DEVELOPMENT AND TESTING OF SOIL IMPURITIES REMOVING APPARATUS FOR POTATO
/
马铃薯土杂去除装置研制与试验

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DOI: https://doi.org/10.35633/inmateh-65-50

Keywords: *potato, soil impurities, flexible rubber finger conveying mechanism, slender filament rotary brushing mechanism, removal rate, damage rate*

ABSTRACT
Aiming at the problem that contain more soil impurities of potato post-harvest, which affects subsequent deep processing, an apparatus for removing soil impurities from potato was developed. The whole structure is mainly composed of frame, feeding port, flexible rubber finger conveying mechanism, slender filament rotary brushing mechanism, discharging port and the like. The research and analysis determined that the main parameters influencing the soil impurities removal performance were the movement speed of conveying mechanism, the movement speed of brushing mechanism and the clearance between conveying mechanism and brushing mechanism (hereinafter referred to as the mechanism clearance). Taking the main influencing parameters as test factors, and the soil impurities removal rate and potato damage rate as indexes, the orthogonal test with three factors and three levels was carried out. The optimal parameter combination was obtained as follows: the movement speed of conveying mechanism was 0.35m/s, the movement speed of brushing mechanism was 0.40m/s, and the mechanism clearance was 55mm. At this time, the average soil impurities removal rate was 87.18%, and the potato average damage rate was 1.95%, which met the requirements of potato cleaning operation.

摘要
针对马铃薯产后含有较多土杂影响后续深加工的问题，设计了一种马铃薯土杂去除装置。该装置主要由机架、入料口、柔性橡胶拨指式输送机构、细长毛回转式刷洗机构和出料口等组成。通过研究分析确定了影响去土杂作业性能的主要参数为输送机构运动速度、刷洗机构运动速度、输送机构与刷洗机构间隙（简称机构间隙）。以主要影响参数为试验因素、去土杂率和马铃薯损伤率为试验指标，开展了三因素三水平正交试验，获取了最优参数组合为输送机构运动速度0.35m/s、刷洗机构运动速度0.4m/s 和机构间隙55mm。最优参数下的验证试验结果表明，平均去土杂率为87.18%、马铃薯平均损伤率为1.95%，满足马铃薯去土杂作业要求。

INTRODUCTION
Potato is an important grain and vegetable crop in the world, which is widely planted in many countries. In recent years, under the background that the adjustment of China's grain planting structure and potato staple food strategy, the potato planting area in China has increased. Although China is a big potato producer, its mechanized production level is very low, especially there is a big gap between China and other countries in potato post-harvest mechanized processing, which seriously restricts the whole mechanization process and industrial development of potato. Removing the soil impurities of potato is necessary for primary processing (making whole flour, starch, dried potatoes, etc.), edible processing (making potato chips, French fries, etc.), and deep processing (making adhesives, biodegradable materials, fine chemical raw materials, etc.), which will directly affect the quality of potato processed products (*Bai et al, 2019*).

Because potato tubers grow underground and have irregular shapes, mechanical harvesting operations contain more soil impurities. Although the existing potato harvester has a certain function of soil impurities removal (*Hrushetsky et al, 2019*), it still contains a lot of soil impurities, which needs further removal.

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At present, potato cleaning technology is mainly divided into dry-cleaning and wet cleaning according to different operation methods and use requirements. Dry-cleaning technology is mainly used in the primary processing stage of potato (*Yang et al, 2020*). Without water treatment, it can effectively avoid the rot caused by washing and soaking. According to different operation principles, wet cleaning technology is mainly divided into spray brush roller type, drum type and squirrel cage type (*Ji et al, 2020*), which are widely used in potato food processing and deep processing.

At present, the research on potato post-harvest processing apparatus focuses on sorting, grading and damage detection. For example, some scholars developed a kind of potato sorter, which can realize the potato cleaning and sorting operations (*Wang et al, 2017*). Based on the machine vision technology, some scholars studied the grading method of potato (*Su et al, 2018*). Some scholars developed a machine vision system for potato tuber detection based on ultraviolet imaging, and proposed an algorithm for automatically detecting the thresholds between tuber, clod and conveyor belt (*Al-Mallahi et al, 2010*).

