A Study of Impact Energy on Eggshell Crack

Po-Ting Chou¹, Jeng-Liang Lin²*
¹Dept. Biomechatronic Engineering, National Chiayi University, Taiwan
²Dept. Biomechatronic Engineering, National Chiayi University, Taiwan
*Corresponding Author, Tel +886-5-2717656, Email: jllin@mail.nctu.edu.tw

Abstract. The lengthy and irregular cracks occur when eggs are impacted. These egg samples with cracks can be used for thermal image to study the display of the crack. The purpose in the study was to analyse eggs impacted by free fall and measure the crack length with a self-developed image analysis system, further investigating the relationship between the impact energy and the crack length. The image analysis system comprised Image Import, Gray Level Processing, Binary Transform, Dilation and Labelling. Finally, all crack blocks could be obtained, as well as the area, perimeter and length could be determined. The test results showed that a height of free fall between 24-42 mm or an impact energy of 12-26 mJ would cause cracks similar to those when eggs were collected. The larger energy was, and the longer crack length was, presenting in linear relationship, as well as the egg source to the relation would be greatly influenced.

1. Introduction

The egg collection and processing system comprised egg feeding, egg washer, dryer, and post inspection. If some cleaned and dried eggs were not cleaned or damaged, they must be picked out by the post inspection to ensure the quality of egg. The final purpose of this study was to establish a set of wash and dry procedures associated with the egg-wash operation, where the temperature difference in the cooling and heating processes was acquired by thermal image to analyse the crack pattern of eggshell and display effect in thermal image, offering another choice from the sound detection [1-2]. A crack manually produced on the surface of eggshell was the first step in the study. Because the impact is one of major factors to produce the cracks on eggshell, the impact of free fall on eggs can simulate cracks when they are collected. After they suffered from the impact energy, the lengthy and irregular cracks would be formed. These samples could be used in the tests of crack detection by thermal image [3]. The purpose of this study was to analyse the impact of free fall on eggs, influence the crack pattern from different heights, as well as measure the crack length by the self-developed image analysis system to further investigate the relationship between the impact energy and the crack length.
2. Materials and Methods

The crack impact test was conducted in the manners of eggs falling freely to hit the hard board, where the height of free fall (about 2-4cm) was accurately adjusted by a plain paper and the bottom was a hard plate in horizon. The impact energy that eggs rolled from the top of paper to the lower plate would crack eggshell. Eggs in the test were purchased from a supermarket and cracked by the impact energy of free fall from four heights. 12 eggs were required and labelled as A01-A12 when repeating three times from every height. In order to test the influence of eggs from the different sources, 8 eggs were purchased from the other supermarket to crack in free fall from the same heights. All heights were repeated for two times, and eggs were labelled as B01-B08.

The way to test the impact energy was free fall from the height. Stacking paper in different quantities can simply produce the height difference. There were four heights of free fall in the study, which are 24, 28, 34 and 42 mm. The height of free fall selected between 24-42 mm was because the results of preliminary test showed that it was difficult to observe the cracks from a height less than 24 mm, and the height greater than 42 mm would produce large cracks and outflow egg liquid.

The crack length analysed by image process needs to shoot the eggshell cracks in a specific way, so that can obtain the clear images to accurately measure the crack length. The structure to shoot the crack images was a plain plastic box with a depth of 12 cm, where a piece of black paper was laid on the bottom and two supports were fixed on the top to load the camera. The side of a cracked egg upwardly faced, so that the eggshell image in black background could be obtained at the fixed height, as shown in figure 1.

![Figure 1. Image acquiring setup for cracked egg](image)

The major axis and the minor axis of an egg were measured by a caliper before test, so that the length of every pixels in the image could be determined during the image process, and then weighed by an electronic scale to calculate the impact energy by potential energy formula \( W = mgh \). Afterward, eggs were loaded on the edge of stacked paper and lightly free fallen to ensure other forces were considerably small except for gravity. One or two images then were shot when every egg fell from a height to crack. In order to match a resolution of 320 × 240 for thermal imager, the image resolution for the image analysis system was set as 320 × 240. Because tiny cracks on eggshell might not appear in the image due to the original images being directly imported to the image analysis system, a marker was used to draw black lines on the cracks. Therefore, the cracks could be clearly appeared on the image analysis system.
3. Image Analysis System

Plant characteristics, such as leaf shape and area, have been studied numerously with image analysis [4-7]. Crack length on eggshell was determined by image analysis that was programmed by Visual Basic, where the interface form is shown in figure 2.

