American Journal of Applied Science and Technology

VOLUME Vol.05 Issue 06 2025
PAGE NO. 128-136
DOI 10.37547/ajast/Volume05Issue06-28

Improving The Calibration Quality Of A Vibrating Sieve-Type Potato Sorting Machine By Optimizing Its Technological Parameters

Bakhadirov Gayrat Atakhanovich

Doctor of Technical Sciences, Professor, Institute of Mechanics and Seismic Stability of Structures named after M.T.Urazbaev of the Academy of Sciences of the Republic of Uzbekistan

Tursunaliev Ismoil Esonalievich

Researcher, Fergana State Technical University, Fergana, Uzbekistan

Received: 27 April 2025; **Accepted:** 23 May 2025; **Published:** 30 June 2025

Abstract: A promising and efficient vibrating sieve-type potato sorting machine, which is a structural component of a mechanized complex for post-harvest processing and storage of potatoes, has been studied. The relevance of developing effective methods for designing and calculating sorting equipment that classifies potato tubers into fractions by size is emphasized. As a result of theoretical research aimed at designing an optimal configuration of a vibrating sieve sorting machine, a highly efficient device was developed. According to the experimental results, the highest calibration accuracy reaches 94%. This level of performance is achieved under the following operating conditions: product feed rate – 18 tons/hour, sieve vibration amplitude – A = 30 mm, vibration motor speed – 300 rpm, inclination angle of the calibrating surface – β = 7°, crank inclination angle – ε = -6°, and spring stiffness of the vibration mechanism – k = 13 N/mm.

Keywords: Potato sorting, tuber fractions, potato sorting machine, sieve-type sorting device, vibrational sorting, efficiency, quality.

Introduction:

In the scientific literature, potato calibration is described as the process of passing tubers through square holes of a specified size and sorting them by their maximum diameter [1,2]. Accordingly, at present, enterprises and agricultural clusters in Central Asia—particularly in Uzbekistan and Kazakhstan—specialized in potato and onion production and processing, widely utilize calibration machines equipped with square-hole mechanisms manufactured by foreign companies such as Grimme, Schouten, and Tolsma. Among them, Tolsma machines are most commonly used due to their compact size and simple structure.

Although these machines are considered relatively reliable, they also have certain drawbacks. One of the common disadvantages of such calibrating machines is the jamming of tubers within the sieve holes during operation. Specifically for Tolsma machines, rapid wear of the drive shaft clutch and frequent breakage of transmission belts have been reported.

To identify the causes of such shortcomings in these types of sorting machines, detailed analyses were conducted focusing on the kinematic and dynamic forces acting on the machine's operating components. Recommendations for improvement were developed accordingly [3].

Theoretical studies have emphasized that when modernizing existing machines, it is essential to consider dynamic vibrations, which may cause potato tubers to become wedged into sieve openings and suffer mechanical damage. Hence, while improving the working mechanism of a vibrating sorting machine, it is necessary to take into account the forces acting on the tubers and apply vibration damping measures. One of the simplest and most effective damping methods is the use of springs [4].

The working surface of the sorting machine is installed at an inclined angle relative to the horizontal plane. It consists of three sequentially mounted frames, each fitted with metal rods (sieves) covered with elastic material. The spacing between the rods differs from frame to frame: the first frame has the smallest spacing, the second is wider, and the third has the widest spacing. Each subsequent frame is positioned slightly lower than the previous one.

The front end of the frame assembly is mounted on the machine bed using vertical springs, while the rear end rests on rollers. The base supports of the machine are made of vibration-absorbing material and fixed to the foundation with rubber-like components. An electric motor with an eccentric mass is attached to the vibrating base supports to induce oscillatory motion.

During operation, the pile of root crops is delivered to the inclined sieving surface using a conveyor and guide chute. When the motor is activated, the eccentric mass causes horizontal vibrations of the support structure and both horizontal and vertical oscillations in the springs. As a result of this vibratory motion and the inclined plane, the tubers move along the working surface. During their movement, the tubers fall through the gaps between the rods corresponding to their size and are thus sorted. The calibrated tubers are then transported to their respective collection points via conveyors.

Figures 1 and 2 illustrate the side view and top schematic view of the proposed vibrating sieve-type sorting machine.