In view of the problem that high soil impurities content in potato post-harvest affects the subsequent washing and deep processing, according to the biological characteristics and the impurities characteristics of potato post-harvest, the process of imitating manual potato scrubbing will be adopted, and by means of differential motion principle, the soil impurities will be removed. It is of great significance to design and develop soil impurities removing apparatus suitable for the initial cleaning operation in fields, so as to reduce the operation burden of washing apparatus and further improve the cleaning effect. At the same time, the research of this apparatus will greatly promote the development of potato industry, especially the implementation of potato staple food strategy in China.

MATERIALS AND METHODS

2.1 Whole structure and working principle

2.1.1 Whole structure

According to the characteristics of soil impurities in potato post-harvest and the structural dimensions of potato washing apparatus, the soil impurities removing apparatus was designed as shown in Fig. 1. It is mainly composed of frame, power system, feeding port, flexible rubber finger conveying mechanism, slender filament rotary brushing mechanism, discharging port and walking wheel, etc., which can remove large pieces of soil impurities and residual soil attached to the surface of potato.

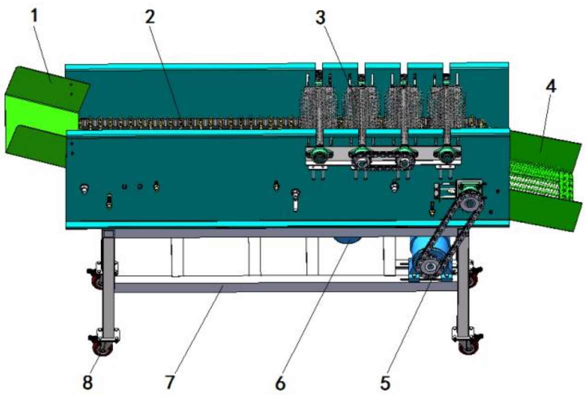


Fig. 1 - Whole structure

1. Feeding port; 2. Flexible rubber finger conveying mechanism; 3. Slender filament rotary brushing mechanism; 4. Discharging port; 5. Driving motor of conveying mechanism; 6. Driving motor of brushing mechanism; 7. Frame; 8. Walking wheel

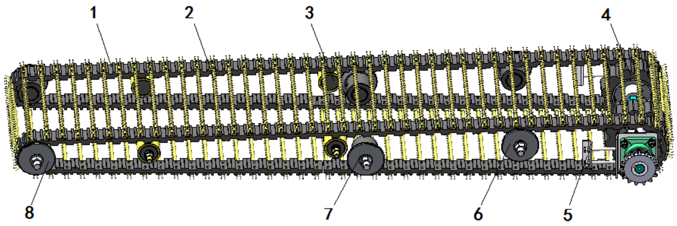
2.1.2 Working principle

The working process of soil removing apparatus is divided into two stages, the first is to remove large pieces of soil impurities and the second is to remove the residual soil attached to potato surface. The specific working principle is as follows. Firstly, the potatoes to be cleaned enter the flexible rubber finger conveying mechanism through the feeding port, and the cleaning operation of clods, crushed stones and other impurities mixed in potatoes is completed under the action of flexible rubber finger of conveying mechanism. Then the potato continues to move backward to enter the next stage, and under the combination action of conveying mechanism and brushing mechanism, the circumferential rolling brushing operation is realized, and the residual soil attached to potatoes surface is removed. Finally, the cleaned potatoes are output from the discharging port.

