Poster Presentation

The 7th TSME International Conference on Mechanical Engineering
13-16 December 2016

POS0013

Design and Experiments of the Seed Feeder Used in a Sweet Pepper Seed Sorting Machine

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Abstract

Quality of sweet pepper seeds plays an important role since it highly affects germination and vitality of pepper seedlings. However, the pepper seeds are very light and small (their diameter is about 3-4 mm), resulting in difficulty in inspecting seed quality manually. Thus, the long-term aim of our research project is to design and to construct an automated sweet pepper seed sorting machine. It will consist of three main stations, i.e., 1) the seed feeder, 2) the seed inspector using image processing, and 3) the seed sorter using a vacuum suction system. The circular rotating plate is used to transport seeds to all three stations. In this paper, design and experiments of the seed feeder is presented. The blades are radial at outer edge of the seed feeder. They rotate and sweep seeds inside the seed feeder into the blind hole of the circular rotating plate which is also rotating. The experimental results showed that the speed of the seed feeder was 60 rpm and the wait time of the circular rotating plate was 3 s, making a maximum seed singulation rate of 76.3%.

***Keywords**:* Sweet Pepper Seeds, Seed Quality, Seed Feeder, Seed Singulation

1. Introduction

Sweet peppers (*Capsicum annuum L.*) are very attractive since they have been one of the most crucial vegetable around the world and they have a diversity of vitamins and nutrients.

Quality of pepper seeds plays an important role in pepper production since good-quality pepper seeds can increase yield and gain higher quality of the pepper crop. Thus, pepper seeds are subjected to several quality measurements. The International Seed Testing Association (ISTA) (see www.seedtest.org) has developed and published standard procedures for sampling and testing seeds in order to evaluate seeds moving in international trade. Seed tests, in general, include purity, health, consistency, germination, moisture content, viability, disease, etc.

Although some biological inspection approaches need advanced techniques and equipment in laboratory, which is difficult to fulfill the real-time operation, seed quality based on physical inspection such as shape, color, and size can be assessed by a trained staff. However, this manual inspection method is very tedious and time-consuming. It also highly relies on human skills and experience [1, 2]. Furthermore, sweet pepper seeds are roughly flat, light and small, resulting in eye fatigue in seed inspection. Thus, the accuracy and the capacity of seed inspection are not consistency. This leads to our long-term goal that is to construct a pepper seed sorting machine that can remove discolored seeds automatically. It can eliminate the requirement of human workers, thus increasing the sorting capacity and accuracy. This machine consists of three main stations (see Fig. 1): The seed feeder, the seed inspector, and the seed sorter. Seeds are transported through each station via the circular rotating plate which turns and stops in such a way that a row of pepper seeds laying on it stops at the working point of each station. This makes all three stations working on a row of pepper seeds in parallel.

In this paper, we addressed only the seed feeder. We proposed a new idea of design and we also evaluated the performance of our developed seed feeder in this paper.