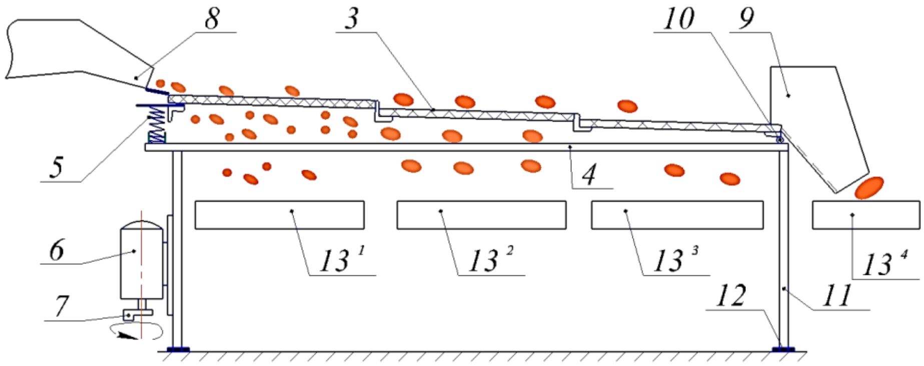


Figure 1. Side view of the vibrating sorting machine.

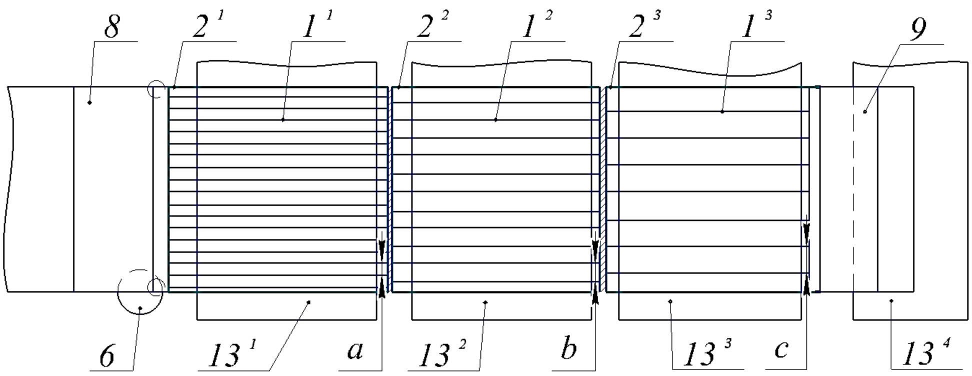


Figure 2. Top schematic view of the working surface of the vibrating sorting machine

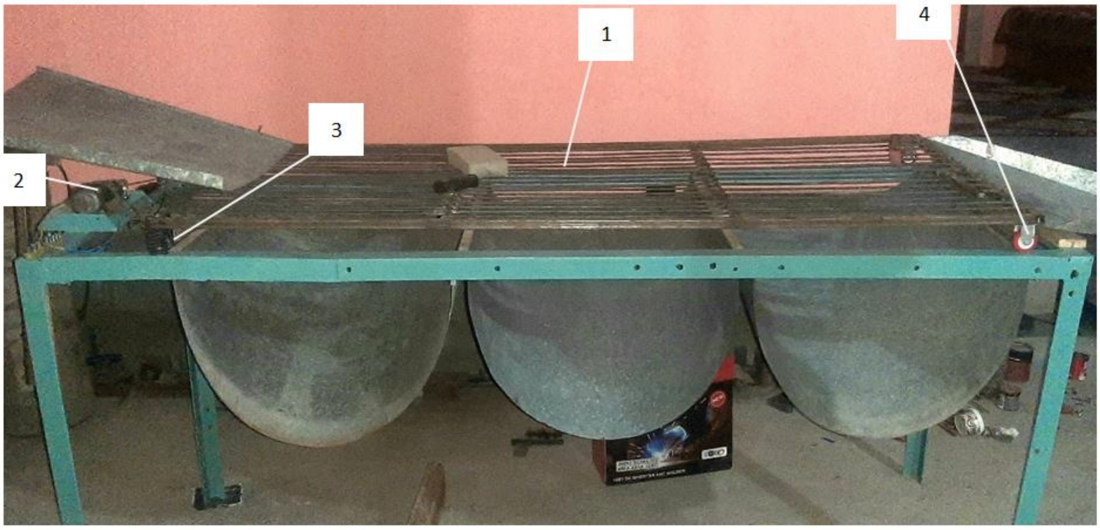
The vibrating sorting machine consists of a working surface (3), formed by three frames (2^1, 2^2, 2^3), each equipped with sieving rods (1^1, 1^2, 1^3) positioned at varying distances from one another. To generate vertical vibration, springs (5) are installed between the working surface and the machine frame (4). The driving unit includes an electric motor (6), with an eccentric mass (7) mounted on its shaft to induce horizontal vibration.

The system includes a feeding conveyor that delivers the heap of potatoes to the inclined sieving surface, and chutes (8 and 9) guide both the incoming tubers and the sorted fractions toward the corresponding conveyors. Rollers (10), kinematically attached to the working surface and capable of moving along the machine base, ensure horizontal displacement of the sieving platform.

The machine frame is supported by elastic steel rod supports (11), which vibrate during operation. To dampen the transfer of vibration to the ground, rubber-like damping elements (12) are placed underneath the supports. The system also includes multiple conveyors (13^1, 13^2, 13^3, 13^4) that transport sorted fractions to designated locations.