2.2 Design analysis of key mechanisms

2.2.1 Design analysis of conveying mechanism

The conveying mechanism is one of the key components of soil impurities removing apparatus, and its structural characteristics have an important influence on the removing effect. The front part of the designed flexible rubber finger conveying mechanism mainly completes the removal of clods, crushed stones and other impurities mixed in potatoes. The rear part cooperates with the slender filament rotary brushing mechanism to complete the removal of residual soil attached to potato surface. As shown in Fig. 2, the conveying mechanism is mainly composed of connecting belt, flexible rubber finger rod, supporting wheel, driving part, tension adjusting part and tightening wheel. The power is provided by driving part motor. And the front and rear connecting positions on the side plates of frame are adjusted by the tension adjusting part.



a) Three-dimensional model **b) Material object**

Fig. 2 - Structure of conveying mechanism

1. Connecting belt; 2. Flexible rubber finger rod; 3. Supporting wheel; 4. Driving part; 5.Tension adjusting part; 6. First tightening wheel; 7. Second tightening wheel; 8. Third tightening wheel

In order to cooperate with potato washing apparatus, referring to the structure size of existing potato washing apparatus, the design conveying mechanism has a width of 470mm, on which 90 flexible rubber finger rods are uniformly distributed. Meanwhile, the conveying mechanism is provided with two pairs of supporting wheels for ensuring the upper surface of flexible rubber finger rods to be horizontal, which is beneficial to the conveying of potatoes. And there are three pairs of tightening wheels. The first pair of tightening wheel is arranged close to the driving part and has the same function as the supporting wheel. The second is arranged in the middle of the conveying mechanism, and its function is to adjust the tension degree of flexible rubber finger rods downwards to ensure the smooth conveying of potatoes. The third is arranged in the rear part of conveying mechanism and plays a role of driven wheel. The supporting wheel and the tightening wheel are connected with the side plate of the frame through bolts. Among them, the diameter of supporting wheel is Φ75mm and the diameter of tightening wheel is Φ90mm.

Design analysis of rod spacing

The structure of conveying mechanism rods and the spacing between the two rods have great influence on the soil impurities removal rate and potato damage rate, and the selection of spacing and the structural design are particularly important. According to the principle of better supporting potato, the rod spacing of conveying mechanism is 50mm with reference to the potato harvester (*Wei et al, 2019; Lv et al, 2015*). At the same time, in the process of removing soil impurities, due to the irregular movement of potato in the conveying mechanism, it is easy to cause collision and friction damage under the action of external force (*Deng et al, 2019*). In order to avoid collision caused by direct contact between potatoes and rods, the rubber fingers are added to play a buffer protection role.

As shown in Fig. 3, according to the width of conveying mechanism and the size of connecting belt, the total length of flexible rubber finger rod is designed to be 466mm, the inner diameter of rod is Φ11mm, the material is 55CrSi, the distance between two outer holes of rod is 437mm, and the distance between two holes on one side is 28mm, which is connected with the belt by bolts. In order to reduce the damage of potato on the rod, the rubber skin with a thickness of 3mm is attached to the rod surface, which can play a role in buffering the loss of potato. Meanwhile, two rows of rubber fingers are designed outside the rubber skin, and the effect of removing soil impurities is further improved through the toggle action of the fingers. Among them, the diameter of lower end of rubber finger is Φ6mm, the diameter of upper end is Φ4mm and the total length is 20mm. The distance between adjacent fingers in each row is 15mm, and the two rows of fingers are triangular dislocation branches.

In order to facilitate the connection between the flexible rubber finger rod and the belt, the 65mm long part at both ends of the rod is processed into a flat structure with a width of 15mm and a thickness of 9mm. The structure has two holes for bolted connection between the belt and the rod.

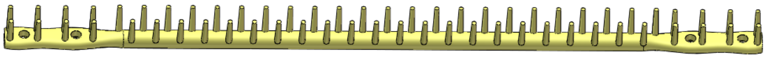


Fig. 3 - Flexible rubber finger rod

Design analysis of driving part

The driven part is the power source of conveying mechanism. As shown in Fig. 4, the driven part is mainly composed of mounted bearings, quincunx rubber wheel, transmission sprocket, tension adjusting plate and hexagonal shaft, etc. In order to facilitate the installation and positioning of quincunx rubber wheel, the drive shaft is designed as a hexagonal shaft with Φ36mm inscribed circle. And in order to ensure good meshing between quincunx rubber wheel teeth and rods, increase the wrap angle of rods in conveying mechanism and avoid tooth climbing phenomenon. Referring to the structure types of rubber wheels used in potato harvester, the number of teeth of quincunx rubber wheel is 11, the diameter of graduation circle is Φ180mm, and two groups of quincunx rubber wheels are evenly distributed on hexagonal shaft with a spacing of 190 mm.