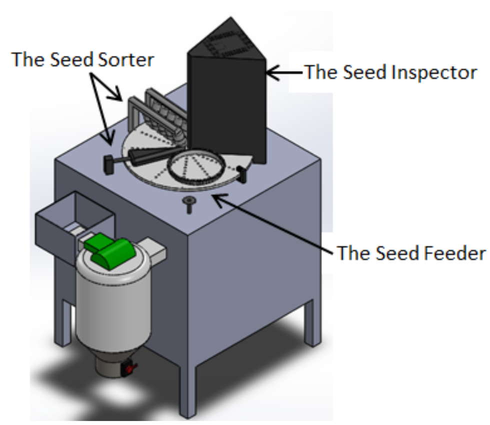


Fig. 1 The design of a seed sorting machine

Cardarelli et al. [3] designed a singulation device to facilitate inspection of rice kernels one by one by the imaging system. They developed a machine vision technique to inspect and estimate the internal damage of rough rice. Melvin et al. [4] designed a cereal grain kernel singulation device to singulate and present kernel samples for analyses by a cabinet X-ray machine. The device consisted of a circular disc having an oblong hole passed under a hopper containing bulk samples. Wan [5] developed an automatic grain quality inspection system that categorized rice appearance into thirteen groups using sixteen parameters. The kernels were placed on a predetermined matrix positioned on conveyor belt. Images were taken by two CCD cameras and kernels were sorted by pneumatic valves to place them in the corresponding containers. Hunter et al. [6] invented an automated high throughput seed processing system that used air jets to transport kernels from one process to another. However, to the best of our knowledge, there is no pepper seed sorting machine available commercially.

The rest of the paper is structured as follows: in Section 2, the physical characteristics of the pepper seeds are investigated. The results are used to design the seed feeder. Section 3 shows the experimental results with discussion and finally, our conclusions are given in Section 4.

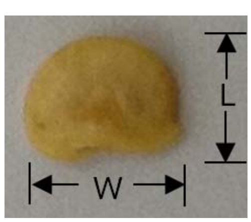
2. Materials and Methods

To design the seed feeder and the circular rotating plate, the study of physical characteristics is necessary. The results are shown in the following subsection.

2.1 The Physical Characteristics of Sweet Pepper Seeds

The sweet peppers (see Fig. 2(a)) have been one of the most important vegetable around the world. They are rich sources of antioxidants and vitamin C [7]. As seen Fig. 2(b), a sweet pepper seed is like a rough flat disc and its color is yellow-brown. In general, the number of seeds per 1 gram is about 150 – 180. Furthermore, their dimension (length, width, and thickness) is very important for designing the seed feeder and the circular rotating plate. Thus, one hundred sweet pepper seeds were chosen. Their length (L), width (W), and thickness (T) were measured using a Vernier Caplipers. The measurements were repeated five times and then the geometric means of the diameter and thickness was calculated [8].

(a)



(b)

Fig. 2 (a) Sweet peppers and (b) sweet pepper seeds

The results show that the average length (L) and the average width (W) of the sweet pepper seeds are 3.86 mm and 3.16 mm, respectively. The geometric means of the diameter and thickness are 3.48 mm, and 0.94 mm, respectively.

Seed color (see Fig. 3) is a key parameter of quality evaluation in this project since discolored seeds, in general, are considered low-quality seeds. Apparently, image processing techniques can be adopted to analyze seed color and other physical quality measurement [9]. To implement such techniques, seed singulation is necessary. Our design has been given in the next subsection.

(a) (b)

Fig. 3 Pepper seeds with (a) normal color (b) discolored surface

2.2 Design of the Seed Feeder

To singulate the seeds, the circular rotating plate with 10 blind holes in a row along the radius of the plate (see Fig. 4) was designed to transport seeds through each station. Its diameter is 17.5 cm and the distance between two blind holes is 14 mm. The diameter of each blind hole is 5 mm which is a little larger than the diameter of the sweet pepper seeds. Since there are 12 rows, the maximum number of seeds on the circular rotating plate is totally 120.

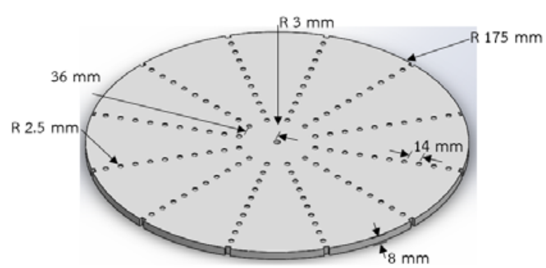


Fig. 4 Design of the circular rotating plate

To sweep the seeds into the blind holes of the circular rotating plate, the seed feeder as shown in Fig. 5 was designed. It consists of a 12 VDC motor used to control the rotating speed of the seed feeder through chain drive. The shape of the seed feeder is cylindrical and its diameter is 13 cm. Its height is 7.2 cm. There are 6 blades at outer edge of the seed feeder. They are used for sweeping seeds from the outer edge to the holes of each row. A rubber strip mounted to the bottom of the cylinder is employed to prevent the seeds from escaping and to reduce the friction presenting when the seed feeder touches the circular rotating plate. In our design, the seed feeder rotates counter-clockwise at the given angular speed continuously, while the circular rotating plate turns clockwise by using a DC motor with a gearbox. The circular rotating plate stops when the row of seeds stays at the working point of each station. The seed feeder and the circular rotating plate rotate at the opposite direction, resulting in reduction of seed overlapping and outspringing.