The working surface (3) is inclined downward from its beginning to the end relative to the horizontal axis (Figure 1). It is composed of three sections, each formed by a frame with sieving rods arranged longitudinally at different spacings: the first frame has the smallest spacing, the second is wider, and the third is the widest (a < b < c), as shown in Figure 2.

For experimental testing, design documentation and a prototype of the sorting machine were developed. The prototype was constructed as a mobile unit, allowing it to be used independently or integrated into a larger post-harvest processing line for potatoes. In addition to the main components shown in Figure 3, the setup includes conveyors for feeding and discharging sorted fractions, as well as a screw mechanism for adjusting the inclination angle of the sieving surface.



1 – sorting surface; 2 – electric motor; 3 – spring; 4 – wheel.

Figure 3. Experimental prototype view of the main components of the sorting machine:

The machine frame is equipped with a screw adjustment mechanism mounted on its supports, which allows for real-time modification of the inclination angle of the sorting surface during operation.

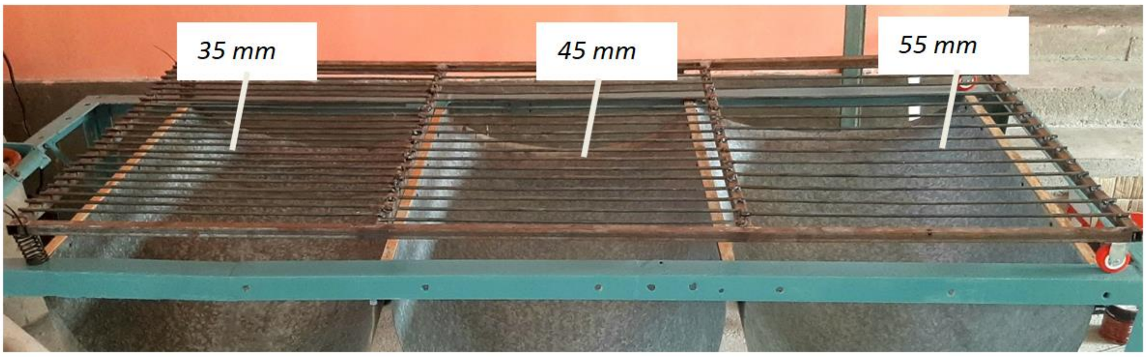


Figure 4. View of the machine's working surface.

Materials and Methods

Due to the low power requirement for the operation of the machine, a 0.75 kW electric motor was installed. The process can be controlled by adjusting the working surface parameters of the vibrating sieve-type sorting device. In the proposed vibrating sorting machine, experimental studies were conducted under laboratory conditions to evaluate the influence of changes in technological parameters—such as vibration amplitude, rotational speed, inclination angle, etc.—on the quality of the sorting process.

During the laboratory experiments with the potato sorting machine, the effects of the following parameters on the calibration of potato tubers were investigated:

- Vibration amplitude of the working unit (A): 26 mm; 30 mm; 34 mm; 38 mm
- Angular speed of the electric motor (ω): 150 rpm; 300 rpm; 450 rpm; 600 rpm
- Inclination angle of the working surface (β): 4°; 6°; 8°; 10°
- Spring stiffness (k): 4 N/mm; 8.5 N/mm; 13 N/mm; 17.5 N/mm
- Crankshaft inclination angle (ε): -9°; -6°; -3°; 0°; +3°
- Feed rate of potato tuber mass (Q): 14.4 t/h; 16.1 t/h; 18.0 t/h; 19.8 t/h

To ensure continuity in the technological calibration process, the rotation frequency of the loading conveyor's drive shaft was selected such that the tuber mass was delivered to the calibration surface proportionally—i.e., the feed timing and the linear velocity of the conveyor belt were synchronized, preventing overloading or uneven feeding.

To study the effect of tuber feed rate in the experimental prototype, the mass of potato tubers corresponding to each selected feed rate was calculated based on the above parameters (see Table 1). This mass was evenly distributed along a specific section of the conveyor belt. For further analysis, the concept of hourly throughput was used, as it is equivalent to specific feed rate when related to the geometric dimensions of the machine's calibration surface.

The performance of the machine during the experiment was evaluated based on sorting accuracy. For this purpose, identical volume samples were taken from the sieve outlet and from each discharge stage. These samples were weighed and then the tubers were separated into their respective fractions. Tubers that did not meet the target fraction criteria but were found within a particular group were separated and reweighed to assess misclassification.

