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Simulation and experiment of the screening device for differential speed round belt conveyor of broccoli pieces

Chennan Yu,[1,2] Xinyao Wang,[1] Yonghong Wu,[1] Limin Liu,[3] Yuanxiang Xu,[1] Tianlong Chen,[1] Xudong Xia,[1,2] Jianneng Chen[1,2]

[1]School of Mechanical Engineering, Zhejiang Sci-Tech University, Hangzhou; [2]Zhejiang Key Laboratory of Intelligent Sensing and Robotics for Agriculture, Hangzhou; [3]Zhejiang Technical Institute of Economics, Hangzhou, China

Abstract

The selection of broccoli pieces is an important step in the processing of broccoli, but the existing screening institutions are prone to mis-screening and the screening effect is mediocre. Therefore, a differential round belt screening mechanism is proposed, which aims to screen out the flower pieces with a size greater than 70 mm after the first dicing process and send them to the secondary dicing device, and through the differential mechanism to adjust the posture of the flower piece, so as to improve the correct rate of selection and improve the efficiency of broccoli processing. Screening kinematics analysis model of the differential round belt is performed, and the speed range of the differential round belt is calculated. A three-dimensional model of the broccoli differential round belt screening device is established based on solid works, and motion simulations of flower piece close crossing, flower piece stacking and flower piece selection are performed based on the solid works. The best differential speed is determined according to the simulation results. The differential speed of the two belts is 0.3m/s and 0.6m/s. A broccoli differential round belt screening device was developed and tested, and the best operating parameters are determined. The corresponding screening success rate is as high as 98.1%, indicating that the differential round belt conveying and screening broccoli pieces is feasible and effective.

Key words: broccoli; differential speed; motion analysis; screening simulation; movement trajectory.

Correspondence: Jianneng Chen, School of Mechanical Engineering, Zhejiang Sci-Tech University, Hangzhou 310018, China.
E-mail: jiannengchen@zstu.edu.cn

Introduction

China's broccoli planting area and total production are among the highest in the world (Qu *et al*., 2009; Li *et al*., 2017; Gao *et al*., 2020). However, the current mechanized dicing of broccoli involves a single-process dicing method, which is divided into three types: dicing only, coring only, and dicing-coring (Goodale, 1972; Evens, 1979; Chen *et al*., 2018). Ma *et al*. (2018) developed a rocker-clamped broccoli cutting machine and its cutting method. The crank and rocker mechanism controls the manipulator to clamp the broccoli and transport it to the cutting position, and then the cylinder drives the cutter to cut. Yu *et al.* (2019) studied the broccoli directional conveying and fully automatic continuous cutting and coring production line, including the feeding device, the posture adjustment device and the cutting device. The broccoli is dropped into the profiling groove by the posture adjustment device and is transported to the cutting device. The spherical cutter is driven by the cam to cut the pieces. Chen (2019) developed a broccoli dicing-coring production line. The dicing mechanism is controlled by a crank and rocker mechanism. The cylinder in the dicing mechanism drives the spherical cutter through the connecting rod to cut the pieces. Wylie and Lewis (1988) researched a cauliflower cutting machine, which uses a crank and rocker mechanism to drive a bowl-shaped knife at the end to complete the cutting.

In summary, there has been little research on broccoli cutting technology at home and abroad. Although some cutting equipment has been developed, the cutting effect is not ideal. There are many large broccoli pieces, which is not conducive to subsequent packaging and storage. Therefore, it is also necessary to process broccoli piece after one cut. The first step is selecting the flower pieces. After the first cut, the flower pieces need to be screened to find the large flower pieces that do not meet the size requirements for the second cut. However, there is currently no relevant technology or equipment suitable for broccoli piece screening. Zeng *et al*. (2018) developed a carrot tassel-root separation device, in which the carrot tassels are clamped by two belts, transported and the roots hit the pull rod to achieve tassel-root separation. Zhang (1996) invented a garlic harvesting device, which separates garlic from the soil through a new type of crushing conveyor belt, and tears large pieces into small pieces to realize the vibration screening of garlic. There are three types of existing agricultural material screening equipment: i) linear inertial vibrating screens and circular inertial vibrating screens (Ding, 2001; Zeng *et al*., 2017); ii) rotor-based multiple frequency vibrating screens (Zhang *et al*., 2006); and iii) linkage mechanism reciprocating vibrating screens (Han *et al*., 2011; Zhang, 2017). These screening devices have complex structures and poor screening efficiency, dramatically increasing the processing time cost of broccoli, and seriously affecting the subsequent storage and shelf life. For this reason, this paper proposes and develops a differential round belt conveyor screening device, and conducts a large number of simulations and experiments to determine the best design parameters of the device. The tested device should be able to screen broccoli after the first dicing treatment, and select large pieces of broccoli for the second dicing treatment, and finally meet the requirements of the size (less than 70 mm) of the broccoli pieces in the market (SN/T), the processing process of broccoli is shown in Figure 1.

Statistical analysis of the size of broccoli flowers after one cut

The first strategy for mechanized dicing of broccoli uses a single-process dicing device with spherical cutters (Chen, 2021). The broccoli is manually placed on the contour tray on the conveyor belt with the bud ball facing down, and the broccoli is transported to the bottom of the spherical cutter on the conveyor belt. Then, dicing and core removal are carried out. After the spherical cutter cuts the rhizomes, they are removed, and the flower pieces remain on the tray and are transported forward via the conveyor belt.

After the first cutting process, the broccoli pieces are mostly ellipsoid-like and composed of flower buds and stems. Now, we define the maximum size of the broccoli piece in three directions: Place the broccoli piece vertically with the bud facing down, and use the horizontal plane with the largest bud area as the measurement plane for the dimensions a and b. Use a vernier caliper to measure the bud width on the measuring surface, and the maximum value obtained is dimension a; then rotate 90° horizontally in the direction of dimension a to obtain dimension b; and dimension c is the distance from the bottom of the curd to the top of the flower core. The dimensional measurement method is shown in Figure 2a. The size of the flower piece after the first mechanized cutting