![Figure 2. Interface of image analysis system](image2.png)

The image analysis system comprised Image import, gray level processing, binary transform [8], dilation and labelling [9]. An image of cracked eggshell drawn by a marker was selected from the Open Picture button in the interface. The width-height ratio of an image was adjusted as 4:3 before image selection. Otherwise, the image would be compressed and deformed. The image at the right side of the figure 3 shows the distorted image after image import.

![Figure 3. True (left) and distorted (right) images after image import](image3.png)

Using the Gray Image button transformed the color image to the gray-level image, and then using the Binary Trans button transformed the image to the black and white image, where eggshell without and with cracks were presented in white and in black respectively (as shown in figure 4).
Figure 4. Analysis screen of crack length

After pressing the Binary Trans button, the Block Labelling button was pressed to label all blocks in black by labelling as well as analyze the area, the perimeter and the length, where the area was the total number of pixel in the block and the perimeter was the total number of pixel on the block edge. However, if the edge pixels were the outer corner ones, the values were multiplied by 1.414 so that a perimeter of the block could be accurately obtained. When performing the image analysis, the Dilation button could be pressed to dilate the crack block. Because the cracks were usually too thin, they had to be dilated in order to prevent determining as different blocks by labelling when blocks connected diagonally. The dilated crack was basically a line in a width of 3 or 5 pixels. If the factors at the end portion were eliminated, the length was about a half of the perimeter.

Because the length unit in the image analysis system was pixel and the length unit of the true crack was mm, the unit must be converted. First of all, the measurements of egg length (mm) divided by the length of eggshell image (pixel) represented the length of every pixel (mm/pixel), and then the unit conversion multiplied by the crack length on eggshell (pixel) could then obtained the actual crack length on eggshell (mm).

4. Results and Discussions

The basic physical properties and results from image analysis of eggs under test are shown in table 1. The major (meridional) axis and the minor (circumferential) axis in the first batch of eggs (A) were between 55-59 mm and 43-45 mm respectively, where the average values were 56.4 mm and 43.6 mm. The weight was in the range of 54-63 g, where the average value was 60.3 g. The major (meridional) axis and the minor (circumferential) axis in the second batch of eggs (B) were 54-61 mm and 43-45 mm respectively, where the average values were 57.6 mm and 43.9 mm. The weight was in the range of 56-66 g, where the average value was 60.7 g. Although the eggs in two batches came from the different sources, basically they had the same size and weight. When the height of free fall was 24-42 mm, the impact energy was 12-26 mJ. As for the length represented by each pixel, the test results showed that there were somewhat different between horizontal and vertical directions. The reason was that the orientation of major axis was not located on the true direction of horizon when shooting the egg image. The maximum and minimum differences in the first batch of eggs (A) were 8.4% for A05 and 0.3% for A02, where the average difference was 2.5%. The maximum and minimum differences in the second batch of eggs (B) were 2.5% for B04 and 0.3% for B06, where the average difference
was 1.2%. The average value of length represented per pixel for both horizontal and vertical direction was 0.325 mm/pixel.

### Table 1. Experimental averages of each height of free fall for the two batch eggs

| Egg #     | Free Fall Height (mm) | Crack Length (mm) | Major axis (mm) | Minor axis (mm) | Weight (g) | X resolution (mm/pixel) | Y resolution (mm/pixel) | Impact energy (mJ) |
|-----------|------------------------|-------------------|-----------------|-----------------|------------|--------------------------|------------------------|--------------------|
| A01~A03   | 24                     | 31.54             | 56              | 44              | 56.77      | 0.324                    | 0.320                  | 13.36              |
| A04~A06   | 28                     | 47.43             | 56              | 44              | 61.14      | 0.339                    | 0.326                  | 16.79              |
| A07~A09   | 34                     | 55.27             | 57              | 44              | 62.65      | 0.325                    | 0.322                  | 20.89              |
| A10~A12   | 42                     | 65.61             | 56              | 43              | 60.48      | 0.334                    | 0.326                  | 24.92              |
| B01~B02   | 24                     | 96.47             | 59              | 44              | 61.64      | 0.323                    | 0.323                  | 14.25              |
| B03~B04   | 28                     | 81.36             | 59              | 44              | 63.18      | 0.324                    | 0.317                  | 17.35              |
| B05~B06   | 34                     | 96.47             | 56              | 44              | 59.59      | 0.321                    | 0.324                  | 19.91              |
| B07~B08   | 42                     | 163.37            | 57              | 44              | 58.37      | 0.326                    | 0.327                  | 24.05              |