Fig. 5 The seed feeder with a DC motor and chain drive

3. Experimental Results

Since the seed feeder and the circular rotating plate have to work together, there are two variables to be adjusted optimally. The first one is the angular speed of the seed feeder which was set to 45, 50, 54, 58, 60 and 63 rpm. The other is the wait time of the circular rotating plate which was set to 1 2, 3 and 4 s. Thus, there were 72 experiments in total.

The experimental setup is shown in Fig. 6. The 250 grams of sweet pepper seeds were first poured into the seed feeder. The angular speed and the wait delay were set and then both the seed feeder and the circular rotating plate started rotating. The circular rotating plate was stopped by using the photo interrupter. When the wait time was over, it rotated again. After nine rows of seeds finished singulating, the system stopped. This process was repeated 3 times.

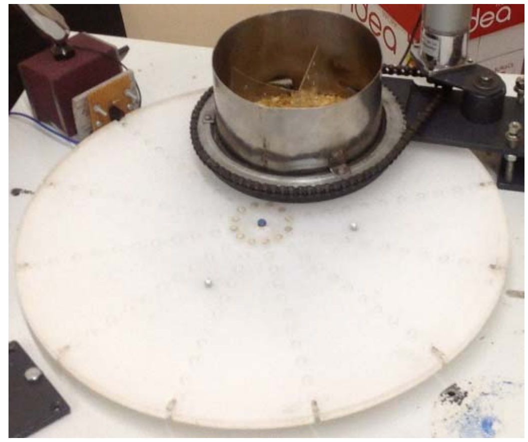


Fig. 6 Experimental setup

To evaluate the performance of the seed feeder, we addressed three cases: (a) only one seed stayed inside one blind hole, (b) more than one seed stayed inside the blind hole, (c) the seed lay outside the blind hole but on the rotating plate. The likeliness of case (a) should be high, while the likeliness of the other two cases should be zero or very low. The main causes of case (b) were that the depth of the blind hole was not completely flat and there was a small gap between the seed feeder and the circular rotating plate. The main causes of case (c) were that, due to rough flatness of the seeds, their thickness was over the depth of the blind hole, making the seed touched the rubber strip and sprang out of the hole and lay on the plate.

Tables 3, 4, and 5 show the results for all three cases, respectively, when the motor speed and the wait time were varied.

Table. 3 The number of seeds corresponding to case (a)

The Angular Motor Speed (rpm)	Wait Time of the Circular Rotating Plate (s)				Average Number of Seeds
	1	2	3	4	
45	74.0	70.3	74.7	75.3	73.6
50	70.7	66.3	75.7	71.0	70.9
54	74.7	74.0	75.3	73.0	74.3
58	74.6	73.7	75.3	77.0	75.2
60	74.0	76.3	76.3	78.3	76.2
63	74.3	74.3	74.3	75.7	74.7

Table 4. The number of seeds corresponding to case (b)

The Angular Motor Speed (rpm)	Wait Time of the Circular Rotating Plate (s)				Average Number of Seeds
	1	2	3	4	
45	7.7	6.7	6.0	5.7	6.5
50	8.3	8.0	5.0	7.7	7.3
54	5.0	4.7	6.0	7.0	5.7
58	7.7	4.0	4.0	4.3	5.0
60	5.3	3.0	3.3	5.0	4.2
63	5.3	5.7	3.3	5.3	4.9

Table 5. The number of seeds corresponding to case (c)

