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Full Length Research Paper

Egg freshness detection based on digital image technology

Qiaohua Wang[1], Xiaoyan Deng[2], YiLin Ren[1], Youchun Ding[1], Lirong Xiong[1], ZhouPing[3], Youxian Wen[1]and Shucai Wang [1]*

[1]College of Engineering and Technology, Huazhong Agricultural University, Wuhan, 430070, P.R. China.
[2]College of Basic Sciences, Huazhong Agriculture University, Wuhan, 430070, P.R. China.
[3]National Engineering Research Center for Information Technology in Agricultural, Beijing, 100085, P.R. China.

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Yolk index and air room height, two main measures for egg freshness detection, are very difficult to be accurately measured in practices. This paper investigated an image-based egg freshness detection method. The perspective image of egg was obtained by computer vision device. The characteristic regions, including the yolk region and air room region were separated from the obtained egg picture by image processing. The pixel areas and lengths of the above characteristic regions were respectively calculated and analyzed. The relative ratios of the pixel area and length of characteristic regions to that of the whole egg region were selected as characteristic parameters. It was shown that the above relative ratios increased while egg freshness reduced according to a detailed analysis. Three detection models of egg freshness were set up based on the correlations between the characteristic parameters and freshness. The test results showed that the accuracy rates of these models were 93, 94 and 92% respectively. The egg freshness detection based on image characteristic of yolk and air room was efficient and feasible.

Key words: Egg yolk, air room, freshness, digital image, computer vision.

INTRODUCTION

Egg freshness detection is an interesting and important topic in the food safety researches, mainly due to the fact that egg is closely related to the everyday lives of common people and egg content changes easily during storage. Many researches have focused on egg freshness detection over the last decade.

Egg content mainly consists of yolk, albumen and air room. There is a layer of yolk membrane between yolk and albumen. With the extension of storage time, moisture of albumen gradually evaporates from the shell pores and penetrates into yolk. This process continues until the yolk membrane is completely broken up because of the reduction of membrane elasticity (Zhu, 1985; Geng, 1998). There is no air room in the newborn egg. When the egg cools down, the egg content will shrink, which leads to the formation of air room. The size of air room can increase due to water evaporation, the CO_2 dissipation and the drying shrinkage of egg contents. At the same temperature and humidity, the longer the storage time, the larger the air room size is (Zhang, 1998). So yolk index and air room height can be viewed as main measures of egg freshness.

Yolk index is the ratio of egg yolk's height to its diameter, which can only be measured by breaking the egg, whereas the height of air room is usually accessed by

*Corresponding author. E-mail: wsc01@mail.hzau.edu.cn. Tel: +86-027-87285346. Fax: +86-027-87285346.

a self-made ruler. Nonetheless, those methods are tedious and inefficient. Nowadays spectroscopy (Chen Bin, 1996; Liu and Qiao, 2002; Liu et al., 2003; Patel et al., 1998) and image techniques (Chen et al., 2001; Wang et al, 2006) have been commonly applied in the physical determination of egg freshness. Those methods which based on the color characteristics of images require critical experimental conditions and high-quality pictures. In this research the morphological characteristics of the transmitted light images were pre-processed, and the characteristics of sensitive area could be accurately shown after an effective image processing had been done. Then the correlations between egg freshness and morphological characteristics of egg contents were discussed, and the non-destructive detection models for the egg freshness were set up.

MATERIALS AND METHODS

Egg samples

Clean and fresh eggs, four hundred in total were collected from Hatchery in Huazhong Agricultural University. All of the eggs were numbered and stored in biochemical incubator at 25℃.

Experimental system

The computer vision equipment used to take egg images was shown in Figure 1. The testing equipment consisted of a light source, a light tube, a light room with radiator, a dark room, a transformer, a Canon digital camera and a computer. The mini light meter DT-1300 was used to measure illuminance with 5900 lux in this test.

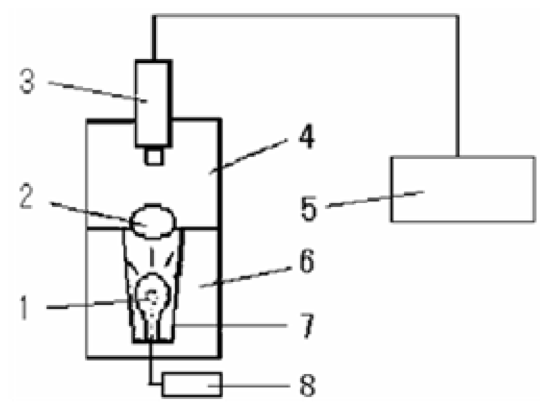


Figure 1. Computer vision device of egg image (1-Light source, 2-Egg, 3-Digital camera, 4-Dark room, 5-Computer, 6-Light room with radiator, 7-Light tube, 8-Transformer)

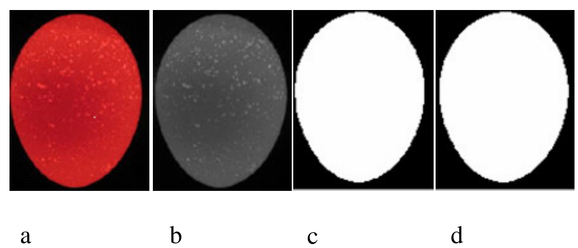


Figure 2. Egg image processing (a-Original image, b-Gray scale image, c-Binary image, d-Median filter).