Table 1. Experimental loading masses of potato tubers corresponding to different feed rates

Kartoshka tuganaklari uyumini uzatish	
Soatiga, t/s	Soniyasiga, kg/sek
14,4	4
16,1	4.5
18	5
19,8	5,5

Data Processing and Evaluation

The obtained experimental data were tabulated, and the following evaluation criteria were applied:

- Sorting accuracy for each individual fraction was determined using the formula:

$$\mu_1 = \left(\frac{M_i}{M}\right) \cdot 100\% \tag{1}$$

Where:

M_i – mass of tubers that meet the requirements of the target fraction;

M – total mass of all tubers that fell into the fraction.

- Overall sorting accuracy of the machine was calculated as:

$$\mu\Sigma = (\sum_{i-0}^{n} M / M_{\Sigma}) \cdot 100\% \tag{2}$$

Where:

n – number of fractions;

M_{Σ} – total mass of all sorted tubers.

The data obtained from the laboratory experiments were processed using statistical variation methods

[5], and to enhance visual comprehension, the results were also expressed through graphical relationships.

RESULTS

Based on the literature review [6, 7, 8, 9, 10], the main operating modes and parameters of existing potato sorting machines with sieve-type calibrating surfaces—featuring square, round, or hexagonal holes—have been established. In such machines, the inclination angle of the calibrating surface (β) and the crankshaft deviation angle (ε) typically range between 6° and 10°. The vibration amplitude (A) of the sieve generally varies between 10 mm and 40 mm, while the vibration frequency (ω) of the sieves lies within the range of 23 to 37 s^{-1}.

Effect of Vibration Amplitude and Frequency on Sorting Accuracy

Previous research [8] has shown that the two most influential parameters in the calibration process of potato tubers are the angular speed of the sieve and the vibration amplitude. Therefore, the initial phase of the present investigation focused on determining the influence of these two parameters on the sorting efficiency of the vibrating sieve-type potato sorting machine.

As discussed in the previous section, the actual vibration frequency of the sieve is not directly proportional to the frequency of the vibration-generating mechanism [11]. Hence, the experiments were carried out based on the rotational speed of the electric motor.

Experimental results revealed that when the vibration amplitude of the sieve was A = 26 mm or lower and the motor rotation speed was 150 rpm, the sorting process of the potato tuber mixture did not occur across any tested vibration frequencies. This was attributed to the insufficient displacement of the potato mixture along the sieving surface, which caused the tubers to accumulate on the surface instead of moving and separating.

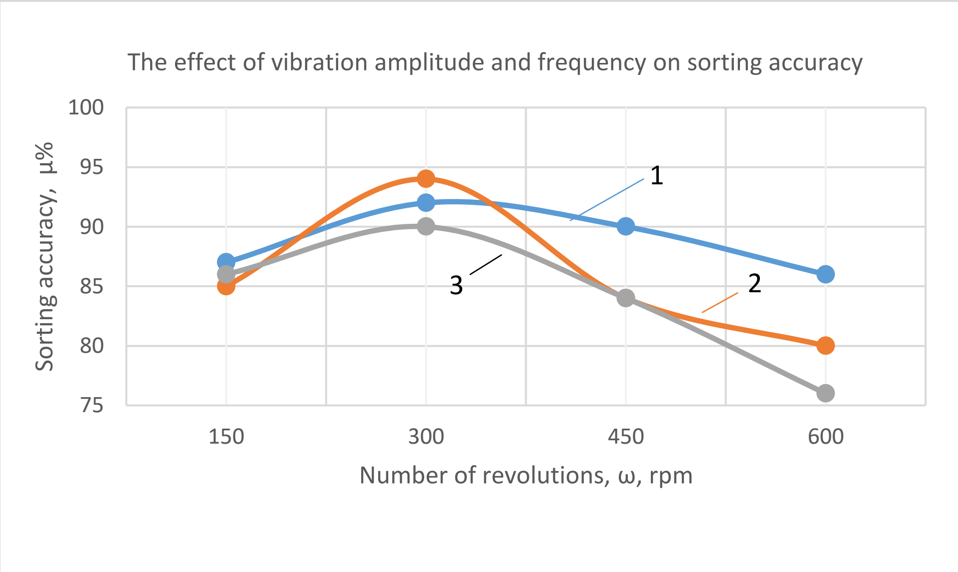


Figure 5. Effect of electric motor rotation speed on calibration accuracy:

1 – A = 26 mm; 2 – A = 30 mm; 3 – A = 34 mm.

Influence of Vibration Amplitude and Frequency on Sorting Accuracy

At a constant vibration amplitude of A = 26 mm (Figure 5, curve 1), the calibration of the potato tuber mass begins at a vibration frequency of ω = 150 rpm, where the sorting accuracy (μ) is 87%. As the frequency increases to 300 rpm, the accuracy reaches a peak of 92%, which is considered the optimal value for this amplitude. However, further increases in frequency result in reduced accuracy: at ω = 450 rpm, the accuracy decreases to 90%, and at ω = 600 rpm, it drops further to 86%. This decline is attributed to the increasing movement speed of the tuber mixture across the sieving surface at higher vibration frequencies, which reduces the time available for effective separation.