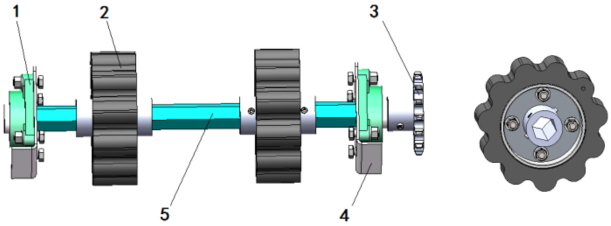


Fig. 4 - Structure of drive part

1. Mounted bearings; 2. Quincunx rubber wheel; 3. Transmission sprocket; 4. Tension adjusting plate; 5. Hexagonal shaft

2.2.2 Design analysis of brushing mechanism

The brushing mechanism is another key component of soil impurities removing apparatus, and its structural characteristics also have an important impact on soil removing effect. As shown in Fig. 5, the designed slender filament rotary brushing mechanism mainly consists of brush roller, brush roller mounting plate, height adjusting part, etc. The power input is realized through the motor and three groups of chain transmission parts. The brushing mechanism can be adjusted up and down along the side plate of frame under the action of height adjusting part, so as to adjust the clearance between the conveying mechanism and the brushing mechanism, and adapt to different size of potatoes and different feeding amounts.

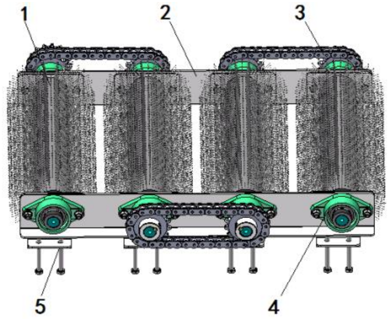


Fig. 5 - Structure of brushing mechanism

1. Brush roller; 2. Brush roller mounting plate; 3. Chain transmission part; 4. Mounted bearings; 5. Height adjusting part

Design analysis of brush roller

On the basis of the actual operation needs, the brushing mechanism is designed to be uniformly distributed at the upper rear position of conveying mechanism, which consists of four groups of brush rollers, and the distance between each group is 220mm. In order to meet different transmission coordination, the four brush rollers are same except for mandrel length. As shown in Fig. 6, the brush roller is mainly composed of mandrel, brush filament attachment and nylon filament. The attachment material of nylon filament is plastic with diameter of Φ100mm and length of 470mm. And considering the irregular shape and size of potato, there are many sprout eyes (where potato tubers germinate) on the surface, and the skin of potato is very thin, which is easily damaged by external force. Therefore, the slender soft nylon filament with a diameter of Φ0.3mm and a length of 50mm is selected to reduce the potato damage in the process of brushing. At the same time, the designed slender soft nylon filament can better clean the soil impurities in the sprout eye.

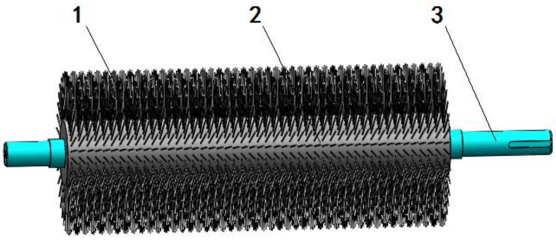


Fig. 6 - Structure of brush roller

1. Nylon filament; 2. Brush filament attachment; 3. Mandrel

Design analysis of mechanism clearance

The clearance between brushing mechanism and conveying mechanism has an important influence on soil removing effect. Excessive clearance leads to the failure of brushing mechanism to contact with potatoes, resulting in the reduction of soil impurities removal rate, while too small clearance will increase its squeezing force on potatoes, which will easily lead to the damage of potato skin. As shown in Fig. 7, for the convenience of measurement, the distance between the tangent line at the bottom of outer circle of brush roller and the upper plane of rubber finger is defined as the clearance, which can be adjusted by the height adjusting part. According to the size of potato in China and the movement characteristics of potato on the conveying mechanism and the brushing mechanism, the mechanism clearance *L* is preliminarily designed to be 35 to 75 mm.

