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Evaluating the optimal working parameters of the color sensor TCS3200 in the fresh chili destemming system

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ABSTRACT

In a previous study, a fresh chili destemming system has been proposed, and the TCS3200 color sensor was used as low-cost equipment in the arrangement section of the system. However, the working and installing parameters have not yet been investigated in detail. This study focused on investigating the optimal working conditions of TCS3200 on the fresh chili destemming system. The study included three experiments including the effect of the red and green color channels, the effect of the height between the sensor and fruits, and the effect of the running velocity on the received signal level of the sensor. A total of 260 ripen fruits were chosen to test. The results showed that the red channel generated a stronger signal than the green one. The optimal height from the sensor to the fruits was obtained at 25 mm, and the maximum conveyor velocity is limited to 100 mm/s. This study helps to determine the optimal operating parameters and enhance the working ability of a low-cost sensor. However, the high-speed pushing actuating mechanism should be developed in further works.

1. INTRODUCTION

Chili is an important and valuable agricultural product, especially in the Mekong Delta (Vo et al., 2015). The stem removal is a necessary stage in the processing process (Vo, 2016). Several studies have been done to automate this important step (Gunes & Badem, 2016; Herbon et al., 2010; Kodali, 2015).

The destemming principle using a clamping belt has been implemented and achieved the complete separation of the stem from the fruit’s body (Huynh et al., 2019). In this operating principle, chili is fed into the groove on the conveyor belt one by one by the feeding mechanism (Fig. 1). It is positioned completely within the width of the conveyor. The chili is conveyed through the arrangement section, where a color sensor is used to detect and send an appropriate signal to push it so that the excess stem is outside the conveyor. In the last destemming section, a belt is used to clamp and pull the stem far downward; while the body of the fruits remains on the conveyor belt and they gradually separate from each other. As a result, the stem is separated and falls to the bottom, while the body is kept on the conveyor until the end.

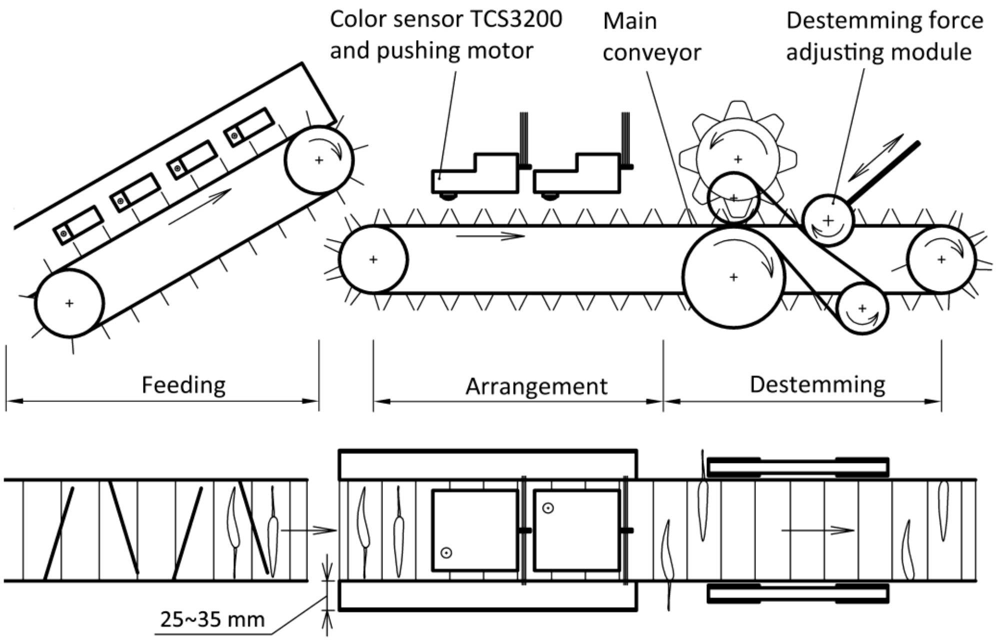

Figure 1. Working principle of the destemming system

The above model uses the color sensor TCS3200 as a low-cost solution for the fresh chili destemming. Thus it is necessary to determine the optimal operating parameters to exploit the full potential of the sensor. This study focuses on evaluating the influence of parameters such as the sensor installation height, the color channel used for identification fruits, and the maximum allowable operating speed. Experiments were performed on 260 fruits with 1,320 testing times. Then, results are recorded to compare, analyze, and discuss, and further research directions are also suggested.