Experimental procedure

With using above computer vision equipment, the experimental procedure is designed as follows:

(1) Every day images of ten eggs were taken and stored in computer at same time.
(2) The ten eggs were broken, Haugh unit of representing egg freshness was measured, and the data (Haugh unit) and storage time were recorded.
(3) Repeated steps (1) and (2) everyday until the yolks of the sample eggs stored for this experiment were found to become broken. Here Haugh unit was measured by the method proposed by Wang et al., 2006.

RESULTS AND DISCUSSION

Image processing

Separation of the whole egg: The original picture obtained from the computer vision equipment is shown in Figure 2-a. The separating method of the egg region from the original picture is as follows: Convert the color image into gray scale image (Figure 2-b); Process the images by the binarization method (Figure 2-c); denoising filter and remove interferential value. Thus, a binary image with high quality was achieved (Figure 2-d). From Figure 2-d, the pixel area and length of the whole egg region can be easily calculated and measured.

Separation of egg yolk: The egg yolk could not be seen in the original egg image (Figure 2). In this research, the three-components of R, G and B were separated from egg color picture and then the color picture was converted into the gray scale image for finding the feature region of egg yolk.

The gray scale image and its histograms for the R-, G- and B-component were shown in Figure 3-a, b and c respectively. It was found that the yolk could only be viewed darkly in the gray scale image of G-component. Meanwhile it also was found that there were more than two peaks

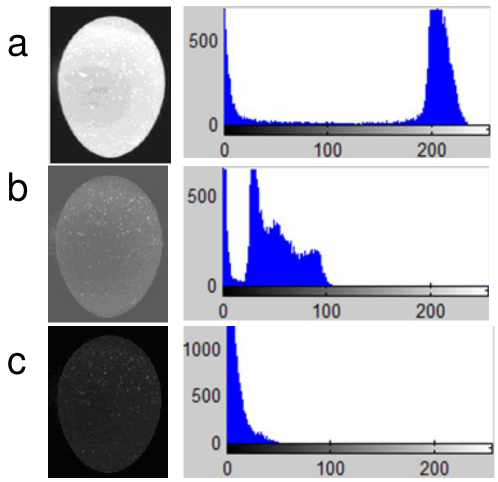


Figure 3. Gray scale images of R-, G-, B-component and its histograms (a-R, b-G, c-B).

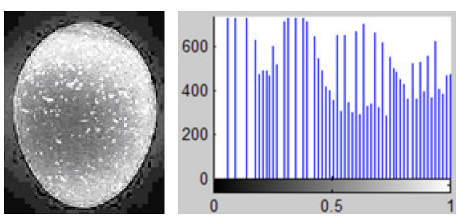


Figure 4. Gray scale image and it histogram equalization of G-component.

for all the histograms of R-, G- and B- component, in which the pixel values centralize in several ranges. Thus the gray scale image of the G-component was selected to separate the yolk region from the whole egg image. However, its most gray levers were lower than 100, and the image contrast was not strong. To enhance image contrast, the data mapping was used to extend the gray levers to the range of [0, 255]. According to the gray lever changes, the histogram equalization was adopted to enhance the gray scale image and its histogram was shown in Figure 4. As a result, the region of egg yolk could be clearly viewed in Figure 4.

However, it was still very difficult to calculate the yolk area from Figure 4. For segmenting the yolk region, the binary image of egg was obtained with the binary procedure controlled by a threshold. The threshold was selected based on the histogram of gray scale image. The result was shown in Figure 5-a.

Various kinds of noises existed in the obtained digital

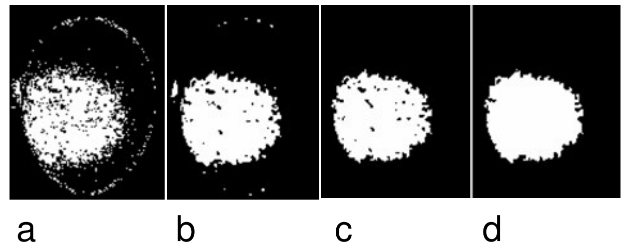


Figure 5. Image processing of egg yolk (a-Binary image of G component, b-Median filtering, c-Dislodge small points in foreground, d-Fill egg yolk region).

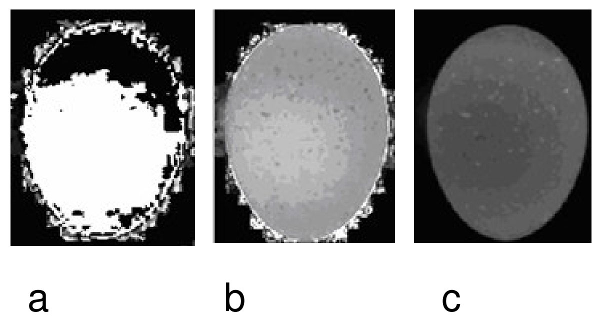


Figure 6. Gray scale image of HIS (a-H, b-S, c-I).