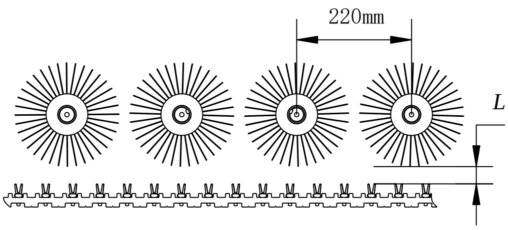


Fig. 7 - Diagram of mechanism clearance

2.2.3 Analysis of potato in conveying and brushing

The main function of conveying and brushing stage is to remove the residual soil attached to potato surface. According to the physical and impurities characteristics of potato, the process of manually brushing potato with a brush is imitated. As shown in Fig. 8, ignoring the deformation and additional force of brush roller and flexible rubber fingers caused by potato support, taking a single potato between the flexible rubber finger rod of conveying mechanism and brush roller of brushing mechanism as an example, at this time, besides its own gravity, the potato is mainly affected by the downward pressure and backward friction of brush roller, and the oblique upward support and friction of flexible rubber finger.

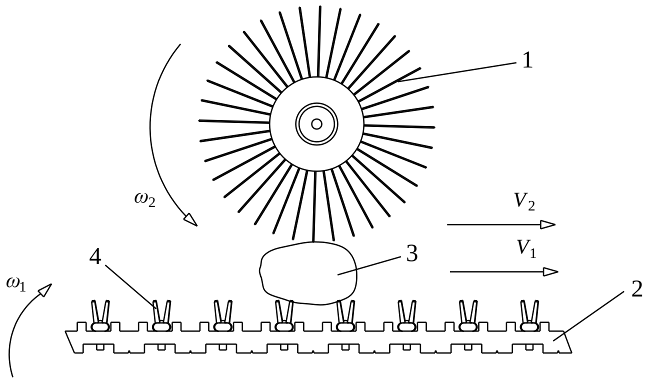


Fig. 8 - Analysis of potato in conveying and brushing

1. Brush roller; 2. Connecting belt; 3. Potato; 4. Flexible rubber finger

The movement speed of conveying mechanism can be expressed as:

$$V_1 = \omega_1 R = \pi D_1 n_1 / 60 \tag{1}$$

where: V_1 is the movement speed of conveying mechanism, m/s;

ω_1 is the angular velocity of conveying mechanism, rad/s;

R is the dividing circle radius of quincunx rubber wheel, mm;

D_1 is the dividing circle diameter of quincunx rubber wheel, mm;

n_1 is the rotating speed of conveying mechanism, r/min.

The movement speed of brushing mechanism can be expressed as:

$$V_2 = \omega_2 \mathrm{r} = \pi D_2 n_2 / 60 \tag{2}$$

where: V_2 is the movement speed of brushing mechanism, m/s;

ω_2 is the angular velocity of brushing mechanism, rad/s;

r is the round radius of brush roller, mm;

D_2 is the round diameter of brush roller, mm;

n_2 is the rotating speed of brushing mechanism, r/min.

The movement speed of conveying mechanism and the brushing mechanism has an important influence on soil removing effect, and the appropriate speed relationship between them is the key and difficult point of design. In order to ensure that potatoes can be removed with high quality and low loss between the two mechanisms in the operation process, so that the potato surface is in full contact with the brush roller at 360 degrees, the movement speed of conveying mechanism should match the movement speed of brushing mechanism (*Chen et al, 2018; Bulgakov et al, 2018*).

The soil impurities removal operation mainly removes large pieces of soil impurities and residual soil attached to potato surface. Too fast movement speed will not get a good effect of removing soil impurities, and too slow movement speed will easily cause subsequent potato accumulation and damage. Considering the work efficiency and performance, and on the basis of the preliminary pre-test research, the moving speed range of conveying mechanism and the brushing mechanism is 0.20 to 0.60 m/s, and the specific values need to be determined by subsequent tests.