2. MATERIALS AND METHODS

2.1. Response of the color sensor TCS3200

The TCS3200 sensor is a popular sensor from Texas Advanced Optoelectronic Solutions (TAOS, 2010). It has 64 photodiodes, including 16 green filters, 16 red filters, 16 blue filters, and 16 clear ones. The divide rate of the output frequency is set at 100%.

The return signal is a frequency in form of a square wave (50% duty cycle) proportional to the intensity of the input light source, and is calculated as follows (Sergey, 2005):

$$f_0 = f_D + R_e \times E_e \quad (1)$$

Where: f_0 is the output frequency;

f_D is the output frequency for dark condition (E_e = 0);

R_e is the device responsivity for a given wavelength Hz/(mW/cm^2);

E_e is the incident irradiance in mW/cm^2;

The received signal from TCS3200 is read by *pulseIn()* command (Arduino, 2021). And the frequency f_0 is converted to the length of pulses, equivalent to the period T of the signal.

$$T = 1/f_0 \quad (2)$$

2.2. Working principle of the arrangement section

The arrangement section is designed in the form of a module, installed at the height *h* above the conveyor (Fig. 2a). It includes a TCS3200 color sensor to read the color value, a microcontroller UNO R3 to process the signal and output the corresponding control signal to the TB6600 driver to control the pushing motor.

As described in the control flowchart, after starting, the sensor performs a color reading when the fruit is conveyed at velocity *v* (Fig. 2b). When this signal reaches a certain pre-set value, the microcontroller outputs a signal to control the stepper motor with a waiting time *t*. This is the traveling time of the chili on the distance *l* from the sensor to the pushing position and is calculated as:

$$t = l/v \quad (3)$$

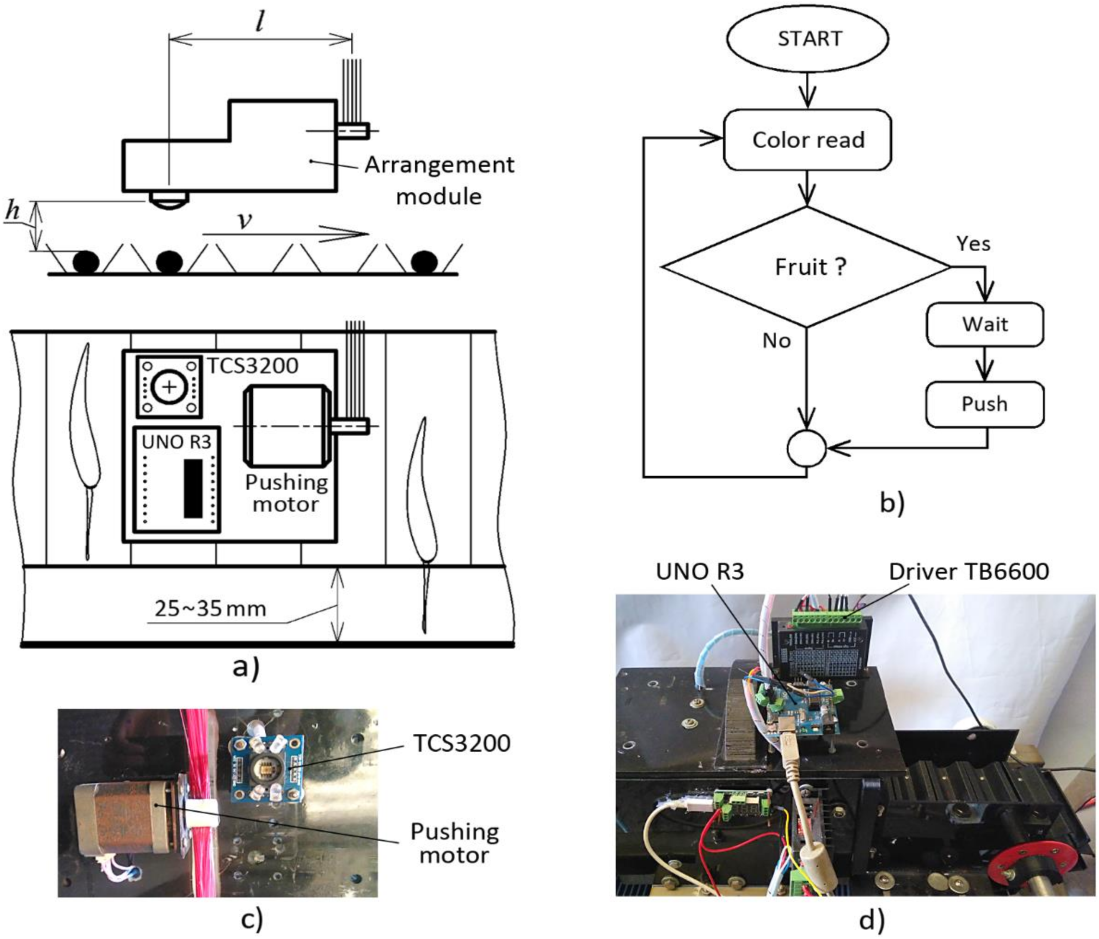

Figure 2. The arrangement module

a) Working diagram *b) Control flowchart* *c) Inside view* *d) Outside view*

2.3. Experimental set up

2.3.1. Testing chili

The testing fruits are fully ripe red fruits, intact, free of diseases, belonging to the *Chanh Phong F4* variety – the most commonly grown variety in the Mekong Delta today. The selected ones have stems with straight shapes, the largest diameter is 9±0.5 mm, and the whole length is 80±5 mm.

2.3.2. Experiment 1: Color channel evaluation

The chili is placed in a groove and passed under the sensor at a velocity of 100 mm/s at a specified height h = 20 mm. To avoid effects, the whole of the arrangement section is made in black. The ripen fruit has a red body and a green stem. So, these two color channels are recorded and evaluated. 100 chilies were tested 3 times per fruit, for a total of 300 tests.

2.3.3. Experiment 2: Effect of the height of the sensor

The chili is conveyed at a fixed speed of 100 mm/s at different installation heights. As suggested from the sensor manufacturer's specification sheet, the distance should be 2÷25 mm (TAOS, 2020). Due to space limitations, the sensor cannot be placed closer than 15 mm. Therefore, the sensor height h is surveyed at the following values: 15, 20, 25, 30, and 40 mm. The blue and red signals are recorded for analysis. Tests were run in every batch of 10 fruits. 100 chilies were tested 3 times per fruit, for a total of 300 tests.

2.3.4. Experiment 3: Effect of the conveyor running velocity

To evaluate the effect of running speed on the working ability of the sensor. Each batch test of 10 chilies were performed at different speeds: 10, 20, 30, 40, 50, 60, 80, 100, 120, 140, 160, and 180 mm/s. The sensor height is set to 25 mm. 60 chilies were tested 12 times per fruit, for a total of 720 tests.

3. RESULTS

The red and green channel values were drawn at different sensor heights and running velocity 100 mm/s (Fig. 3 and Fig. 4). The graph segment from 0 to 100 is corresponding to the f_D value without the movement of the conveyor. Then, the belt was run, and the reading signal changes up and down fluctuation (from node 101 to node 250) due to the V-shaped groove which causes a change in sensor height. Although the groove is fabricated in black, it is not completely dark, thus causing oscillation in this segment (Fig. 3).

