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Research Article

Design and Fabrication of Egg Quality Assessment System Based on Image Processing

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ABSTRACT

Eggs are a nutritious and important food in human daily diet, which is considered as a protein source of food. The most acceptable index for evaluating egg quality is Haugh unit with two factors, i.e. the weight of intact egg and the height of broken egg's albumin. Hauge unit has three classification: firm (higher than 72), reasonably firm (higher than 72), and weak (less than 60). Average results for Haugh unit on the first, fourth, eighth, twelfth, and sixteenth days (five eggs in each step) were 113.39, 91.47, 74.56, 72.04, and 64.14 respectively. On the first, fourth and eighth days, eggs were intact but the quality of the eggs decreases on the next days. This research aims to sort healthy eggs from others and swell the rate of sorting.

RESEARCH ARTICLE

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- Healthy egg
- Quality measurement,
- Recognision system,
- Haugh unit

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INTRODUCTION

Nowadays, the food industry is developing all over the world (Earle and Earle, 1997). It is necessary to implement efficient methods to calculate product quality factors and obtain acceptable results. Eggs are nutritious and important food in human daily diet, which are considered as source of protein, minerals, vitamin and fatty acid food (Anderson, 2011; Karsten *et al.*, 2010). Quality control is an important and impartible part of the food and agriculture industry (Bazyar *et al.*, 2019) which affects the quality of ultimate product (Mitra, 2016). The egg producing and processing, as a part of the country's food industry, needs to control and measure the input product with low costs (Moore and Sandground, 1956). There are two ways for testing the egg quality by image processing; destructive and nondestructive methods. Direct accessing to each index of the albumin height (H) is an advantage of employing the destructive methods. Therefore, the method of this research is important for the global poultry industry to ensure the health, productivity and internal quality of eggs.

Two hundred egg samples were stored at a temperature of 30±7°C and 25±4% relative humidity. The results of albumin PH, Haugh unit (HU) and Yolk coefficient obtained from the destructive and nondestructive tests to determine the egg quality. The intelligent system used for egg classification over its quality was based on GA and PCA methods.

In another study, a system based on machine vision and artificial intelligent techniques used to grade egg samples. The researchers analyzed Hue-Saturation-Value (HSV) color space to detect the size, cracks and breakage of eggshell. They utilized Mamdani fuzzy logic method along with center average method for defuzzifier. The result of classification rate was 95% for size detection, 94.5% for crack detection and 98% for breakage detection (Omid *et al.*, 2013).

Ramírez-Gutiérrez *et al.* (2019) investigated the computer vision for deformation on curved surfaces of eggshell. In this study 75 sample eggs without deformation and 75 samples with deformations are analyzed. Vision system consists of a camera with a CCD sensor and a laser-structured light pattern with lighting conditions in concentrations lower than 1 lux to catch the images. Image processing implemented in 8 steps to obtain acceptable curvatures and calculate the number of pixels between real and interpolated curves. The most accurate result for classifying the defective samples with artificial neural network was 97.5%.

Zhang *et al.* (2015) applied a synthesis of hyperspectral image and multivariate analysis to assess egg internal quality. Hyperspectral imaging system consists of a CCD camera, an imaging spectrometer, a light unit, a motorized horizontal stage and Spectral Image System (v10E software). In this study, spectral analysis used to estimate Haugh unit (HU) and morphological analysis of images to detect bubble formation and scattered yolk. Eggs with internal bubbles and scattered yolk measured by support vector classification (SVC) model with 90.0% and 96.3% of were precision, respectively and Haugh unit (HU) was 84%.

Our proposed method is based on image processing techniques for assessment of the egg quality. The aim of the present study is to measure the albumen height, yolk height and yolk diameter. Based on the results, the Haugh unit (HU) results are criterion to grade the eggs into different groups.

MATERIALS AND METHODS

The manner of image analysis is shown in Figure 1, including image acquisition, image processing and extraction of features for measurement of internal quality.