The Angular Motor Speed (rpm)	Wait Time of the Circular Rotating Plate (s)				Average Number of Seeds
	1	2	3	4	
45	3.0	3.7	5.0	2.0	3.4
50	3.3	8.3	3.3	6.0	5.2
54	3.7	2.0	2.7	2.3	2.7
58	3.3	5.0	4.7	3.0	4.0
60	2.3	2.0	1.3	1.7	1.8
63	4.0	5.0	3.7	4.3	4.3

To investigate the main effect for cases (a), (b) and (c), the angular motor speed and the wait time of the circular rotating plate versus the average number of seeds are plotted as shown in Figs. 7 – 9, respectively.

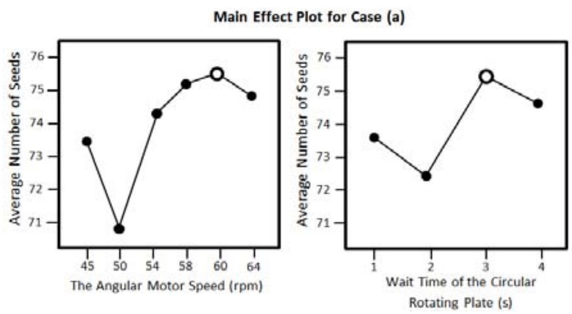


Fig. 7 Main effect plot of motor speed and wait time in case (a)

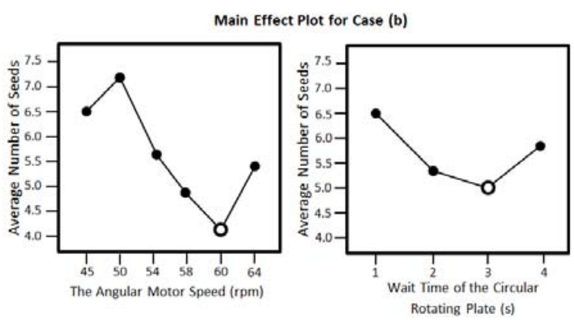


Fig. 8 Main effect plot of motor speed and wait time in case (b)

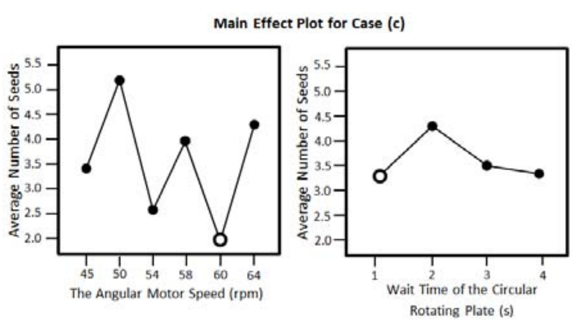


Fig. 9 Main effect plot of motor speed and wait time in case (c)

As shown in Figs. 7 – 9, the angular motor speed and the wait time of the circular rotating plate that made the highest number of seeds for case (a) and the lowest number of seeds for cases (b) and (c) was 60 rpm and 3 s, respectively.

4. Conclusions

Seed quality is very important for crop production and can affect planting quality. Thus, our long-term aim is to build an automated pepper seed sorting machine. However, in this paper, we focused on the seed feeder which is the first station of the seed sorting machine. The objective of this station is to singulate seeds. It consisted of a seed feeder that contained seeds inside and the circular rotating plate that transported singulated seeds to the next two stations, i.e., the seed inspector and the seed sorter. Based on our analysis, we found that the angular speed of the seed feeder was 60 rpm and the wait time of the rotating plate was 3 s, making the highest number of seeds that can stay inside the blind hole of the rotating plate.

Currently, we are testing the new material mounted to the bottom of the cylinder of the seed feeder. The solution can increase singulation rate.

5. Acknowledgements

The authors would like to thank the Agricultural Research Development Agency (ARDA) for financial support and A.G. Universal Co., Ltd. for supporting seed samples and providing useful seed quality information.

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