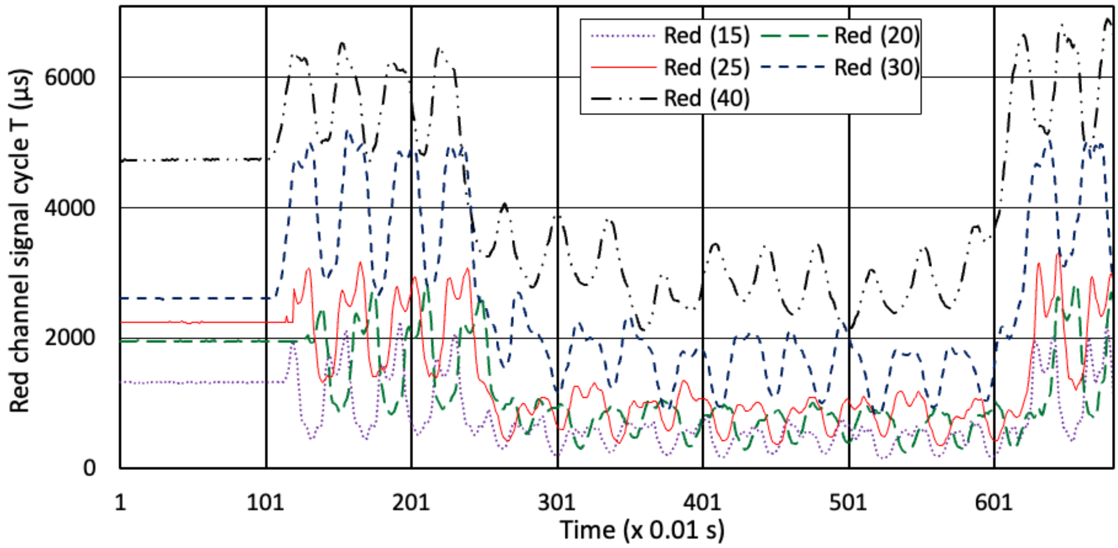

Figure 3. Effects of the sensor height on the red channel of 10 fruits

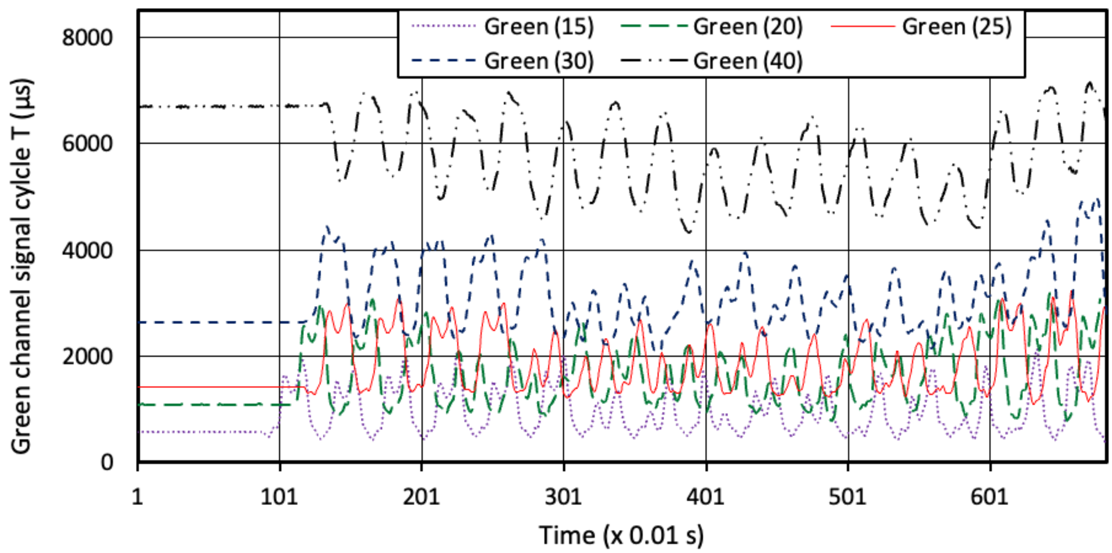

Figure 4. Effects of the sensor height on the green channel of 10 fruits

In the graph segment from 251 to 600, there was ripe red fruit inside the groove, thus the graph changes due to the intensity of the red channel. A significant difference in the graph would be easier to set the threshold value. At the height of 10 mm and 40 mm, the threshold could not be found because the lowest peak point is higher than the highest valley (Fig. 3 and Fig. 4). At the height of 20 mm, the difference is significantly smaller than that at the height of 25 mm and 30 mm. Thus the peak and valley signal values of the height 25 mm and 30 mm are presented in Table 1. In which, the V_{max} is the maximum of 10 valleys, while V_{avg} is the average of them. And P_{min} and P_{avg} are respectively the minimal and the average of 9 peaks.