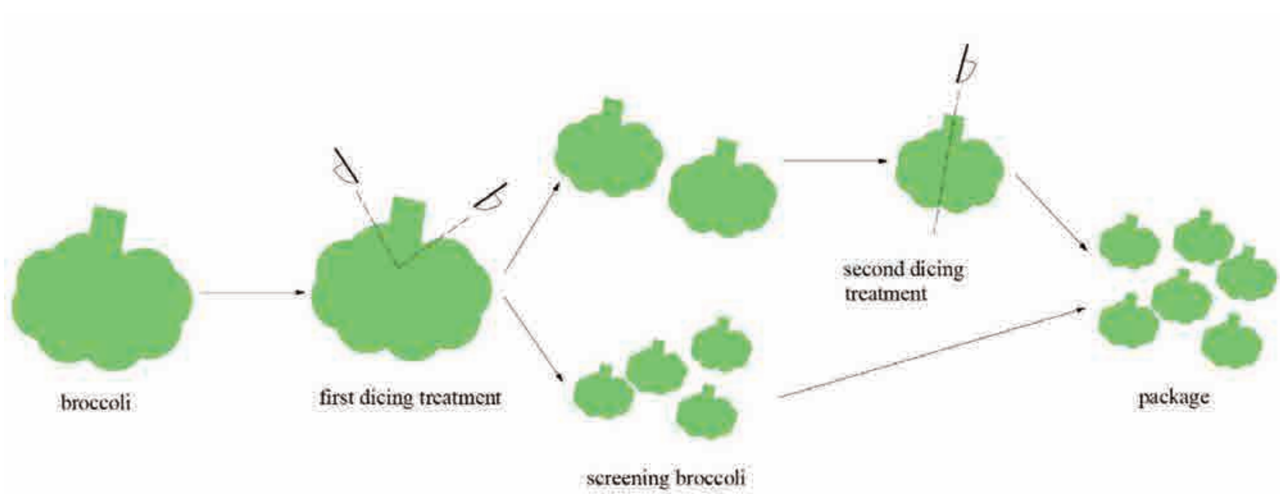


Figure 1. Flow chart of broccoli processing.

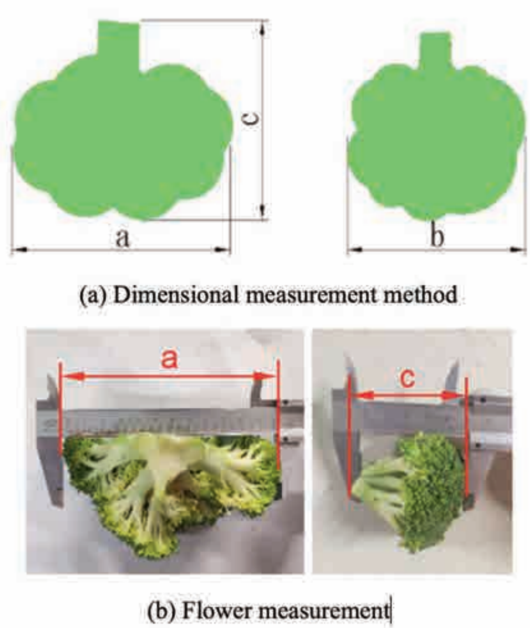


Figure 2. Schematic and actual diagrams of flower measurement.

process was determined to provide a basis for the design of the screening device. Broccoli that had been diced once was packed in a collection box, and the size of the flower pieces was measured with a Vernier caliper. The measurement process is shown in Figure 2b. From the cut pieces processed for the first time, 120 flower pieces were randomly selected for size measurement, and statistical analysis was performed. The purpose of the broccoli piece screening device is to screen out small flower pieces smaller than 70 mm; thus, only the maximum size of the small flower pieces and the size of the large flower piece in three directions needed to be measured. The size of the small flower pieces is between 40 mm and 55 mm. The size distribution of large flower pieces in three directions is shown in Figure 3, a is above 70 mm and is mainly between 80 and 90 mm, b is less than 70 mm and is mainly between 50 and 70, and c is mainly between 40 and 60 mm.

Design of a differential round belt conveyor and screening device

Design requirements and proposal of a differential screening plan

Design requirements: i) during the screening process, small flower pieces with the largest size less than 70 mm are dropped into the collection box, and the large flower pieces are screened out and cut them again in the subsequent process. ii) The broccoli screening process must occur in a single row, and the posture must be able to be continuously changed to prevent two or more flower pieces from crowding together and being synchronously conveyed, thus unable to achieve screening. iii) The screening process must improve the efficiency of broccoli piece screening. For this reason, this paper proposes a broccoli piece screening scheme based on differential round belt conveying. The screening scheme is shown in Figure 4. If the flower pieces are squeezed or overlap, they are screened by two round belts with the same running speed direction but different sizes of v_1 and v_2 so that the flower pieces are staggered. According to the design requirements, the diameter of the designed round belt is 18 mm, and the inner distance between the two round belts is 70 mm. To prevent the broccoli from being deviated or ejected to the side when it is transported into the device through one cut, baffles should be installed on both sides of the device to limit the position.

Establishment and application of the motion analysis model of flower pieces falling into the screening device

After the first cutting process, the broccoli piece is transported to the end of the device platform with the conveyor belt and falls

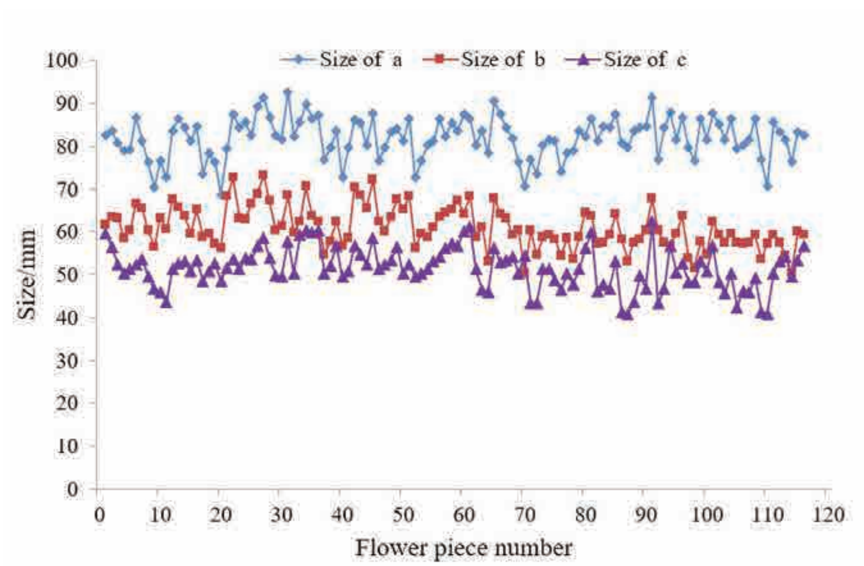


Figure 3. Size distribution of large flower pieces.