When the vibration amplitude is increased to A = 30 mm (curve 2), the sorting process begins even at the lower frequency of ω = 150 rpm, yielding an accuracy of 85%. As the frequency increases, the accuracy improves significantly, reaching a maximum of 94% at ω = 300 rpm. However, similar to the previous case, any further increase in vibration frequency results in a drop in sorting accuracy, falling to 84% at ω = 450 rpm.

Curve 3 in Figure 5 represents the case when the sieve vibration amplitude is A = 34 mm. The sorting process starts at ω = 150 rpm and achieves a maximum accuracy of 90% at ω = 300 rpm. Beyond this frequency, the accuracy declines sharply, with only 76% accuracy observed at ω = 600 rpm, which does not meet agro-technical requirements for sorting.

These results demonstrate a clear pattern: as the angular vibration frequency increases, the sorting accuracy initially improves up to a certain optimal point, after which it begins to decline. This behavior is explained by the increased horizontal movement speed of the potato tubers along the sieving surface at higher frequencies, which limits the effectiveness of fraction separation.

As shown in the plotted dependencies, the highest sorting accuracy of 94% was achieved when the vibration frequency was ω = 300 rpm and the vibration amplitude was A = 30 mm.

Effect of the Inclination Angle of the Sieving Surface on Calibration Accuracy

Previous studies on vibrating sieves [6, 8, 12, 13] have demonstrated that an inclination angle of the sieving surface within the range of β = 10° to 30° produces effective results. However, these investigations were primarily conducted on general-purpose vibratory sorting devices used for screening raw construction materials, such as rock and ore.

In contrast, studies specifically related to agricultural products—particularly those targeting potato tuber calibration—have shown that the optimal sorting accuracy is achieved at inclination angles of β = 6° to 8° [14]. Based on this, our laboratory experiments were carried out within a narrower range of β = 4° to 10°, with additional focus on β = 7° in certain modes.

Studying the effect of the sieve surface inclination angle on calibration accuracy allows for identifying the most optimal installation angle for the sieves. Figure 6 presents the results of this analysis for three selected vibration frequencies:

1 – ω = 300 rpm;

2 – ω = 450 rpm;

3 – ω = 600 rpm.

Initial experimental results revealed that the highest sorting accuracy was observed at a vibration amplitude of A = 30 mm and vibration frequency of ω = 300 rpm. Under these fixed vibration conditions, the influence of the calibration surface inclination angle (β) within the range of 4° to 10° was examined (see Figure 6).

When the angle was β = 4° (curve 1), the sorting accuracy was 86%. As the inclination increased to 6°, accuracy improved by 6%, reaching 92%. However, when the angle was further increased to β = 8°, the accuracy slightly declined to 90%. Since the difference between β = 6° and β = 8° was marginal, we decided to conduct an additional experiment at β = 7°, which resulted in the maximum observed accuracy of 94%.

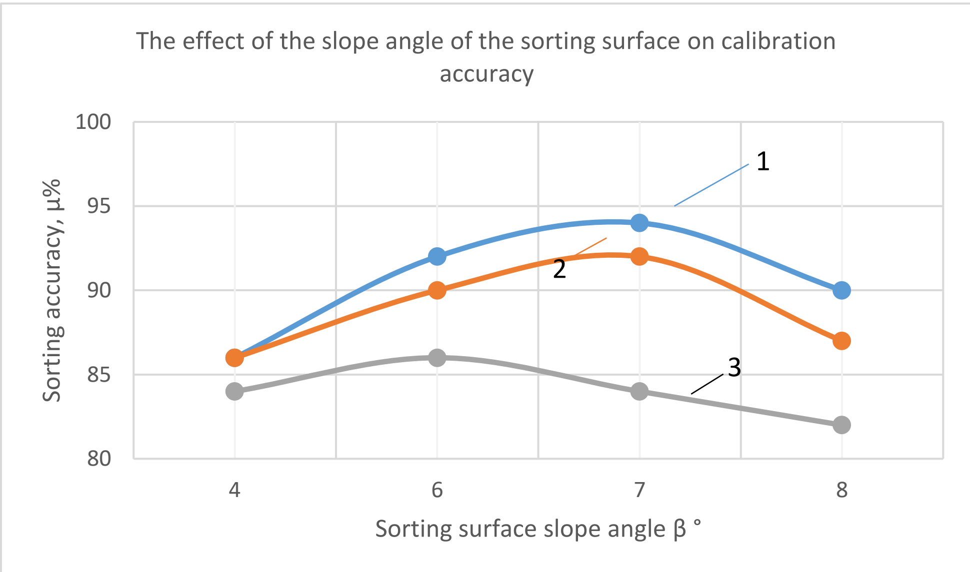


Figure 6. Effect of the slope angle of the sorting surface on calibration accuracy

At a rotation speed of ω = 450 rpm, the dependence of calibration accuracy on the inclination angle of the sieving surface (curve 2) exhibits a trend similar to that of curve 1 (ω = 300 rpm). The highest sorting accuracy of 92% was achieved at an inclination angle of β = 7°. However, when the inclination was increased to β = 8°, the accuracy dropped to 87%.