Table 1. Comparison of the received signal (µs) between the height of 25 mm and 30 mm on the red channel at velocity 100 mm/s

Height	V_{max}	V_{avg}	P_{min}	P_{avg}	$(P_{min} – V_{max})$	$(P_{avg} – V_{avg})$
25 mm	582.0	441.9	820.0	940.8	238.0	154.0
30 mm	1546.0	1056.7	1700.0	2088.1	498.8	1031.4

As described in Table 1, the height of 30 mm generates the most significant differences between the peak average and the valley average as 1031.4 µs in comparison to 498.8 µs at the height of 25 mm. However, when considering the difference between the minimum peak and the maximum valley, the height of 25 mm obtains the most significant difference at 238 µs in comparison to 154 µs at the height of 30 mm. Thus 25 mm distance is the most suitable height to get the clearest difference between the state of with and without the chili.

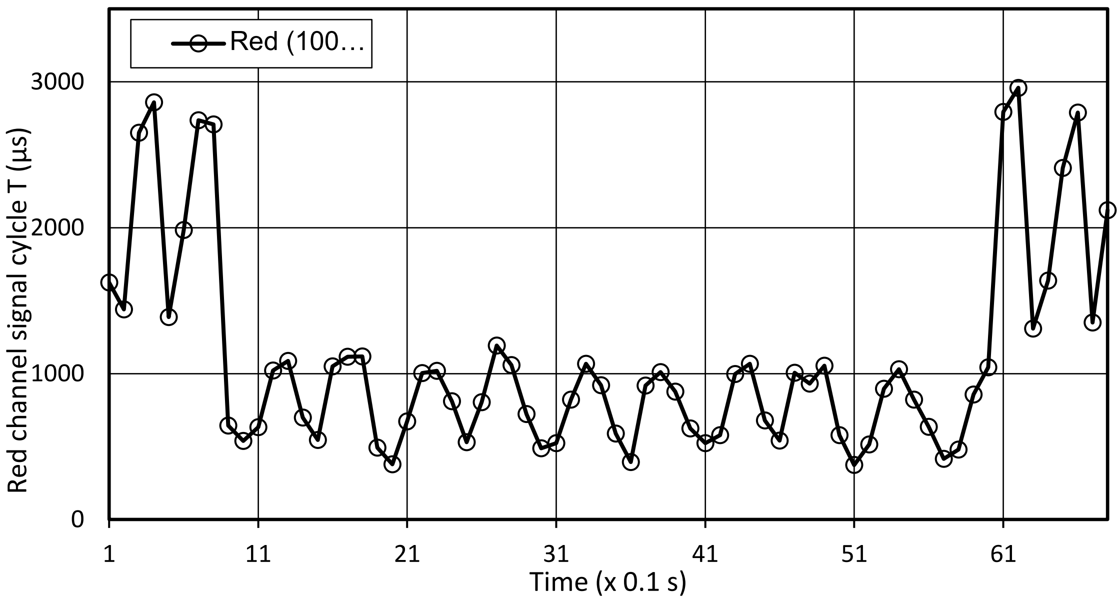

Figure 5. Effects of the velocity on the red channel at the velocity 100 mm/s and the height of the sensor at 25 mm

For the green channel, the difference is only recognizable at the height of 25 mm to 30 mm (Fig. 4). This is explained because the size of the stem is usually small, so the radiation intensity is also reduced accordingly. When the sensor is placed at a distance higher than 30 mm, the radiation intensity decreases. In another case, when the sensor is placed too close, the radiation time that the chili passes through the sensing area is reduced, so the radiation intensity is also reduced. Comparing between two color channels, the red one is selected as the detection factor because it generates significant signals.