2.2.4 Prototype testing

Test conditions

The test is carried out in a cooperative company. The test material is Dutch No.15 potato. The average three-dimensional (length×width×height) of potatoes is 86.13mm×61.98mm×47.25mm, the average moisture content is 78.12%, and the average mass is 89.34 g. The test equipment mainly includes soil impurities removing apparatus, tachometer, electronic scale, etc. The test photos are shown in Fig. 9.

a) Test material **b) Test prototype**

Fig. 9 - Test material and prototype

1. Brush roller of brushing mechanism; 2. Flexible rubber finger rod of conveying mechanism

Test factors and indicators

Through theoretical analysis and pre-test research, the main influencing factors of soil impurities removal performance are the feeding amount, the movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance. In order to improve the effect of removing soil impurities and ensure that the potatoes are fed in a single layer without blockage, the feeding amount of potatoes is finally selected as 3t/h. And the test contents and methods are as follows. Firstly, the parameter ranges of the conveying mechanism, the brushing mechanism and the mechanism clearance are obtained by using single factor test. Then, taking the conveying mechanism, the brushing mechanism and the mechanism clearance as test factors, taking the soil impurities removal rate and the potato damage rate as test indexes, the orthogonal test of three factors and three levels is carried out. The height difference between the conveying mechanism and the brushing mechanism is made to the specified distance by the height adjusting part. The conveying mechanism and the brushing mechanism can change the movement speed by adjusting the rotating speed of their respective matched driving motors.

During the test, three groups of potato samples are taken at the discharging port at equal time intervals, and the mass of each sample is not less than 50 kg. Defining the soil impurities removal rate of potato is the percentage of the weight of potato cleaned after the removing apparatus operation among the sampled potato. The damage rate of potato is defined as the percentage of mechanical damage potatoes in the sample after the action of the removing apparatus. Among them, after operation of soil impurities removing apparatus, the potato with more than 1.5 cm impurities diameter and less than 3 sides were cleaned. And the potato with more than 1.5 cm long damage skin on its surface or with a single damage skin with an area of more than 200mm^2, is defined as a damaged potato.

Choosing potatoes surface with new mechanical damage and no removing soil impurities from each sample, and weighing their quality respectively. The soil impurities removal rate (T_C) and potato damage rate (T_S) calculation methods are as follows:

$$T_C = \frac{M - M_1}{M} \tag{3}$$

$$T_S = \frac{M_2}{M} \tag{4}$$

where: M is the weight of potato samples, kg;

M_1 is the weight of potato without removing soil impurities, kg;

M_2 is the weight of potato with new mechanical damage, kg.

RESULTS

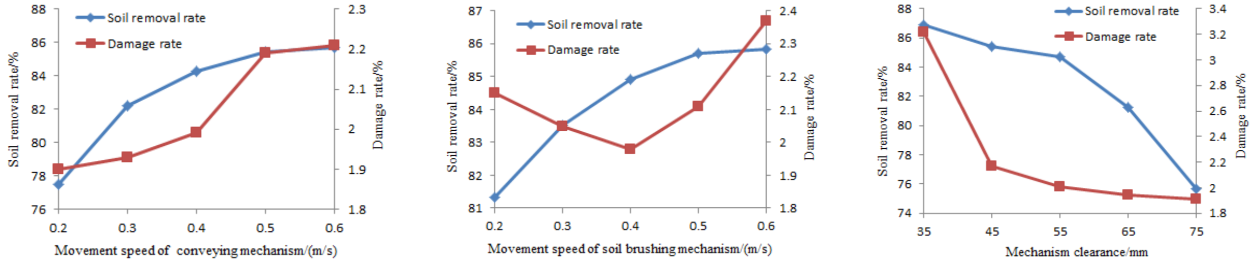
Single factor test scheme and results

In Fig.10 is shown the influence of the movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance on soil removal performance. Fig. 10a is a graph showing the influence of the movement speed of conveying mechanism on potato damage rate and soil impurities removal rate when the movement speed of brushing mechanism is 0.4m/s and the mechanism clearance is 55 mm. Fig.10b is a graph showing the influence of the movement speed of brushing mechanism on the potato damage rate and soil impurities removal rate when the movement speed of conveying mechanism is 0.4m/s and the mechanism clearance is 55 mm. Fig.10c is a graph showing the influence of the mechanism clearance on potato damage rate and soil impurities removal rate when the moving speed of conveying mechanism and brushing mechanism are 0.4m/s, respectively.