At a higher rotation speed of ω = 600 rpm (curve 3), the calibration accuracy increased gradually with the inclination angle. For example, at β = 4°, the accuracy was μ = 84%, and when the angle increased to β = 6°, the maximum observed accuracy was μ = 86%. Further increase in the inclination angle led to a gradual decline in accuracy, reaching only 82% at β =

8°, which does not satisfy the agro-technical requirements for potato sorting.

From the data presented above, it can be concluded that the highest calibration quality is achieved at a sieve surface inclination angle of β = 7° and a vibration frequency of ω = 300 rpm, where the sorting accuracy reaches a maximum value of 94%.

Effect of Crankshaft Inclination Angle on Sorting Accuracy

As previously noted in this section, most existing vibrating sieve-type potato sorting machines have a crankshaft inclination angle (ε) ranging from 6° to 10° relative to the horizontal, which generally corresponds to the inclination angle β of the sieving surface.

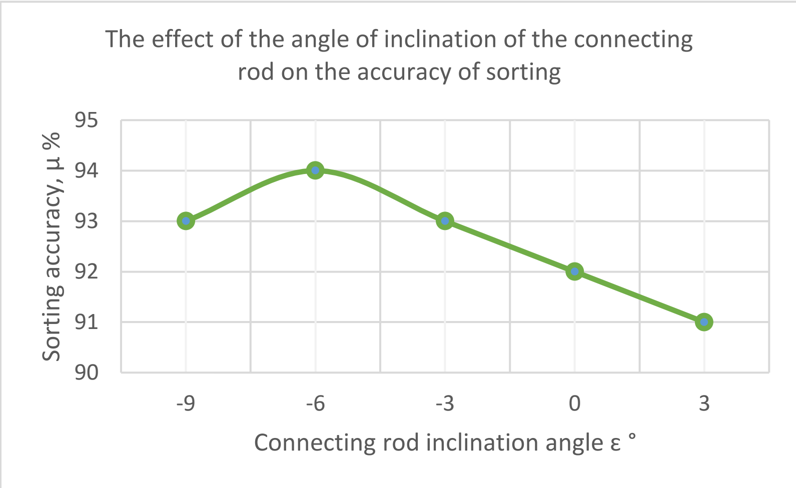


Figure 7. The effect of the connecting rod inclination angle on the sorting accuracy: where, ω = 300 rpm; A = 30 mm; β = 7°.

To determine the influence of the crankshaft inclination angle on calibration accuracy, a series of experiments were conducted at a fixed vibration frequency of ω = 300 rpm, vibration amplitude of A = 30 mm, and sieving surface inclination angle of β = 7°. Based on the experimental results, a dependency graph was plotted (Figure 8).

The curve representing the effect of crankshaft inclination angle on calibration accuracy exhibits a parabolic trend. The highest accuracy of μ = 94% was observed at a crankshaft angle of ε = –6°. For any other angle, the calibration accuracy declined progressively.

These findings suggest that the optimal crankshaft inclination angle for the experimental vibrating calibration unit is ε = –6°.

Effect of Spring Stiffness on Calibration Accuracy

Kinematic and dynamic analyses of vibrating machines used for potato tuber sorting indicate that studying the springs used for vibration damping is crucial for evaluating their influence on sorting quality. For this purpose, springs with high, low, and medium stiffness—relative to the weight of the sieving surface—were selected for testing.

In the developed sorting machine, the springs serve a dual purpose: they absorb dynamic vibrations and prevent tubers from jamming between the sieving rods upon impact. However, the spring installation must ensure that their mechanical properties do not negatively affect the calibration accuracy.