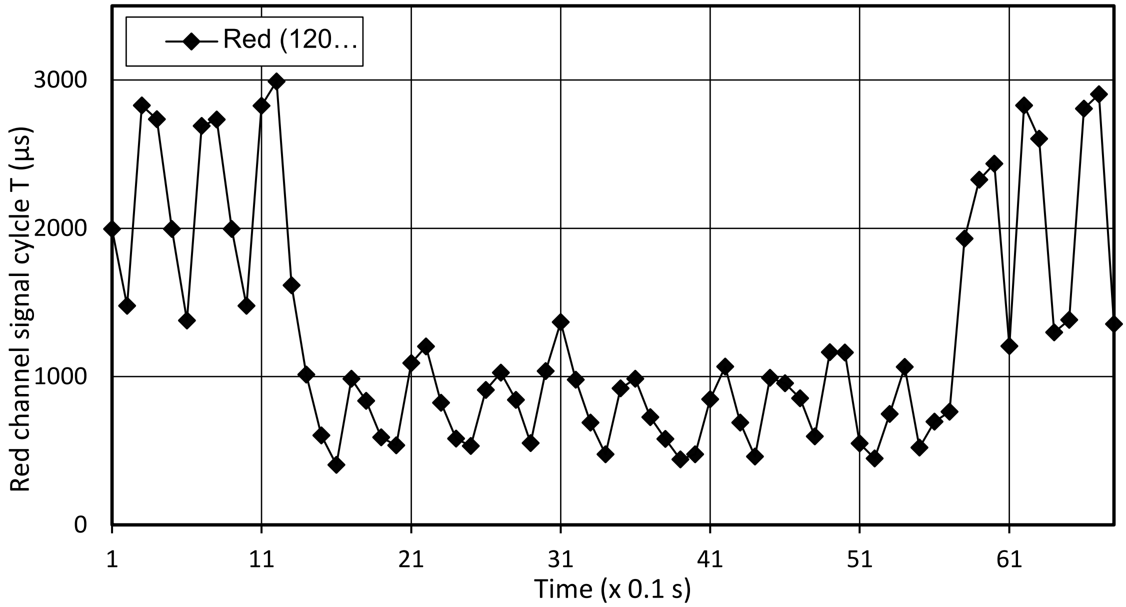

Figure 6. Effects of the velocity on the red channel at the velocity 120 mm/s and the height of the sensor at 25 mm

Results showed that the distinction between the with-chili and non-chili groove is clear in the low-speed range. At the velocity from 10 mm/s to 100 mm/s, the difference between the status of with and without fruits was detected by 10 valleys in the graph (Fig. 5). At a velocity of 120 mm/s, it is also possible to recognize with a little fluctuation in the graph (Fig. 6). From 140 mm/s, it becomes difficult to distinguish (Fig. 7), and at 160 mm/s the difference is completely indistinct (Fig. 8).