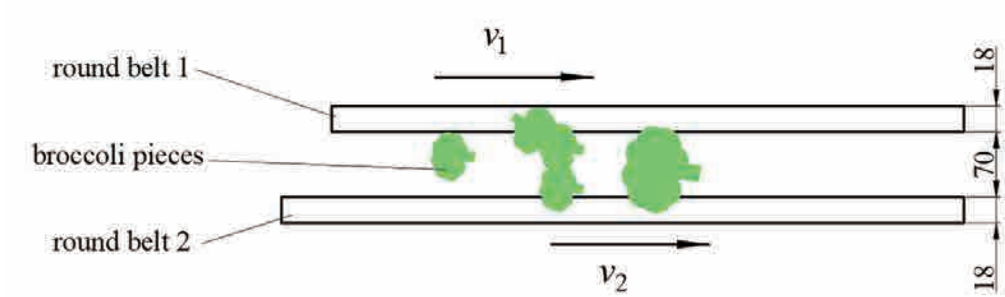


Figure 4. Schematic diagram of the basic scheme of the broccoli screening device.

into the screening mechanism with a horizontal throwing motion with an initial speed of v_0. The speed of the conveyor pulley of the primary cutting device is n_1, the diameter of the drum is d_1, and the vertical height from the end of the device to the screening device is h. The speeds of the two-round belts in the screening device are v_1 and v_2, respectively (Li *et al*., 2020). Analysis of the horizontal throwing movement speed of the flower pieces is shown in Figure 5. The initial velocity v_x of the flower piece is obtained according to the speed of the first cutting conveyor belt wheel and the diameter of the drum:

$$v_0 = \frac{n_1 \cdot \pi \cdot d_1}{60} \quad \text{(Eq. 1)}$$

where n_1 is the speed of the sprocket and d_1 is the diameter of the drum. After a flower piece is horizontally thrown, the speed at which it falls into the screening device is:

$$\left.\begin{array}{l} v_x = v_0 \\ v_y = g \cdot t_1 \\ h = \frac{1}{2} g t_1^2 \end{array}\right\} \quad \text{(Eq. 2)}$$

where v_x is the horizontal speed when the flower pieces fall to the screening device, v_y is the vertical speed when the flower pieces fall to the screening device and t_1 is the time it takes for the flower pieces to fall to the screening device.

Assuming that the roller diameter d_1 of the conveyor wheel of the first cutting conveyor line is 120 mm, the motor speed n_1 is5.23 rad/s, and the vertical height h from the conveyor chain plate of the first cutting of broccoli to the differential round belt is 220 mm. Substituting the above known quantities into Eq. (1) and (2) yields $v_x = v_0 = 0.314$m/s, $v_y = 2.076$m/s, $t_1 = 0.212$s. The v_x provides a basis for determining the speed range of the differential screening round belt designed in this paper to improve the efficiency of flower piece screening.

Analysis of the movement and force of the flower piece on the differential round belt

During the horizontal throwing movement of the flower piece, since the center of gravity of the flower piece is on the budball part, the posture of the flower piece will be adjusted during the descending process and finally the budball part will face downward, avoiding the shortest interface of c from falling perpendicular to the direction of movement of the round belt. When the broccoli pieces are sent to the screening device from the conveyor belt after a one-time cutting process, due to the height difference between the end of the conveyor belt of the one-time cutting device and this mechanism, some broccoli pieces bounce to both sides after colliding with the round belt. To prevent the broccoli from falling due to collision, baffles are installed on both sides of the round belt. In this way, after the flower piece collides, since it is approximately an ellipse, it eventually falls into the gap between the two round belts.

Suppose that when $v_1 < v_x < v_2$, two flower pieces fall on the screening device at the same time. When the flower pieces touch the two differential round belts, one flower piece decelerates on the round belt 1 with speed v_1, and the other flower piece accelerates on the round belt 2 with speed v_2. Driven by the round belt, the speed of the two flower blocks changes, and the relative position gradually changes, and finally falls into the gap between the two round belts. The process of staggering the two flower pieces is shown in Figure 6. The speed of the two flower pieces can be obtained as follows:

$$\left.\begin{array}{l} v_1 = v_0 - a_1 t_3 \\ v_2 = v_0 + a_2 t_2 \end{array}\right\} \quad \text{(Eq. 3)}$$

where t_3 is the deceleration time of the flower piece on round belt 1, a_1 is the acceleration of flower piece 1 on round belt 1, t_2 is the acceleration time of the flower piece on round belt 2, and a_2 is the acceleration of flower piece 2 on round belt 2. The displacement of the two flower pieces can be obtained as follows:

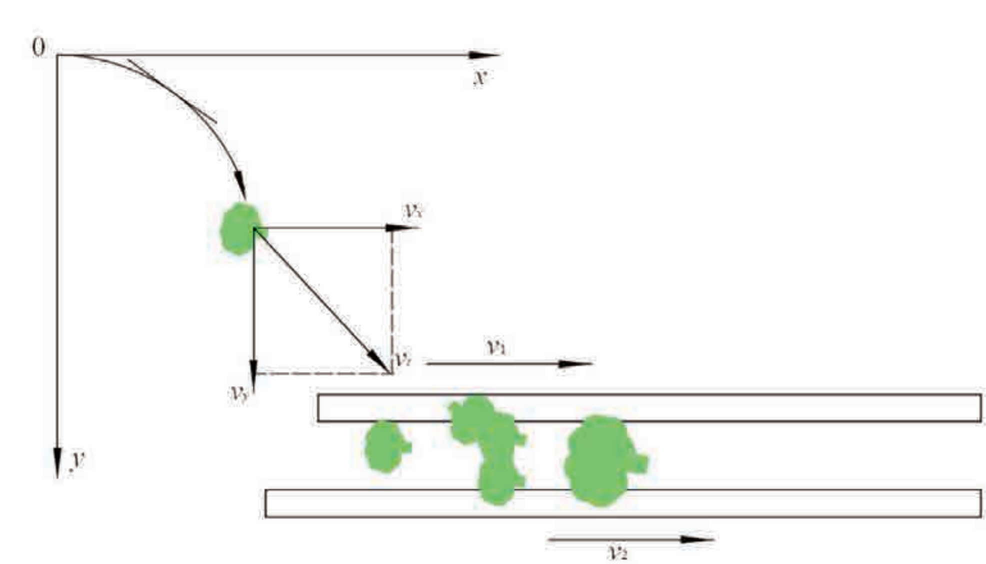


Figure 5. Schematic diagram of flower piece movement analysis.

$$\left.\begin{aligned} s_1 &= v_0 t_3 - \frac{1}{2} a_1 t_3^2 \\ s_2 &= v_0 t_2 - \frac{1}{2} a_2 t_2^2 \end{aligned}\right\} \quad \text{(Eq. 4)}$$

where s_1 is the displacement of the flower piece during the deceleration phase in round belt 1 and s_2 is the displacement of the flower piece during the acceleration phase in round belt 2.