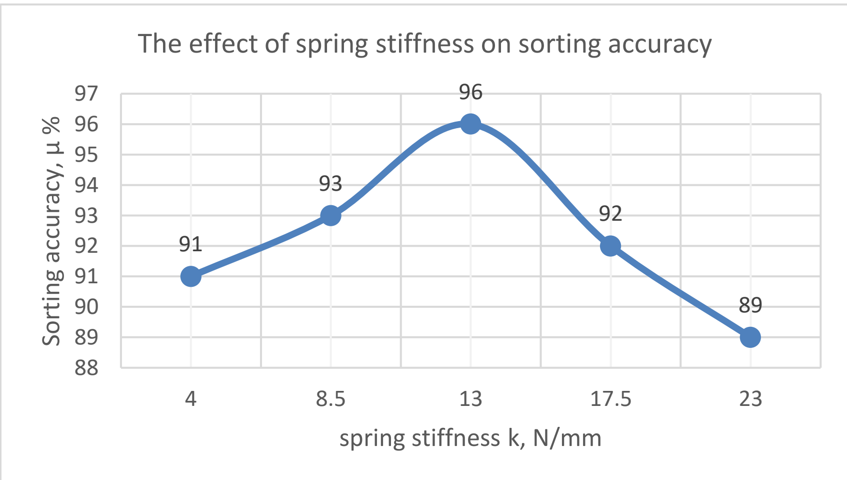


Figure 8. Effect of spring stiffness on sorting accuracy

The following initial parameters were set for this experiment: vibration amplitude A = 30 mm, vibration frequency ω = 300 rpm, sieving surface inclination angle β = 7°, and crankshaft inclination angle ε = –6°.

As observed in Figure 8, the calibration accuracy varies significantly with changes in spring stiffness. The curve demonstrates that as the spring becomes softer (lower stiffness), the accuracy decreases. Springs with high stiffness are unable to absorb dynamic "shock" loads effectively. At the lowest tested stiffness of k = 4 N/mm, the sorting accuracy was minimal. The highest accuracy of μ = 96% was recorded with a spring stiffness of k = 13 N/mm. Beyond this point, further reduction in stiffness resulted in a decline in calibration performance.

These findings indicate that spring stiffness directly influences the machine's ability to dampen vibrations, which in turn affects the sorting quality. An optimal stiffness value ensures both smooth vibrational damping and accurate separation of tubers.

Effect of Tuber Feed Rate on Calibration Accuracy

During the calibration process, it is crucial that the flow of potato tubers across the sieving surface remains uniform and in a single, evenly distributed layer. Therefore, the rate at which the tuber mass is fed into the machine has a significant impact on the sorting accuracy.

To achieve the highest sorting performance and accuracy, it is necessary to determine the maximum allowable feed rate that does not compromise the machine's operational quality. Excessive feed can lead to tuber overlap, reduce effective contact with the calibration surface, and consequently decrease sorting accuracy. Thus, balancing high throughput with minimal performance loss is essential for optimal operation.

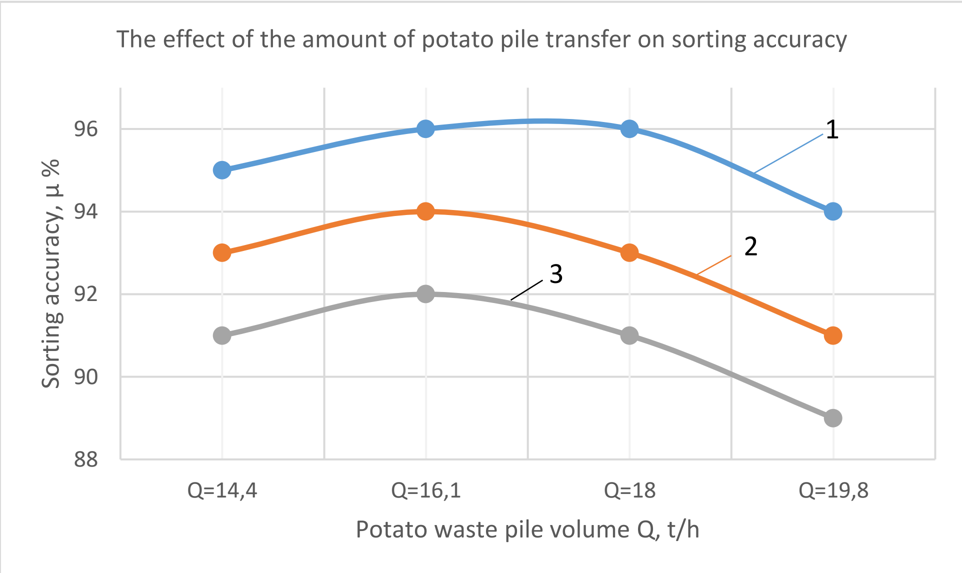


Figure 9. The effect of the amount of potato pile transfer on sorting accuracy

The experiments were conducted using the following fixed parameters: vibration amplitude A = 30 mm, frequency ω = 300 rpm, sieve inclination angle β = 7°, spring stiffness k = 13 N/mm, and crankshaft inclination angle ε = –6°. The feed rate of the potato mixture was regulated by adjusting the mass on the loading conveyor.

At the minimum feed rate of 14.4 t/h, the overall calibration accuracy of the machine was 93% (Figure 9, curve 2). As the feed rate increased to 16.1 t/h, the accuracy improved slightly to 94%, reaching its maximum. However, a further increase in feed rate caused the machine to become overloaded, leading to tubers accumulating on the sieving surface and a decrease in calibration accuracy. For instance, at Q = 18.0 t/h, the accuracy dropped to approximately 93%, and at Q = 19.8 t/h, it declined further to 91%.