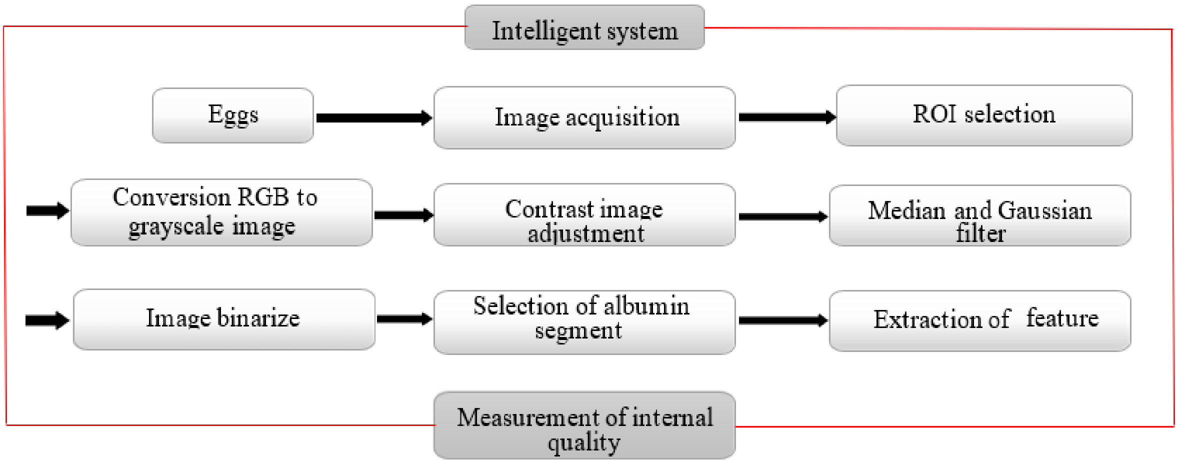


Figure 1. Experimental procedures.

Sample Collection

In this study, twenty-five intact and fresh egg samples were bought from store in Karaj, Iran. The intact eggs kept in the laboratory, out of refrigerator, at 26±2°C. The samples divided into 5 groups, each containing 5 eggs and the duration of the test was 20 days, once in four days.

Apparatus

Our proposed egg quality assessment system is shown in Figure 2.

Figure 2. Egg quality assessment system: (1) light box; (2) smart phone; (3) laptop.

This box was simulated in 3D sketch on SolidWorks software (2018) and made of wood to eliminate effects of environmental noises. Dimensions of box in length, width and height are 60, 60 and 50 cm, respectively. The light box dimensions in length, width and height are 15, 15 and 20 cm, respectively and it contains a 7W SMD bulb. One of the most important stages in egg morphological analysis is the uniform orientation of the light, surrounding the egg surface, to be designed in the dark environment. Luo *et al.* (2001) used imaging system (Digi Eye) includes digital camera, illumination box and computer to obtain the images.

Heredia *et al.*, 2006 used Digifood to obtain morphological parameters, which is better than CIELAB coordinates of image processing.

We used HTC TM one X9 smart phone to acquire sRGB (color) images. The camera of phone is 4160 × 2368 pixels in horizontal and vertical directions, respectively and Focus Length is 27 mm. Smart phone was fixed approximately 200 mm in horizontal distance from the center of the egg sample. Data information transferred through a USB cable to laptop for image processing operations. A Lenovo TM laptop with following specifications were employed for the experiments; windows 10 Enterprise, Intel® Core TM i5, NVIDIA Geforce GT740M and installed memory (RAM) is 4GB.

Egg Weight

The nutrient content of eggs depends on the weight of the egg that affects by many factors such as heredity, breed, strain, age of hen, body size, feed and water consumption, ambient temperature and diseases (Şekeroglu and Altuntaş, 2009). Egg weight is one of the important egg quality factors; the evaluation of samples egg weight obtained by using an electronic balance scale (Jadever scale model) with 0.01g accuracy.

Analysis Methods

The acquired images by the camera of phone were stored in .jpg format and processed by Matlab® (MathWorks, Inc., USA) with using an algorithm to identify the height of albumin which consists of 2 steps:

a) Image pre-processing: evaluating the best process method, including filtering and segmentation.

b) Image analysis: descriptive area of the light pattern is obtained from the image to extract feature of selective pixels.