From Fig. 10a, it can be seen that with the increase of the movement speed of conveying mechanism, the potato damage rate and the soil impurities removal rate both show an upward trend. The reason is that when the movement speed of conveying mechanism is high, the potatoes are bounced and turned over continuously, and are strongly impacted and rubbed by the brushing mechanism and the conveying mechanism. At this time, the soil impurities removal effect is good, but the potato damage rate is high. However, when the movement speed of conveying mechanism gradually decreases, the turning movement of potatoes weakens, and potatoes are discharged without being completely brushed in the circumferential direction, which leads to the decrease of soil impurities removal rate. On the whole, when the movement speed of conveying mechanism is in the range of 0.30 to 0.40 m/s, the soil impurities removal rate is higher than 82%, and the potato damage rate is lower than 2%.

From Fig. 10b, it can be seen that with the increase of the movement speed of brushing mechanism, the potato damage rate first decreased and then increased, and the soil impurities removal rate showed an overall upward trend. The reason is that when the movement speed of brushing mechanism is low, the potato touches the brushing mechanism for a long time which causes damage to potatoes. At this time, the soil impurities cleaning ability of the brushing mechanism is weak, resulting in a decrease in the soil impurities removal rate. When the movement speed of brushing mechanism increases gradually, the ability of removing soil impurities increases, but when the speed is too high, it will cause potato damage. On the whole, when the movement speed of brushing mechanism is in the range of 0.30 to 0.50 m/s, the soil impurities removal rate is higher than 83%, and the potato damage rate is generally at a low value.

From Fig.10c, it can be seen that with the increase of the mechanism clearance, the potato damage rate and soil impurities removal rate both showed a downward trend. The reason is that when the mechanism clearance is small, the squeezing and rubbing action between potatoes is enhanced in the conveying mechanism and brushing mechanism. At this time, although the effect of removing soil impurities is good, it is easy to cause potato damage. When the mechanism clearance gradually increases, the potato is weakened by the action of conveying mechanism and brushing mechanism, and the potato damage rate decreases, but at this time, the soil impurities removal rate will also decrease. On the whole, when the mechanism clearance is in the range of 45 to 55mm, the comprehensive effect of soil impurities removal rate and potato damage rate is better.



a) b) c)

Fig. 10 - Influence of single factor on performance of removal soil impurities

Orthogonal test scheme and results

Through the single factor test analysis, it is obtained that the range of factors with good performance of soil impurities removal is that the movement speed of conveying mechanism is 0.30 to 0.40 m/s, the movement speed of brushing mechanism is 0.30 to 0.50 m/s, and the mechanism clearance is 45 to 55 mm. The orthogonal test of three factors and three levels is designed (Liu *et al, 2021; Bao et al, 2020*), and $L_9(3^4)$ test table is selected, and each test is repeated 3 times to take the average value as the test result. The factors and levels are shown in Table 1.

Table 1

Factors and levels of orthogonal test

levels	Factors		
	Movement speed of conveying mechanism	Movement speed of brushing mechanism	Mechanism clearance
	[m/s]	[m/s]	[mm]
1	0.30	0.30	45
2	0.35	0.40	50
3	0.40	0.50	55

The test scheme and results are shown in Table 2, and the test factors, such as the movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance, are expressed by *A*, *B* and *C* respectively.

