Improving the performance parameters of vehicles for intrafarm transport in the agro-industrial complex

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Abstract. The article presents the results of theoretical studies on the process of damaging root crops when they are unloaded from the dump bodies of vehicles. The results have revealed that the maximum speed of fall of individual tubers can reach 6.42 m/s. Moreover, it is well known that the permissible values of this parameter for various fall options (surfaces on which roots and tubers are unloaded) have the following values: steel or wood - 1.9-2.5 m/s; rubber - 5.6-7.5 m/s; free tuber - 3.8-5 m/s and not free tuber - 2.7-5.2 m/s. Accordingly, there is a high probability to damage a tuber when it falls. The technical solution considered in the article helps to reduce the damages of tuberous roots when they are unloaded from the dump bodies of vehicles by reducing the dynamic impact on individual tubers.

1. Introduction

The role of transport in agricultural production is significant [1-2]. The development of agricultural production inevitably leads to an increase in traffic. Therefore, issues of increasing labor productivity and reducing damage to products of the agro-industrial complex of the Russian Federation, which are possible in transport, are now acquiring great importance [3, 4].

A balanced development of all parts of the agro-industrial complex is a necessary condition for solving the problem of providing the country with food and agricultural raw materials. Currently, the weak development of the processing industries of the agro-industrial complex and the industrial infrastructure of the complex lead to huge losses of agricultural products. For example, the loss of harvested grain is 30 % and that of potatoes and vegetables is 40-45 % [3].

One of the most significant and difficult tasks is the fight against damage and loss of agricultural products, in which automobiles and tractors play a very demanding role. As the analysis of materials on harvesting and intrafarm transport of potatoes showed, more than 15-20 % of the production does not reach the consumer [5-9]. Up to 50 % of the time a vehicle is in service is idle at loading and unloading points, which also adversely affects the safety of products. Transport costs in the prime cost of crop production reach 30-40 % or more. An increase in harvest time leads to increased losses and damage. Therefore, an increase in the productivity of intrafarm transportation is necessary: delay of harvesting leads to work when the air temperature is less than 5-7 degrees Celsius, which is one of the main causes of loss and damage.

To transport damageable products, including potato, from the field in most cases dumping trailers
and semi-trailers are used, as well as dumping bodies of vehicles. In addition to universal technology, large agricultural producers may have some specialized models, for example, the KAMAZ BALT GRAND-POLEVIK. But with all the diversity of modern technology, 3 problems remain unsolved:

- damage to tubers when loading into a vehicle;
- damage to tubers during transportation;
- damage to tubers when unloading.

Among specialized equipment there are devices that can significantly reduce the number of damaged potatoes. These include all kinds of devices to still falling tubers when loading, a movable bottom of the vehicle body, rubberized surfaces of the sidewalls of the body, all kinds of devices for gentle unloading of tubers, etc.

For example, the company Fliegl (Germany) manufactures large-capacity trailers (the total mass of the semi-trailer with cargo varies from 11 to 44 tons), which can optionally be equipped with a significant number of replaceable working parts (mounted fan equipment for transporting sawdust, manure distributing equipment, reloading auger and others). Figure 1 shows the ASW semi-trailer with a hydraulic folding conveyor “POM-Over” with a cleaning belt for reloading potatoes, carrots, etc.

![Figure 1. ASW Fliegl trailer wagon with POM-Over conveyor belt.](image)

The use of this specialized equipment can significantly improve the efficiency of transportation of agricultural products from the field. First, the hydraulic folding conveyor allows unloading or reloading products with minimal dynamic effects (the height of the fall of tubers during overload or unloading is set to less than the maximum permissible values by changing the working position of conveyor “POM-Over”).

Secondly, the design of conveyor “POM-Over” allows additional purification of agricultural products. It is known [3] that when harvesting potatoes, depending on the conditions of work (humidity and soil type, yield, potato harvesting machine settings, etc.), a large amount of fertile soil is taken out of the field (according to agrotechnical requirements for the harvesting process, cleanliness of tubers in the container should be 80% or more, and, therefore, 1 ton of potato can have up to 200 kg of plant and soil impurities). When using standard transport equipment, the entire volume of impurities enters the post-harvest treatment facilities, and in cases of their absence into bins of potato storages. In cases of using an ASW trailer wagon with POM-Over conveyor belt, the soil is sifted out of the potato pile and remains near the vehicle for subsequent return to the field. Based on the foregoing, it follows that this specialized technique will be in demand in medium and large potato farms with an extensive and modern material and technical base.
2. Materials and methods

To ensure the expediency of using such technical equipment in potato farms with a landing area of 100 hectares or less, a universal hinged reloading device for dump trailers was developed [10].

As an example, Figure 2 shows a hinged reloading device mounted on a dump truck tractor trailer 2PTS-4.

Consider advantages of the proposed technical solution. First, the hitch makes possible to unload the potato heap, both to the post-harvest point, and directly to potato warehouse bins. This solves the main problem of the dump bodies of vehicles and semi-trailers - the height of the fall of tubers when unloading is reduced to a minimum. Secondly, the hitch rollers are hydraulically actuated - which makes it possible to adjust the flow of the pile through the partially open tailgate (Figure 2b) without unloading. Thirdly, the rollers of the device have rubber protrusions. On the one hand that prevents damage to the tubers when unloading, and on the other hand, they retain soil and plant impurities present in the trailer. And the most important thing is that the proposed device has a relatively low weight (unlike POM-Over conveyor where a complex system of hydraulic drives is used) and can be used with most domestic trailers and semi-trailers.