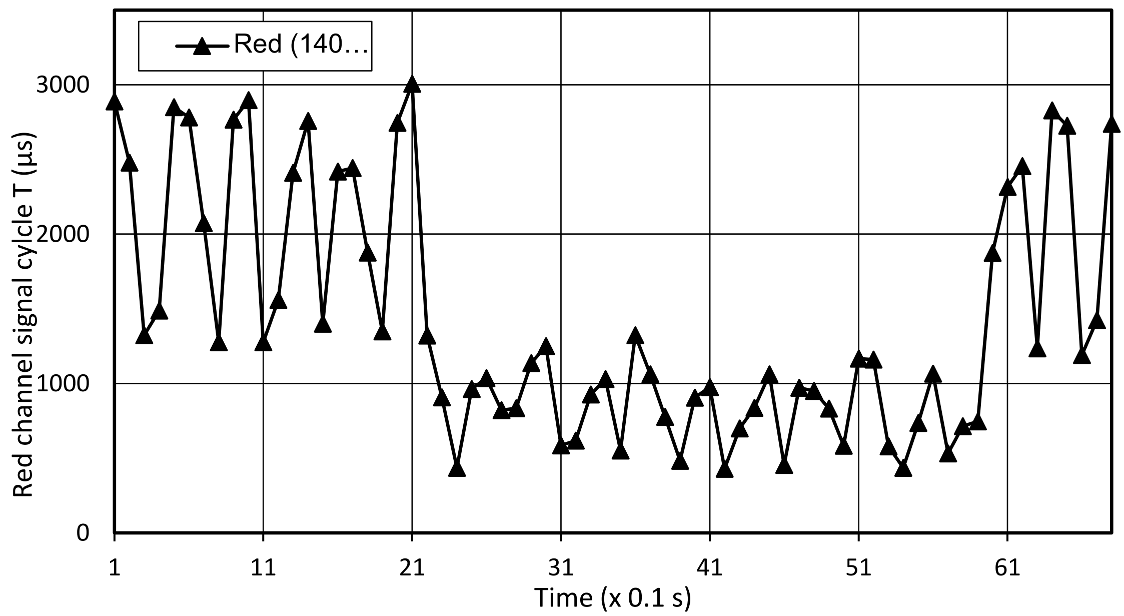

Figure 7. Effects of the velocity on the red channel at the velocity 140 mm/s and the height of the sensor at 25 mm

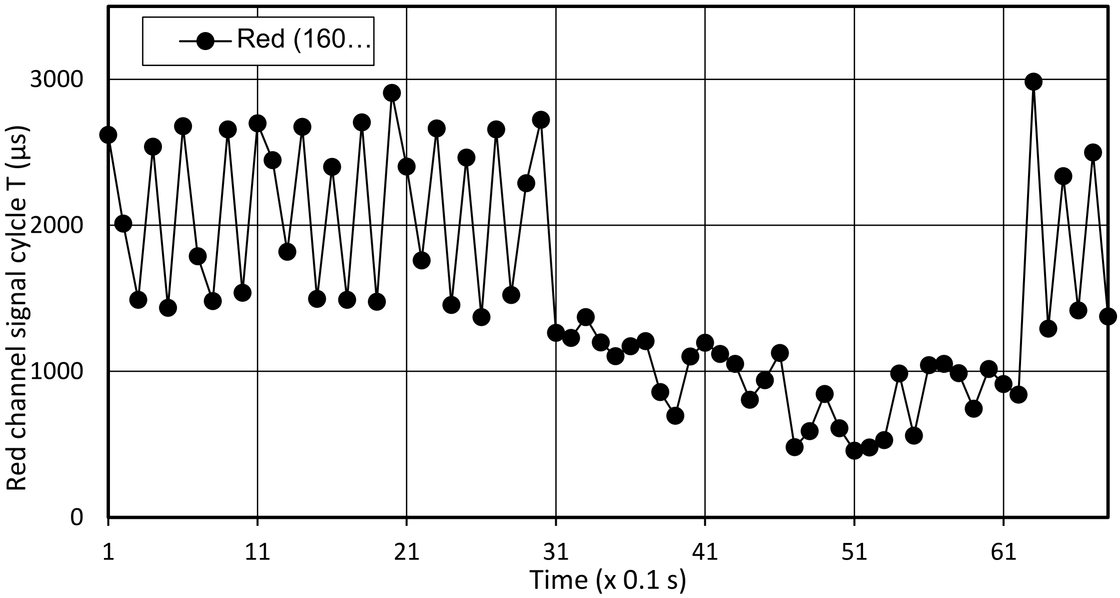

Figure 8. Effects of the velocity on the red channel at the velocity 160 mm/s and the height of the sensor at 25 mm

4. DISCUSSION

The experimental analysis leads to the option of using the TCS3200 sensor to read the red channel of the chili fruit body in the chili arrangement mechanism with the installation height of 25 mm.

With the above results, the velocity of 120 mm/s is considered as the maximum operating speed of the conveyor belt which can ensure the operation of the sensor in the chili arrangement mechanism. In actual working, it is better to reduce 10÷20%, and the recommended optimal value would be 100 mm/s.

Since the fruits' body is much larger than the stem, the intensity of the red color will be greater than that of the green. However, the experiment also confirmed that there was a clear distinction between the presence and absence of fruits in the grooves.