Table 2

Test scheme and results

Test No.	Factors				T_C [%]	T_S [%]
	A	*B*	*C*	Empty column		
1	1	1	1	1	83.61	2.21
2	1	2	2	2	84.24	2.15
3	1	3	3	3	85.18	2.32
4	2	1	2	3	86.72	2.26
5	2	2	3	1	87.21	1.99
6	2	3	1	2	85.97	2.14
7	3	1	3	2	83.82	2.04
8	3	2	1	3	85.63	2.23
9	3	3	2	1	86.24	2.42

Table 2
(continuation)

Test No.	Factors				T_C [%]	T_S [%]
	A	***B***	***C***	**Empty column**		
K_1	253.03	254.15	255.21	T_C		
K_2	259.90	257.08	257.20			
K_3	255.69	257.39	256.21			
R	6.87	3.24	1.99			
Factor order			A,B,C			
Optimal combination			$A_2B_3C_2$			
K_1	6.68	6.51	6.58	T_S		
K_2	6.39	6.37	6.83			
K_3	6.69	6.88	6.35			
R	0.30	0.51	0.48			
Factor order			B,C,A			
Optimal combination			$B_2C_3A_2$			

From Table 2, it can be seen that the test factors, such as the movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance, have different influences on soil impurities removal rate and potato damage rate. The primary and secondary factors affecting the soil impurities removal rate are $A>B>C$, and the optimal combination is $A_2B_3C_2$. The primary and secondary factors affecting the potato damage rate are $B>C>A$, and the optimal combination is $B_2C_3A_2$. Among them, the A_2 is an excellent level shared by soil impurities removal rate and potato damage rate, while B_2 and C_3 have great influence on potato damage rate. As raw materials for fresh or starch production, the cleaning requirement of potato is to remove soil impurities and not damage the inside. Therefore, considering comprehensively, the optimal combination is $A_2B_2C_3$, that is, the movement speed of conveying mechanism is 0.35m/s, the movement speed of brushing mechanism is 0.40m/s, and the mechanism clearance is 55mm.

Verification test and results

Three repeated verification tests were carried out under the condition that the optimal parameter combination was that the moving speed of conveying mechanism was 0.35 m/s, the moving speed of brushing mechanism was 0.4 m/s and the mechanism clearance was 55 mm. The test results are shown in Table 3. The results showed that the average soil impurities removal rate was 87.18% and the average potato damage rate was 1.95%, which met the requirements of potato cleaning operation.

Table 3

Results of verification test

Test No.	Sampling quality	Damage quality	Uncleaned quality	soil impurities removal rate	potato damage rate
	[kg]	[kg]	[kg]	[%]	[%]
1	51.20	1.01	6.61	87.09	1.97
2	50.90	0.92	5.75	88.70	1.81
3	52.10	1.08	7.42	85.76	2.07
Average value				87.18	1.95

CONCLUSIONS

1) A potato soil impurities removing apparatus was designed, which used the principle of conveying-brushing combination to remove large pieces of soil impurities and residual soil attached to potato surface.

2) The single factor test was carried out on the influence of movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance on test indexes. The range of these factors is that the movement speed of conveying mechanism is 0.30 to 0.40 m/s, the movement speed of brushing mechanism is 0.30 to 0.50 m/s, and the mechanisms clearance is 45 to 55 mm.

3) Through orthogonal test, it is determined that the order of influencing factors on soil removal rate is the movement speed of conveying mechanism, the movement speed of brushing mechanism and the mechanism clearance. The order of influencing factors on damage rate is the movement speed of brushing mechanism, the mechanism clearance and the movement speed of conveying mechanism. The optimized combination is that the movement speed of conveying mechanism is 0.35 m/s, the movement speed of brushing mechanism is 0.40m/s, and the mechanism clearance is 55 mm. The verification test shows that the average soil impurities removal rate is 87.18% and the average potato damage rate is 1.95%, the operation performance meets the potato cleaning requirements.

ACKNOWLEDGEMENT

This research was supported by the Central Public-interest Scientific Institution Basal Research Fund (S202110-02), the National Key Research and Development Programme of China (2018YFD0700102), and the Agricultural Science and Technology Innovation Programme of the Chinese Academy of Agricultural Sciences (CAAS-ASTIP).

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