The process of unloading potatoes from a trailer is shown in Figure 3a. After opening the tailgate,
the heap enters the roller conveyor. Due to the rotation of the rollers (Figure 3b), the tubers move along the belt with additional acceleration. This is especially important if the angle of inclination of the conveyor is 45 degrees or less (for example, when reloading into a container with high sides).

The presence of elastic protrusions on the rollers makes it possible to carefully separate the soil impurities from the potato heap (the tubers move along the tops of the elastic protrusions of the rollers, while the soil impurities remain between them and are removed during their rotation).

If one compares the efficiency of the operation of this hinged reloading device with similar means, for example, with a semi-trailer dump truck with a bottom conveyor, one obtains the following advantages:
- a low level of damage to tubers in comparison with a body with a bottom conveyor (contact of tubers with rigid elements of the body during the operation of the bottom conveyor leads to additional damage);
- the speed of unloading potatoes when using the hinged reloading device is almost comparable to the speed of unloading from the serial dump body;
- versatility of the transport being modified, since the installation of the hinged reloading device does not require significant structural changes of the dump body, and its installation is carried out promptly and without the involvement of highly qualified personnel.

3. Result
Consider the possibility of damage to the product during its unloading from the vehicle (basic model of the dump body 2 PTS-4). Based on studies of the contact dynamic interaction of a potato tuber with a surface [1], it follows that the fall rate \( \theta_k \) must be less than the allowable value \( \theta_d \) (Table 1).

\[
\begin{array}{ccc}
\text{Surface} & \text{Fall height, m} & \text{Impact speed } \theta_d, \text{ m/s} \\
\hline
\text{steel, wood} & 0.18-0.33 & 1.9-2.5 \\
\text{rubber} & 1.6-2.8 & 5.6-7.5 \\
\text{free tuber} & - & 3.8-5 \\
\text{not free tuber} & - & - \\
\kappa = 2 & 0.1-0.2 & 2.7-3.6 \\
\kappa = 1 & 0.37-0.66 & 2.7-3.6 \\
\kappa = 0.5 & 0.87-1.6 & 4.1-5.2 \\
\end{array}
\]

Note: \( k \) is the ratio of the radii of tubers \( R_1 \) (the tuber that falls) to \( R_2 \) (the tuber to which it falls).

Determine the speed of the fall \( \theta_\text{f} \) of a tuberous pile when it is unloaded from dump trailer 2 PTS-4:

\[
\theta_k = \sqrt{\theta_0^2 + 2h \cdot \theta_0}\]  \( (1) \)

where: \( \theta_0 \) – initial speed of the tuber heap, m/s; \( g \) – acceleration of gravity, \( g = 9.8 \text{ m/s}^2 \); \( h \) – tubers fall height, \( h = 1.32 \text{ m} \) (height from the unloading surface to the platform of the dump trailer).

At the initial moment of time (at the beginning of the unloading process of a dump trailer) \( \theta_0 = 0 \), but as the platform rises, the tuber heap leaves the state of rest. To find the speed of the fall, we use the formula for calculating the speed of movement of the cargo along a rectangular gutter [11]:

\[
\theta_\text{f} = \sqrt{2 \cdot g \cdot l \sin \beta - f_1 \cdot \cos \beta \cdot \left(1 + \frac{n h_0}{b}\right) + \theta_0^2}\]  \( (2) \)

where: \( l \) – the platform length, \( l = 2.22 \text{ m} \) (the length of 2 PTS-4 platform); \( \beta \) – the tilt angle of platform 2 PTS-4 backward, degree; \( f_1 \) – the coefficient of friction of the cargo on sides and the platform. \( f_1 = 0.56 \) (the coefficient of friction of the tuber against steel); \( \theta_0 \) – the initial cargo speed, \( \text{m/s} \); \( \theta_0 = 0 \text{ m/s} \) (cargo is at rest); \( n \) – the lateral pressure ratio. \( n = 1 \); \( b \) – the platform width, \( m \). \( b = 4.08 \text{ m} \); \( h_0 \) – the height of the tail (main) board, \( m \). \( h_0 = 0.62 \text{ m} \).

4. Discussion
Substituting the original data in the formula (2), we obtain the graph presented in Figure 4.

![Graph of the rate of unloading products from a dump trailer versus its dumping angle.](Image)

Two points are marked on the graph: “A” is the minimum speed and dumping angle of the platform at which full unloading will be carried out; “B” is the maximum dumping angle $\beta_{\text{max}} = 50$ degrees (constructive limitation of dump trailer 2PTS-4) and the speed of unloading $\vartheta_{\text{init}} = 3.91 \text{ m/s}$. Substituting the available data in the formula (1) one gets:

$$\vartheta_k = \sqrt{3.91^2 + 2 \cdot 9.8 \cdot 1.32} = 6.42 \text{ m/s}$$

One obtains that the calculated value $\vartheta_k = 6.42 \text{ m/s}$ corresponds only to the allowable value of the fall rate of tubers on the rubber surface (Table 1). Otherwise, the probability of root crops damage is high.

5. Conclusion

When using the technical solution proposed above, the tuber heap on the dump trailer does not fall down ($h = 0$), but enters the roller conveyor (the rollers are equipped with protrusions of elastic material), which together reduces the possibility of damaging root crops to the minimum.

The above data confirms the efficiency of using the hinged reloading device on the dump trailer and makes possible to reduce additional damage to potato during the unloading process.

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