Through the above analysis of the speed and displacement of the flower piece, the relationship between the speed and time of the flower piece on round belt 1 and round belt 2 is obtained, as shown in Figure 7.

Figure 7 shows that the displacement s_1 of the flower piece in the deceleration stage on round belt 1 is the area W_1+W_3, and the displacement s_2 of the flower piece in the acceleration stage on round belt 2 is the area W_1+W_2. The displacement difference of the two pieces on differential round belt 1 and round belt 2 is the area W_3-W_2.

The force on the flower piece can be analyzed as follows:

When the two small flower pieces fall on the screening device, the lower flower piece receives the same frictional force in the same direction as the speed of the round belt and accelerates; the upper flower piece receives the frictional force in the opposite direction to the speed of the round belt and then decelerates. When the large flower piece moves on the differential round belt, the direction of the friction force on the side contacting round belt 2 is the same as the direction of the round belt speed, so it accelerates. The direction of the frictional force on the side contacting round belt 1 is opposite to the direction of the round belt speed, so it decelerates; thus, a moment is formed (Bulgakov *et al*., 2017). The force analysis of the two cases is shown in Figure 8. The force can be analyzed as follows:

$$\left.\begin{aligned} f_1 &= \mu \cdot F_{N1} \\ f_2 &= \mu \cdot F_{N2} \\ M_1 &= f_1 \cdot l_1 + f_2 \cdot l_2 = \mu F_{N1} l_1 + \mu F_{N2} l_2 \end{aligned}\right\} \quad \text{(Eq. 5)}$$

where F_{N1} and F_{N2} are the elastic forces between the flower piece and the two round belts, respectively; l_1 and l_2 are the distance from the center of the flower piece to the two round belts respectively; M_1 is the moment caused by friction on the flower piece.

Due to the opposite direction of the friction force, when the generated torque is large, the flower piece is more likely to rotate. From the displacement of Eq. (4) and the torque calculation model of Eq. (5), it can be seen that when the generated displacement difference and the resultant torque are large, it is more conducive to the staggering of the two small flower pieces and the rotation of the large flower piece, allowing the selection of small flower pieces and the conveying of large flower pieces one by one.

According to the results of the motion analysis previously presented, the calculation formula for the speed of the differential round belt pulley is obtained:

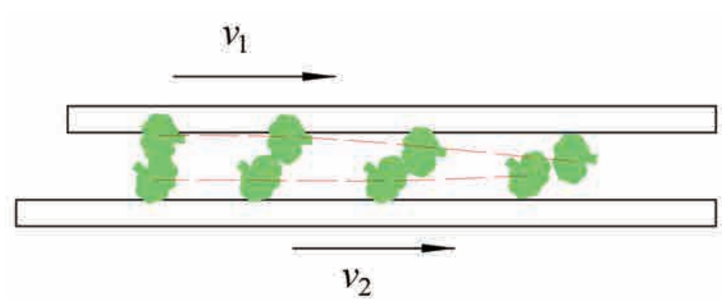


Figure 6. Schematic diagram of the flower staggering process.

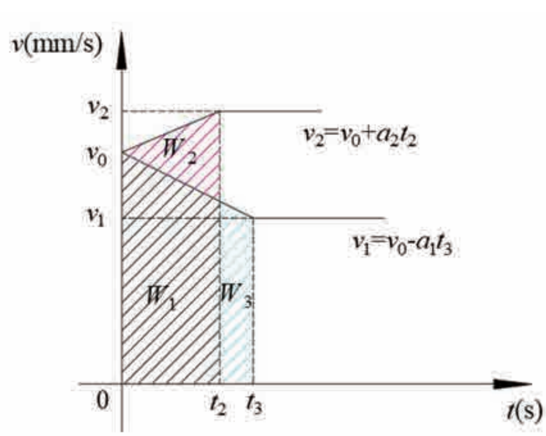


Figure 7. Speed-time graph.

$$n_d = \frac{60 v_x}{\pi d_2} \quad \text{(Eq. 6)}$$

where n_d is the rotation speed of the round pulley and is the diameter of the round pulley. v_x = 0.314m/s and d_2 = 150mm are substituted into Eq. (6), and n_d = 4.18*rad/s* is calculated and convert to the linear speed of differential round belt conveying; when the linear speed of round belt wheel 1 is less than 0.314 m/s, the speed of round belt wheel 2 is greater than 0.314 m/s. This speed range provides the basis for the parameter setting of broccoli motion simulation and the differential speed screening test.

Simulation analysis of round belt differential transmission screening motion based on solid works motion

Simplified establishment of 3D models

From the parameters calculated in the last section, Solid Works software is used to simplify the modeling of broccoli pieces and differential round belts. In order to ensure the correctness of the simulation results, a working machine in the laboratory is selected for simulation, equipped with the Win10 operating system. The Solid Works software used is the 2018 version, which is configured

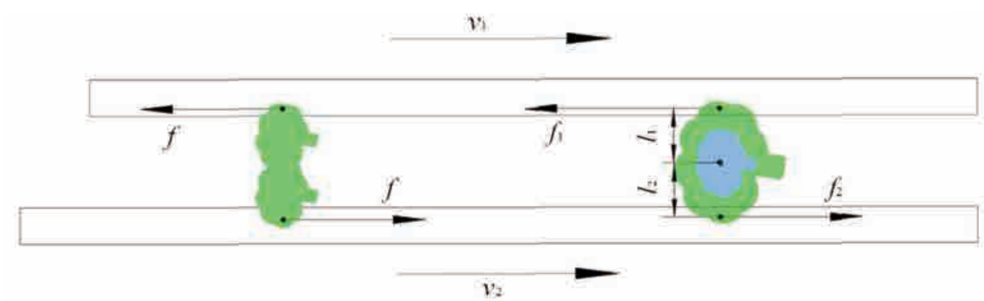


Figure 8. Schematic diagram of force analysis.