Preprocessing

The goal of pre-processing is to modify any noises of image during the test period and to provide necessary information about the eggs.

Initially, we need to extract useful information from the RGB image, which is necessary to separate the important region of image from basic image. This region is called ROI (region of interest). Figure 3a shows the ROI of input image that is restricted to egg segment in 3493 × 943 pixels.

In the next step, we convert the image (Figure 3a) to grayscale mode to extract the morphological features. The level of grayscale intensity [0-255] shows color range between black and white for each pixel (Figure 3b).

Figure 3c shows an operation that increases the contrast of the 8-bit images to perform the image polarity. In this section, by applying a coefficient of intensity [0.01-0.99] to the image (Figure 3b), which is obtained in practical tests, intensity of bright and dark pixels value promoted in image.

One of the most important steps in pre-processing is utilizing the low-pass filter operation, applied on the images for exploring some important relationships between the spatial and frequency domains (Davies, 2012). We used Gaussian and median smooth filtering to eliminate signal components with high spatial frequencies. As indicated in Figure 3d, this filter employed with 3×3 mask to enhance the image with minimum noise and recognize the egg.

In our method, binary process employed to identify the objects on white color sample in black background. The Otsu thresholding method (Otsu, 1979) automatically calculates a threshold for a grey level image (image as shown in Figure 3d) by using I_{binary} function [Equation (Eq.) 1] minimizing the interclass variance of black and white pixels to obtain a binary image (Figure 3e).

$$I_{binary} = \begin{cases} 0 & \text{if } I_{image} \leq T_{otsu} \\ 255 & \text{otherwise} \end{cases} \quad (1)$$

Image Analysis

In this research, height of albumin was determined from morphology formulate operations based on image processing functions to segment yolk and albumin area on the image. In order to distinguish the yolk of egg, processing method was performed on the red channel (:,:,1) of RGB color image and followed the T_{yolk} for identify the yolk (Eq. 2). I_{yolk} (Figure 3f) shows the yolk on binary image.

$$I_{yolk} = \begin{cases} 0 & \text{if } I_{image} \leq T_{yolk} \\ 255 & \text{otherwise} \end{cases} \quad (2)$$

At this point, $I_{albumin}$ (Figure 3g) calculated by Subtracting I_{yolk} from I_{binary} (Equation 3). Subtract operation used to obtain image from the two same size images to extract the area of interest (Du *et al*., 2004).

$$I_{albumin} = I_{binary} - I_{yolk}: [w \mid w \in I_{binary},\ w \notin I_{yolk}] \quad (3)$$

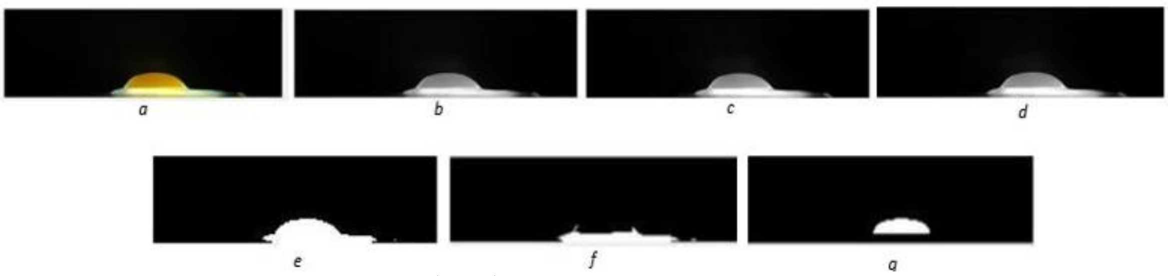


Figure 3. a. Input RGB image (ROI). b. Grayscale image. c. Enhancement image. d. Applied Gaussian and median filter. e. Binary image. f. Yolk section. g. Albumin section.

