum speed of 6 km·h^{-1}, the percentage of damage reaches up to 20% - AVR ESPRIT and 30% - GRIMME, respectively. This is explained by the large supply of potato piles to the conveyors of the combine.
4. Minimal damage to potato tubers will occur at the same speed of movement of the harvester and conveyors. At a significantly lower speed of the conveyors, in relation to the speed of the harvester, the percentage of injuries in both cases is quite significant. In the AVR ESPRIT combine, it decreases from 20% at a speed of 2 km·h^{-1} to 7% at a speed of 4 km·h^{-1}. In the GRIMME harvester, the percentage of damage is reduced from 17% to 10%. This is explained by the large amount of potato piles on the first conveyors.

Author contributions

Conceptualization, V.A.; methodology, V.A and I.G.; software, B.O.; validation, V.A., and O.A; formal analysis, O.A and I.G..; investigation, B.O., I.G. and O.A.; writing – original draft preparation, V.A.; writing – review and editing, V.A. and I.G.; visualization, O.A.; project administration, B.O. All authors have read and agreed to the published version of the manuscript.

References

[1] Hunang T., Wu B., Li L., Zuo T., Xie F. Construction of impact mechanics model and experimental study on impact damage of potato tuber. inmateh - Agricultural Engineering, vol. 66, 2022, pp. 139-149.
[2] Kursat H., Celik R.C., Yilmaz D., Ulmeanu M.E., Rennie A.E.W. Akinci I. Mechanical collision simulation of potato tubers. Journal of Food Process Engineering, 2019, pp. 483-495.

[3] Kitchen N.R., Drummond S.T., Lund E.D. Soil electrical conductivity and topography related to yield for three contrasting soil-crop systems. Agronomy Journal, vol. 95, 2003, pp. 483-495.
[4] Stropek Z., Gołacki K. Studies concerning the response of potatoes to impact. 2022 Institute of Agrophysics, Polish Academy of Sciences, vol. 36, 2022, pp. 115-122.
[5] Sharma V., Singh S., Singh B., Kumar M. Potato Nutritional Quality Loss Due to Bruising: Need Attention During Handling. Food Science and Engineering, 2022, pp. 58-68.
[6] Bulgakov V., Bonchik V., Holovach I., Fedosiy I. Justification of parameters for novel rotary potato harvesting machine. Agronomy Research, vol. 19 (S2), 2021, pp. 984-1007.
[7] Olt J., Adamchuk V., Korniushyn V., Melnik V., Kaletnik H. Research into the parameters of a potato harvester's potato heap distributor, and the justification of those parameters. Journal of Agricultural Science, 2021, pp. 92-99.
[8] Bulgakov V., Ivanovs S., Pascuzzi S., Adamchuk V., Ruzhylo Z. Experimental research of quality indicators of operation of new potato harvester. Engineering for rural development. Jelgava, 2022, pp. 701-707.
[9] Celik K., Akinci I., Erkan M, Rennie A. Determining the instantaneous bruising pattern in a sample potato tuber subjected to pendulum bob impact through finite element analysis. Jornal of Food Process Engineering. 2023, vol. 46, issue11.
[10] Bentini M., Caprara C., Martelli R. Harvesting Damage to Potato Tubers by Analysis of Impacts recorded with an Instrumented Sphere. Biosystems Engineering, 2016, vol. 94, issue 1, pp. 75-85.
[11] TuberLog [online] [11.02.2024] Available at: http://martinlishman.com/tuberlog/