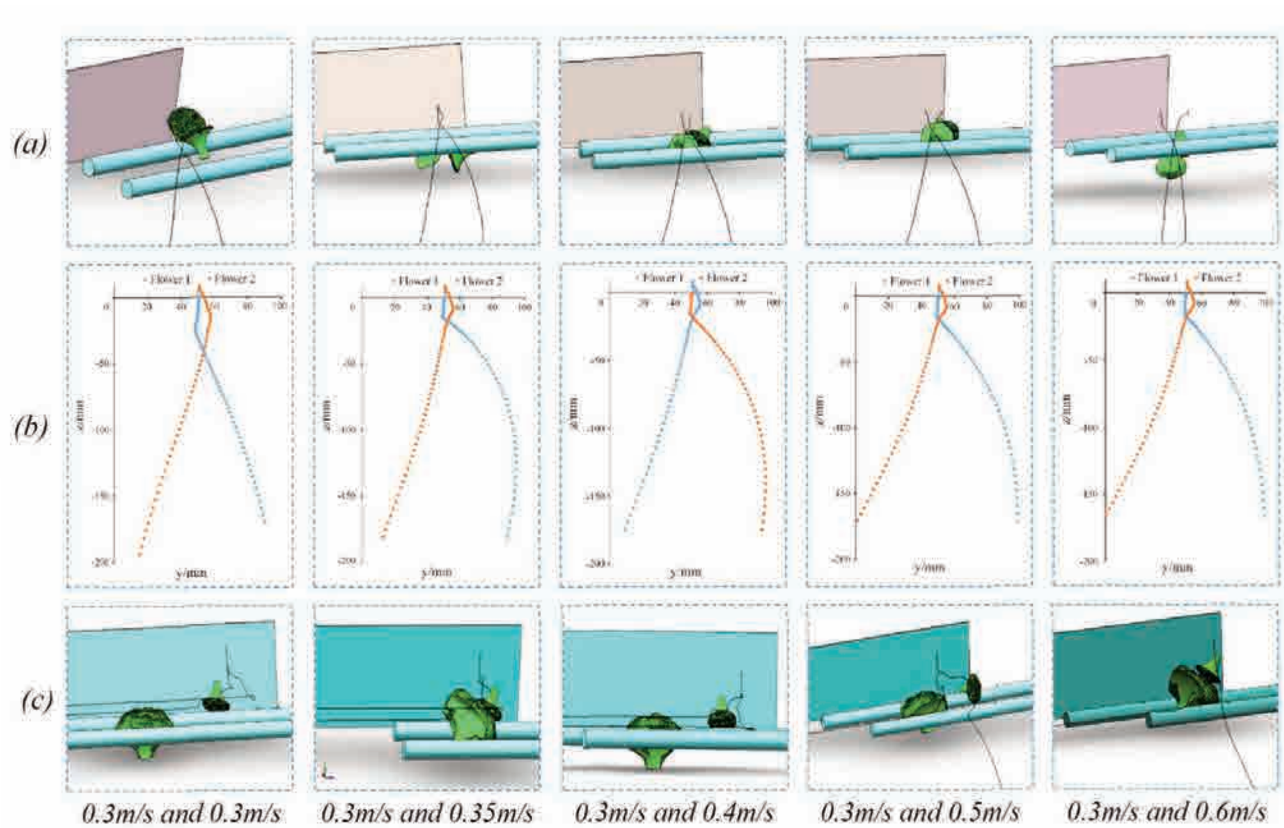


Figure 9. The movement trajectory and position change of the flower piece under each differential speed.

with modules such as part design, assembly design, and motion simulation. The flower piece model is more complicated, so the characteristic parameters of the large flower piece three-dimensional model are reduced during the modeling process (Wang and Tang, 2019; Xiao *et al*., 2019; Ni *et al*., 2020). To effectively simulate and simplify the structure of the differential round belt, the cylindrical rod model is used to replace the actual designed differential round belt, and baffles are set on both sides to prevent the flower pieces from falling out.

Movement simulation of flower pieces close to each other

To induce a certain friction between the round belt and the flower piece, the material property of the round belt is set to nylon (PA) in the simulation environment. At the beginning, the flower pieces cross and fall on the two round belts and fell downward under the action of gravity, so the direction of gravity is set to vertical downward. In addition, set physical contact between the flower block and the round belt, between the two flower blocks, and between the flower block and the baffle, and high-precision contact is enabled (Qing, 2013; Sun, 2015). We set the linear motors in the same direction for round belt 1 and round belt 2 and design the motion simulation of pattern selection under different differential speed by setting the speed value. Since the effect of different differential speed on the movement of the flower piece is related to the initial position of the two flower pieces, the initial position of the flower piece is set as the position when it contacts the round belt and has an initial speed during the simulation process. In the simulation environment, the vertical circular belt movement plane is the x-axis, the flower piece falling direction is the y-axis, and the circular belt movement direction is the z-axis. In the simulation environment described in previous paragraph, motion simulation of two crossed flower pieces on the round belt is carried out, and the trajectory of the center of mass of the flower pieces on the differential round belt is captured through the trajectory tracking function in the motion module of Solid Works. To compare the movement of the flower piece under different differential speed, five sets of motion simulation experiments are performed:0.3 m/s and 0.3 m/s, 0.3 m/s and 0.35 m/s, 0.3 m/s and 0.4 m/s, 0.3 m/s and 0.5 m/s, 0.3 m/s and 0.6 m/s. The result of the movement trajectory of the center of mass of the flower piece is shown in Figure 9a. To evaluate the movement trajectory of the flower piece more intuitively, a plane coordinate system is established with a y-axis and z-axis to derive the trajectory of the flower piece movement and obtain the flower piece position coordinate curve under each differential speed, as shown in Figure 9b. It can be clearly seen in the figure that the coordinates of the two flower pieces in the z-direction change. Under the action of the differential round belt, the two flower pieces are transported and separated from each other before and after. Therefore, when the difference between the z coordinates of the two flower pieces is greater, the effect of staggering the two flower pieces is better. Combining the time, it takes for the flower piece to fall from the beginning to reach the maximum value of the z-coordinate difference, a summary table of the simulation results of the flower piece is created (Table 1). By analyzing the parameters in the table, it can be found that when the differential speed of the two belts is 0.3m/s and 0.6m/s, the screening effect of the flower piece is the best.

Motion simulation of flower piece stacking

Flower piece stacking mainly refers to the situation where small flower pieces are stuck between a large flower piece and the baffle (Fabbri, 2012). The simulation environment is similar to that described in the previous section. Through the trajectory tracking function in the motion module, the position coordinates of the movement trajectory and the center of mass of the flower piece on the differential belt are captured, and the movement trajectory results of the flower pieces under the differential speed of 5 groups are obtained, as shown in Figure 9c.

To assess the movement trajectory of the flower pieces more intuitively, the y-axis coordinate of the center of mass of the two flower pieces in each group of differential speed over time is derived, as shown in Figure 10.