Because the sensor could sense in a certain area, there is a phenomenon that the previous fruit has not come out yet, the next one has entered. So, the generated intensity is high but continuous, making it difficult to distinguish between the chilies and the black grooves. This error occurs at a speed higher than 140 mm/s.

To eliminate the influence of the external light, the entire arrangement mechanism is made with black color, and the inlet is designed as a long box for light shielding. Moreover, the inlet and outlet sections are also designed as small as possible, and an active light source is also added to the internal space to ensure the stability of the light.

The pushing mechanism is a stepper motor, a simple but highly capable method. However, fruits have bouncing back when it collides with the wall at quick pushing. This is also needed attention to developing.

This current system conveys chilies by a V-shaped trough with a pitch of 40 mm. In comparison to a previous computer vision system that could detect the stem's position of the chili to acquire the same arrangement function (Gunes & Badem, 2016), the color sensor could generate the same yield of 2.5 fruits per second at a running speed of 100 mm/s. However, this current method has the advantage that it does not require high-cost equipment as well as complex image processing algorithms.

Although there are sensors with higher speed and more sensitive sensing capabilities, this research helps to take full advantage of a low-cost sensor TCS3200.

In this study, fruits were fed manually. The feeding mechanism has also been built as described in the link https://youtu.be/tIvBWlSQ748. Sometimes, 2 fruits were fed together. Therefore, feeding fruits one by one should be done in further study.

5. CONCLUSIONS

This research has found the optimal working conditions of the TCS3200 color sensor in the arrangement section of the fresh chili destemming system by experimental method. It enhances the full advantages of a low-cost sensor and is considered a useful solution for solving the destemming process. The red color of the fruits' body generates a stronger received signal than the green and is the recommended color channel. The sensor installation height is determined to be best at 25 mm. In addition, the conveyor belt velocity should be limited to 100 mm/s to ensure the sensor's response. The development of a high-speed pushing mechanism should be done in further studies.

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REFERENCES

Arduino. (2021, July 26). *Advanced I/O functions*. https://www.arduino.cc/reference/en/

Gunes, M., & Badem, H. (2016). Detecting Direction of Pepper Stem by Using CUDA-Based Accelerated Hybrid Intuitionistic Fuzzy Edge Detection and ANN. *Journal of Sensors.* Volume 2016, Article 4052101. http://dx.doi.org/10.1155/2016/4052101

Herbon, R., Cillessen, D., Gamilo, E., & Hyde, A. (2010, June 20-23). *Designing a High Volume Chile De-stemming Machine* [Conference presentation]. 2010 ASABE Annual International Meeting, Pittsburgh, Pennsylvania, USA.

Huynh, Q. K., Nguyen, V. C., Le, Đ. K. L., & Le, P. H. (2019). A study on chili fruit processing process and new design of chili destemming system. *Can Tho University Journal of Science*, *2A*, 9-16. DOI:10.22144/ctu.jvn.2019.032 (in Vietnamese).

Kodali, N. B. (2015). System and method of de-stemming produce. *United States Patent and Trademark Office (USPTO)*. Patent number: US9173431B2.

Sergey, Y. Y. (2005). Intelligent Opto Sensors' Interfacing Based on Universal Frequency-to-Digital Converter. *Sensors & Transducers Magazine (S&T e-Digest)*, *56*, 326-334.

Texas Advanced Optoelectronic Solutions (TAOS). (2010). *TCS3200 - DB: Color Sensor Module*.

Vo, T. T. L. (2016). Assessment of agri-product value chains in the Mekong Delta: Problems and solutions. *Can Tho University Journal of Science*, *2*, 100-111. doi.org/10.22144/ctu.jen.2016.001

Vo, T. T. L., Nguyen, P. S., Lam, H., Truong, H. K., Vo, T. K., Le, T. G., Nguyen, T. T. A., & Huynh, H. T. (2015). Analysis of chili value chain in Dong Thap Province. *Can Tho University Journal of Science*, *38*, 107-119 (in Vietnamese).