Image Calibration

To validate the extracted feature, calibration is essential. As shown in Figure 4, image calibration which taken by the camera in landscape mode, The ROI region image was 60 mm or 943.31 pixels wide and 220 mm or 3493.41 pixels length. So, with this method, image pixels count deforms by a proportion of millimeter unit; difference between the millimeter size on the real environment and image processing method result accuracy is less than 0.32 mm.

Haugh Unit

According to Haugh unit (Brant *et al.*, 1951) eggs can be divided into three states:

(AA) grade, firmness, top quality (Haugh unit ≥ 72);

(A) grade, reasonably firm, low quality (Haugh unit 60 – 71);

(B) grade, weak, deteriorated (Haugh unit < 60);

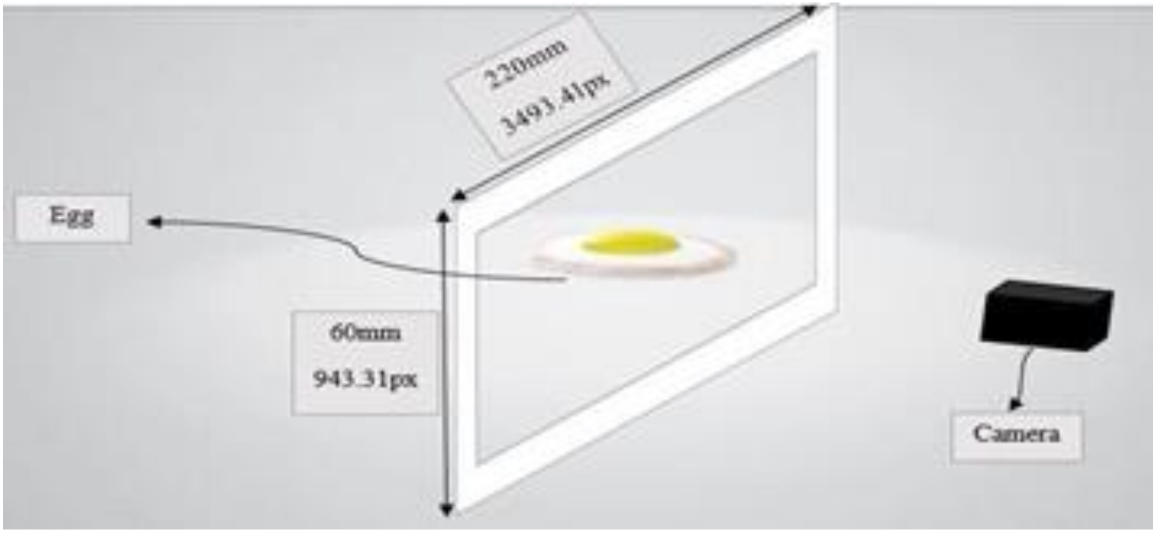


Figure 4. Schematic of the imaging system.

Haugh unit score is calculated by using egg weight and albumin height for each individual egg based on the following formula (Hough, 1937):

$$HU = 100 \log_{10}(H - 1.7W^{0.37} + 7.6) \quad (4)$$

Where HU is observed Haugh unit, H is height of the albumin and W is weight of the egg.

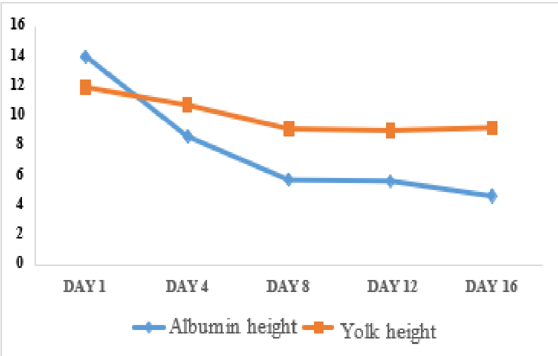
RESULTS AND DISCUSSION

The obtained results indicate an image processing analysis method from I_{yolk} and $I_{albumin}$ images. Table 1 shows the analysis results from the various test days for albumin height and Haugh unit, that indicates the quality of eggs with AA, A or B grade. According to Table 1, the Haugh unit decreased over time, so the eggs on the first and fourth days were intact and well for consumption; On the eighth and twelfth days, some eggs were grade A, then on the sixteenth day, when mean of Haugh unit were less than 72, the eggs included A or B grades and needed assessment for quality.