According to the above simulation results, the following can be concluded:

i) When the speed of the two round belts conveyor line is 0.3 m/s and 0.3 m/s, 0.3 m/s and 0.35 m/s, 0.3 m/s and 0.4 m/s, the effect on the stacking of the flower piece is not great; the y-axis coordinate of the flower piece does not change in the subsequent period. This shows that the flower pieces are still stacked and that there is no staggering.

ii) When the speed of the two round belts conveyor line is 0.3 m/s and 0.5 m/s, the flower pieces are staggered at 0.35 s; the small flower pieces keep falling in the y direction, and the position of the large flower pieces does not change much, indicating that the flower pieces are staggered.

iii) When the speed of the two round belts conveyor line is 0.3 m/s and 0.6 m/s, the flower pieces are staggered at 0.13 s; the small flower pieces keep falling in the y direction, and the position of the large flower pieces does not change much, indicating that the flower pieces are staggered. Compared to the set of line speeds of 0.3 m/s and 0.5 m/s, the time is shorter and the effect is higher.

When the linear speed of round belt conveying is 0.3 m/s and 0.6 m/s, it is more conducive to the staggering of flower pieces.

Flower piece differential screening simulation

Based on the simulation analysis presented in the above section, the screening effect is the best when the speed of the two round belts conveyor line is 0.3 m/s and 0.6 m/s. According to the differential speed, the flower pieces after one cut are transported into the differential round belt screening device for the simulation of differential screening. The simulation process is shown in Figure 11. It can be seen from the simulation results that round belt conveyor line speeds of 0.3 m/s and 0.6 m/s have better effects. In

Table 1. Flower piece simulation results.

Differential speed (m/s)	Separation time (s)	Maximum coordinate difference in the z direction (mm)	Effect
0.3 and 0.3	0.16	28	The worst
0.3 and 0.35	0.15	22	The poor
0.3 and 0.4	0.14	34	The medium
0.3 and 0.5	0.13	36	The better
0.3 and 0.6	0.11	48	The best

2 s, the differential speed screening of small flower pieces is basically finished, and the large flower pieces are still conveyed on the round belt. Therefore, in the simulation environment of this differential speed, the selection of flower pieces is good, which is consistent with the simulation results presented in the above sections, verifying that the effect of selection of flower pieces is the best under this differential speed. In this chapter, based on the solid works motion simulation module, the simulation experiments of flower piece close, flower piece stacking, and flower piece differential selection are carried out respectively. Judging from the screening effect of the above three extreme cases, the differential round belt screening mechanism has solved the problem of incorrect screening caused by close and stacked flower pieces. Comparing the simulation results, it can be found that when the differential speed of the two belts is 0.3m/s and 0.6m/s, the device has the best screening effect.

Materials and Methods

Broccoli piece differential round belt conveyor screening test and results

The broccoli variety used in this study is Zheqing No. 95, which has an erect plant shape and a tall round and compact flower bulb with a diameter of about 130 mm. Since this research device is aimed at the broccoli block after the one-time dicing and core removal process, it is necessary to connect this device to the end of the one-time dicing device during the test. The whole broccoli is placed in the feeding port of the one-time cutting device. After the broccoli is cored and cut, it drops into the differential round belt screening device from the end of the device to perform the screening test. Five sets of differential speed are selected for comparative tests. After the screening, the number of flower pieces is counted and data processing is performed to obtain the test results. Solid Works software is used to construct a three-dimensional model and a test bench. The model and test bench are shown in Figure 12. The differential round belt material is nylon (PA) with a diameter of 18 mm; the pulley is made of nylon material, and the pitch diameter is 150 mm. The two driving wheels are driven by different shafts. Bearings are installed in the two driven wheel apertures through the same root driven shaft drives so that two round belts are driven by the same motor for differential motion.

According to the results of the motion analysis, the linear velocity of the round pulley 1 is less than 0.314 m/s, and the round pulley 2 is greater than 0.314 m/s. Therefore, in the motion simulation of the broccoli piece, combined with the differential speed of the existing vegetable screening equipment, five sets of round belt differential speed are set: 0.3 m/s and 0.3 m/s, 0.3 m/s and 0.35 m/s, 0.3 m/s and 0.4 m/s, 0.3 m/s and 0.5 m/s, 0.3 m/s and 0.6 m/s. It can be seen from the results that the best simulation effect can be achieved under the differential speed of 0.3 m/s and 0.6 m/s. In order to verify the correctness of the simulation results and determine the best transmission speed, the above five sets of differential speed are still selected for testing. After the first dicing, the flower piece falls on the differential round belt. First used a high-speed camera to record the differentially screened video, the model of the