Since the potato mixture moves sequentially through multiple calibration zones, this affects the accuracy of sorting specific fractions. Medium fractions may contain both smaller and larger tubers, which reduces their purity. Therefore, Figure 9 also includes two additional curves:

- Curve 1 represents large fraction calibration accuracy;
- Curve 3 represents medium fraction accuracy.

The behavior of curves 1 and 3 was similar to that of curve 2. At a feed rate of 20.0 t/h, calibration accuracy reached 96% for large fractions and 92% for medium fractions—both values satisfying agro-technical calibration standards.

From these relationships, it can be concluded that product feed rate has a significant impact on sorting accuracy, and the optimal feed rate for the proposed vibrating sieve-type potato sorting machine is 18.0 t/h.

CONCLUSION

Based on the laboratory investigation of the vibrating sieve-type potato sorting machine, the following conclusions can be drawn:

- The developed vibrating sieve-type sorting machine demonstrated high performance, as well as favorable technical and quality indicators.
- The maximum calibration accuracy of 94% was achieved when the sieve surface was inclined in the direction of product movement. This performance was observed under the following conditions:
  - Feed rate: 18 t/h
  - Vibration amplitude: A = 30 mm
  - Motor speed: 300 rpm
  - Sieve inclination angle: β = 7°
  - Crankshaft angle: ε = –6°
  - Spring stiffness: k = 13 N/mm
- High-quality sorting can be achieved by maintaining the potato feed rate within the range of 17–18 t/h.
- The sorting accuracy and productivity of the proposed experimental machine were found to be superior compared to existing commercial machines that separate potato tubers into three fractions using traditional sieve mechanisms.

REFERENCES

1. Bahadirov G, Sultanov T, Umarov B, Bakhadirov K. Advanced machine for sorting potatoes tubers. IOP Conf Ser Mater Sci Eng. 2020;883:012132. doi:10.1088/1757-899X/883/1/012132.
2. Bahadirov G, Umarov B, Obidov N, Tashpulatov S, Tashpulatov D. Justification of the geometric dimensions of drum sorting machine. IOP Conf Ser Earth Environ Sci. 2021;937(3):032043. doi:10.1088/1755-1315/937/3/032043.
3. Бахадиров Г.А., Умаров Б.Т., Турсуналиев И.Э. Кинематический и динамический анализ механизма машины для сортировки картофеля и лука грохотного типа. Сельскохозяйственные машины и технологии. 2025;(2): 396.
4. O‘zbekiston Respublikasi Adliya vazirligi huzuridagi Intellektual mulk agentligi. Foydali model № FAP 02273: Vibratsion saralash mashinasi. Rasmiy axborotnoma. 2023;(5):273 b.
5. Solea E, Dette H. Nonparametric and high-dimensional functional graphical models. Electron J Stat. 2022;16(2):6175–6231.
6. Deng W, Li Z, Zhang H, et al. Simulation analysis and experimental testing of the grading performance of small potato grading device. J Food Process Eng. 2024;47(2):e14549.
7. Bello R.S. Agricultural Machinery Design Considerations: A Textbook. Cambridge: Agritech Publishing; 2022. 11 p. (Modern Agricultural Engineering Series).
8. Волосевич П.Н. Совершенствование технологического процесса калибрования клубней картофеля [dissertation]. Саратов; 1998. 20 p.
9. Liu C, Zhang Y, Wang M, et al. Recent research progress on key technologies and equipment for mechanized potato harvesting. Agriculture. 2025;15(7):675.
10. Johnson C.M., Auat Cheein F. Machinery for potato harvesting: a state-of-the-art review. Front Plant Sci. 2023;14:1156734.
11. Камалов Т.И. Линейный асинхронный электропривод самоуравновешенной установки для сортирования картофеля [dissertation]. Уфа; 2017. 48 p.
12. Волков Е.Б., Глухих И.А., Ляпцев С.А. Теоретический анализ технологических параметров вибрационных грохотов. Современные проблемы науки и образования. 2013;(6, прил. «Технические науки»):12.
13. Волков Е.Б., Ляпцев С.А. Влияние угла наклона рабочей поверхности вибрационного грохота на эффективность грохочения. Современные проблемы науки и образования. 2013;(4).
14. Иванов А.Г., Ерохин М.Н., Казанцев С.П., Дородов П.В., Хузяхметов И.И., Хакимов И.Т. Повышение эффективности грохотных картофелесортирующих машин путем совершенствования привода с модификацией алгоритма движения решет. Сельскохозяйственные машины и технологии. 2023;17(2):13–19. doi:10.22314/2073-7599-2023-17-2-13-19.