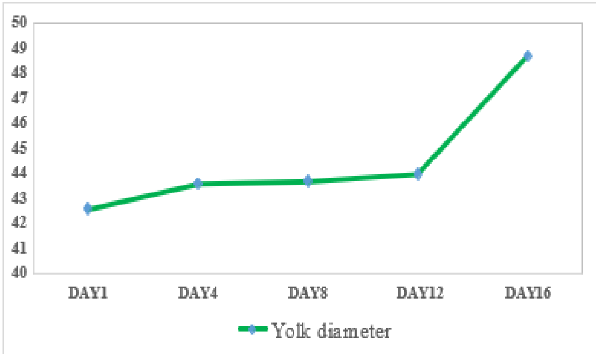
Table 1. Results obtained from the available information.

Test days .... Unit / Egg samples	Day 1			Day 4			Day 8			Day 12			Day 16		
	H	HU	Q	H	HU	Q	H	HU	Q	H	HU	Q	H	HU	Q
1	14.7	114.9	AA	8.7	91.6	AA	5.7	75.4	AA	5.9	75.1	AA	4.5	62.2	A
2	14.5	115.6	AA	9.4	96	AA	5.5	74.3	AA	5.5	69.8	A	4.1	58.4	B
3	12.6	108.9	AA	8.6	91.5	AA	5.5	71.9	A	5.0	65.6	A	5.2	70.7	A
4	13.8	112.7	AA	8.1	87.7	AA	6.2	79.2	AA	5.1	68.8	A	4.5	64.1	A
5	14.2	114.6	AA	8	90.3	AA	5.5	71.7	A	6.1	80.8	AA	4.7	65.1	A

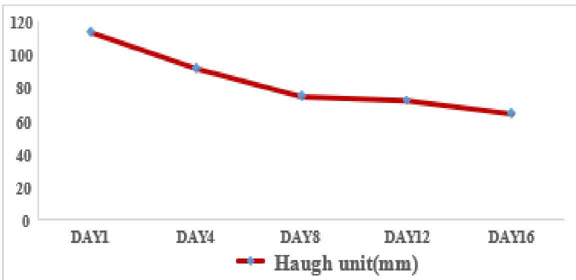
Figure 5a shows the decrease of albumin and yolk height at each test day which represents the average of five repetitions per day. This decrease of albumin height was due to the reduction of moisture, viscosity and transparency of albumin. Within some days, the vitelline membrane of yolk becomes thinner and the water absorbs to the yolk, so the shape of the yolk becomes like a balloon and the color gets darker. Thus, the yolk height decreased over consecutive days, then the yolk diameter increased and it is more intense from the twelfth to the sixteenth day as mentioned in Figure 5b.



a



b



c

Figure 5. Plot of albumin and yolk height parameters (a), Plot of Yolk diameter (b), Plot of Haugh unit parameter (c).

The descending trend of Haugh unit were calculated once in every four days and is presented in Figure 5c. Albumin height and egg weight scale decreased over the test days, which affects the value of Haugh unit from day one to day sixteenth.

CONCLUSION

This research was based on information available on egg quality assessment by image processing method. Also, the relevant indices such as albumin height, yolk height, yolk diameter and Haugh unit is calculated. It was important to implement an image processing algorithm to reduce noise of image and separate albumin and yolk section from each other. The obtained results were used to classify the egg based on the internal quality assessment to the three value; AA, A and B grade. Therefore, the quality of the eggs has been declining for several consecutive days, which has been attributed to the decrease in albumin height and Haugh unit; A process that necessitates an examination of egg quality after eighth day. Considering the importance of egg quality assessment in the food industry, the method was an assured technique to achieve acceptable results.

DECLARATION OF COMPETING INTEREST

We declare that we have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Ehsan Sheidaee: Investigation, methodology, conceptualization, formal analysis, validation, writing.
Pourya Bazyar: Data curation, writing, review, editing, visualization.

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