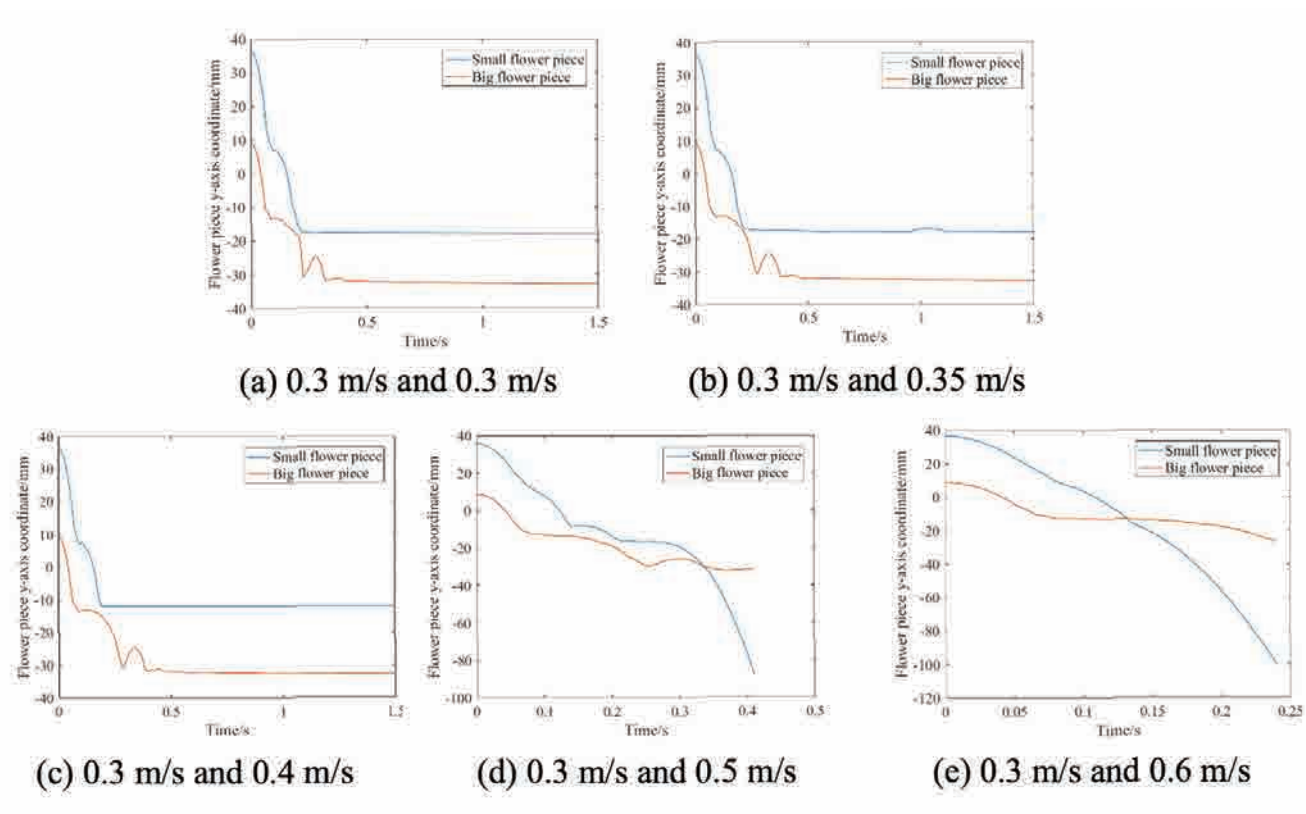


Figure 10. Graph of flower piece y-axis coordinates with time.

high-speed camera is Photron Fastcam Super 10K, Model 10KC, its memory time reaches 2.2 s, the resolution of the camera is 512×480, the shooting rate of the camera is 250 fps. And then used image analysis software to analyze the movement of the flower piece on the differential round belt, as shown in Figure 13. The image analysis software is used in conjunction with the camera, called Blaster's MAS. As shown in the figure, in the three sets of differential speed tests using 0.3 m/s and 0.3 m/s, 0.3 m/s and 0.35 m/s, 0.3 m/s and 0.4 m/s, the flower pieces are not staggered during the differential transmission to the end of the round belt, and the screening effect is poor. When the differential speed is 0.3 m/s and 0.5 m/s, 0.3 m/s and 0.6 m/s, the flower piece can be staggered in

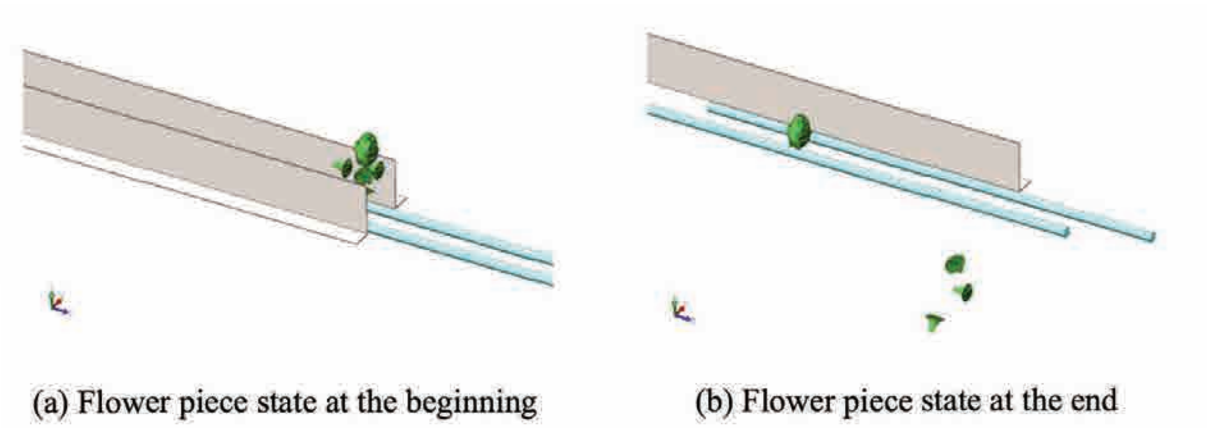


Figure 11. Flower piece differential screening simulation.

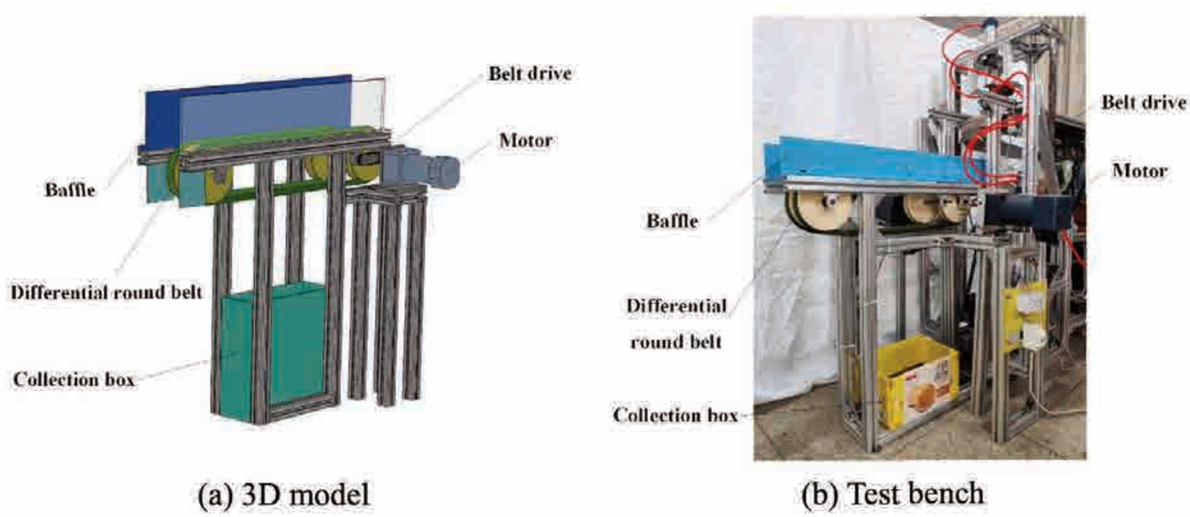


Figure 12. 3D model and test bench.