Some of the physical crack images after eggs were impacted by free fall are shown in figure 5. Eggs free falling from a height of 2.4 cm (A01) would cause shorter cracks. Eggs free falling from a height of 2.8 cm (A04) would cause longer cracks, but would not outflow egg white. Eggs free falling from a height of 3.4 cm (A07) would cause longer cracks. Although cracks were deep a little bit, egg white would not outflow. Eggs free falling from a height of 4.2 cm (A11) would cause even longer cracks, whereas some egg white would outflow. Therefore, for an impact test in free fall, a height should not be greater than 4.2 cm. In the impact of free fall from the same height, the cracks in the second batch of eggs appeared more obvious than those in the first batch of eggs to indicate that the eggshell strength was greatly related to the sources, which could be related with the chicken breed, feed and environmental management. When eggs free fell, the circumferential area would directly suffer from the impact energy. Since the strength on the circumferential area was smaller than that on two meridional areas [10], the cracks were likely located in the circumferential area. In some tests with higher impact energy, the cracks on eggshell could extend to the reverse side of the impact. If this result occurred, two crack images would be required to shoot so that the crack length on eggshell could be determined completely.

![Figure 5. Physical crack images after eggs being impacted by free fall](image)

Height of free fall had great influence on cracks of eggshell (figure 5), where the higher height was and the cracks would be more obvious. However, impact energy was the factor to cause cracks on eggshell. In consideration of height in free fall and egg weight, variation of the impact energy on the crack length (figure 6) could be obtained. The results showed that eggs under an impact energy of 12-26 mJ would crack. The larger energy was and the crack would be longer in a linear relationship.
Although the crack length was in a linear relationship with the impact energy, the relation would show the large difference owing to the different sources. The slope in the first batch of eggs (A) with the impact energy in a linear relationship of crack length was 2.95 mm/mJ, and the slope in the second batch of eggs (B) was 9.02 mm/mJ.

![Image]

**Figure 6.** Influence of impact energy on crack length, where the data in blue diamond and red square were eggs in the first (A) and second (B) batches

5. Conclusions
The self-developed image analysis system in this study could measure the crack length, and further investigate the relationship between the impact energy and the crack length by free fall impact. Based on the test results, specific conclusions are as follows.
The cracks produced from a height of free fall between 24-42 mm could simulate the crack on the eggshells when eggs were collected.
The self-developed image analysis system could analyse the length per pixel in the image by the measurement of the egg size and the appropriate image shooting, where the average value of the length per pixel in the image was 0.325 mm. Then, the crack length on eggshell could be determined by the pixels of the crack edge in the image.
Eggs would produce the cracks when suffering from an impact energy of 12-26 mJ. The larger energy was and the crack would be longer in a linear relationship and related with the egg source.

6. References
[1] Li C, Chang J, Cheng C. and Hsieh L. 2011. A Novel Non-Destructive Technology for Inspecting Eggshell Cracks Using Impulsive Response Time. Food Sci. Technol. Res. 17 (1): 1-10
[2] Chen Y-C, Hu M-L and Cheng C-W. 2011. Applying Non-Destructive Techniques to Inspect Preserved Egg Products by Decay Rates. Journal of Food Engineering. 104: 30–35.
[3] Shen P-N, Lei P-K, Liu Y-C, Haung Y-J and Lin J-L. 2016. Development of a temperature measurement system for a broiler flock with thermal imaging. Engineering in Agriculture, Environment and Food. 9 (3): 291-295.
[4] Meyer G E and Davison D A. 1987. An electronic image plant growth measurement system. Transactions of the ASAE. 30(1): 242-248.
[5] Ghazanfari A, Irudayaraj J, Kusalik A and Romaniuk M. 1997. Machine vision grading of pistachio nuts using Fourier descriptors. J. Agric. Engng. Res. 68: 247-252.

[6] Kuo T-Y, Chung C-L, Chen S-Y, Lin H-A and Kuo Y-F. 2016. Identifying rice grains using image analysis and sparse-representation-based classification. Computers and Electronics in Agriculture. 127: 716-725.

[7] Van Henten E J and Bontsema J. 1995. Nondestructive crop measurement by image processing for crop growth control. J. Agric. Engng. Res. 61: 97-105.

[8] Otsu N. 1979. A threshold selection method from gray-level histograms. IEEE Transaction on System, Man, and Cybernetics. 9(1): 62-66.

[9] Haralick R M and Shapiro L G. 1992. Computer and Robot Vision (Volume I). New York: Addison-Wesley.

[10] Lin J, Puri V M and Anantheswaran R C. 1995. Measurement of eggshell thermal-mechanical properties. Transactions of the ASAE. 38: 1769-1776.