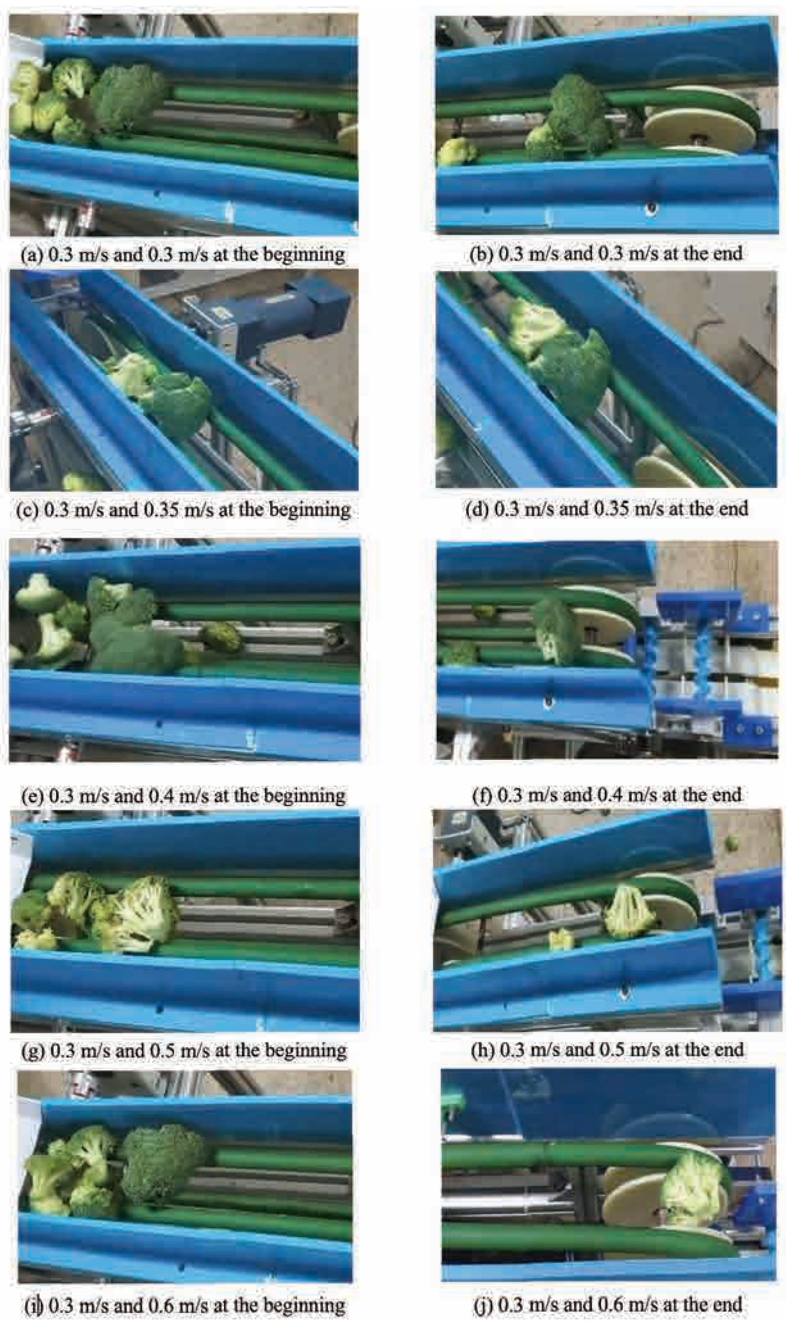
Table 2. Results of flower piece screening.

Differential speed (m/s) flower pieces	Total number of were not screened out	Number of flower pieces that that were screened out	Number of flower pieces	Screening success ratio
0.3 and 0.3	140	27	113	80.7%
0.3 and 0.35	164	20	144	87.8%
0.3 and 0.4	158	12	146	92.4%
0.3 and 0.5	168	8	160	95.2%
0.3 and 0.6	160	3	157	98.1%

the cross and stacking conditions during the differential transmission process, and better screening and delivery of flower pieces is achieved when the differential speed is 0.3 m/s and 0.6 m/s.

Results and Discussion

A test was conducted on 100 broccolis, and the flower pieces obtained after the first cutting treatment fell into the differential round belt conveyor screening device. For each group of differential speed, 20 broccolis were screened for testing. The total number of flower pieces, the number of flower pieces that were screened out, and the number of flower pieces that were not screened out were counted, and the screening success rate was calculated as the ratio of the number of successfully screened flower pieces to the total number of flower pieces. The test results are shown in Table 2. According to the general requirements of the screening device, the success rate is often more than 95% in order to show that the device has a better screening effect. According to the criteria of the screening success rate, the two groups of 0.3:0.5 and 0.3:0.6 in the above table all meet the evaluation criteria and therefore have a better screening effect. But this experiment needs to find the optimal differential speed , so choose the group of 0.3:0.6, which is the highest screening success rate among the five groups of trials, indi-



(a) 0.3 m/s and 0.3 m/s at the beginning
(b) 0.3 m/s and 0.3 m/s at the end
(c) 0.3 m/s and 0.35 m/s at the beginning
(d) 0.3 m/s and 0.35 m/s at the end
(e) 0.3 m/s and 0.4 m/s at the beginning
(f) 0.3 m/s and 0.4 m/s at the end
(g) 0.3 m/s and 0.5 m/s at the beginning
(h) 0.3 m/s and 0.5 m/s at the end
(i) 0.3 m/s and 0.6 m/s at the beginning
(j) 0.3 m/s and 0.6 m/s at the end

Figure 13. Flower piece selection test.

cating that the round belt under this differential speed is more conducive to screening broccoli pieces. Moreover, at this differential speed, large and small broccoli pieces that are stacked can be staggered, small flower pieces can be filtered out, and large flower pieces can be transported.

Conclusions

A new type of broccoli differential round belt screening device is designed, which can adjust the posture of broccoli through the differential round belt mechanism, thereby improving the accuracy and processing efficiency of broccoli screening. Based on the motion simulation module of Solid Works software, the simulation results of broccoli screening under five differential speeds are obtained, and the optimal differential speed of the round belt is determined to be 0.3 m/s and 0.6 m/s. The prototype of the screening device was developed and tested, and the results showed the correctness of the simulation results. Under the same speed setting, the screening success rate of broccoli pieces reached the highest 98.1%. The test results show the rationality and feasibility of the broccoli differential round belt screening device designed in this paper. However, related research is still in the laboratory stage. If industrialization is to be realized, the speed of the round belt needs to be adjusted according to the falling of flower blocks; in order to improve the screening efficiency, it is necessary to set up multiple round belts to screen and transport at the same time. In the follow-up research, this will also be used as a research goal to achieve commercialization of the screening device.

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