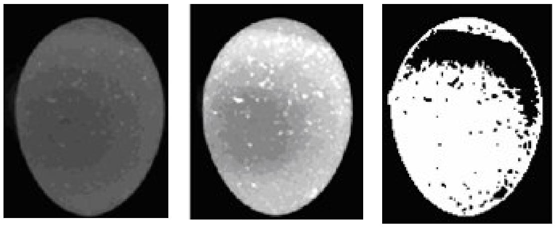
image, so a filter could be selected for image denoising. Medium filtering is a non-linear method of noise reduction. Figure 5-b was the result of medium filtering for the egg yolk image using a 5 x 5 template.

There were still some stray points around the yolk in image. Dislodge those small points in foreground through opening operation (Figure 5-c). Some pores still existed in yolk region after filtering, which would bring large error when calculating yolk's area. Thus, it was necessary to fill egg yolk region to obtain the full yolk image (Figure 5-d).

Separation of air room: RGB and HSI are two commonly used color models in image processing. In this research the HSI model was selected to deal with the air room according to the former experimental experience. Figure 6 was the gray scale image of H, S, I.

It could be viewed from Figures 6-c and 7-a that the air room of I-component was more obvious than others (H- and S-component), so the gray scale image of I-component was chosen for subsequent processing in this research. The feature of air room was more obvious after adaptive contrast enhancement (Figure 7-b) and image binarization (Figure 7-c).

It is required to extract the characteristic parameters:



a b c

Figure 7. Image processing of I (a-Gray scale image, b-Adaptive contrast enhancement, c- Binary image).

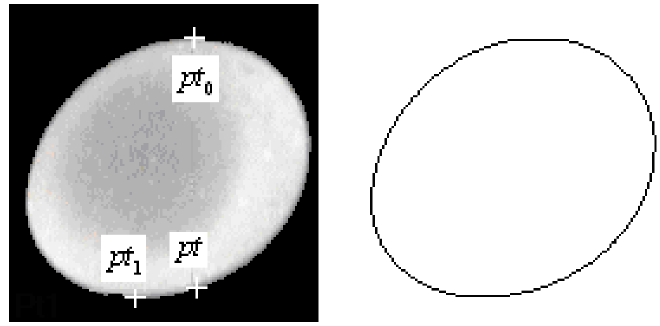


Figure 9. Edge detection by Newton's Dichotomy.

a b c d

Figure 8. Image processing of air room (a-Median filtering, b-Fill egg, c-Dislodge small points in foreground, d-Air room).

the area and height of air room. The following steps are taken in this research: median filtering (Figure 8-a), fill egg (Figure 8-b), dislodge small points in foreground (Figure 8-c) and extract air room (Figure 8-d). From Figure 8-d, the area and height of air room can be easily calculated.

Feature extraction and parameters calculation

The geometric parameters of egg images were calculated by the use of pixel points. However the pixel values show great changes to the small variation of shooting distance. In order to eliminate influence of the external factors and calculate the morphological changes of egg contents accurately, the relative ratios of the pixel area and length of feature regions to that of the whole egg were selected as characteristic parameters.

Calculation of pixel area: Image size is the area of the region enclosed by edge, which is usually calculated by the use of statistical sum of the region's pixels. The image area is closely related to the information of edge points. In this research, Newton's Dichotomy was used to detect the edge between backgrounds and objects rapidly, which has been explained in detail by Zhou et al., (2007). The edge detection procedure can be divided into two steps:

Step 1: Find the highest point and the lowest point of image region using Newton's Dichotomy, marked by Pt_0 and Pt_1 respectively. The two points are used to determine the calculation range of Newton's Dichotomy (see step 2 for details).

Step 2: Take the highest point Pt_0 as the reference point and find its below edge point Pt, whose X coordinate value is same as that of Pt_0. The three points divide the egg region into two parts: area I and area II. Area I is the part of egg region located between two level lines passing through points Pt_0 and Pt respectively, and the area II is the part of egg region located between two level lines passing through points Pt and Pt_1 respectively. Both the two areas are processed by Newton's Dichotomy in order to find and record the edge point of every line in target image. The obtained image edge by Newton's Dichotomy is shown in Figure 9.

It can be considered that the egg image consists of rows horizontal lines arrayed closely. Each line is deter-mined by the right and left edge points. So the egg image's area is equivalent to the sum of every line's length, and the size of egg image depends on position information of the right and left edge points. The difference of X value between the left and right point is the length of each line. The region area can be calculated by formula (1):

$$A = \iint_{(x,y\in object)} dxdy = \sum_{i=pt_0 \cdot y}^{pt_1 \cdot y} (pt_{iR}.x - pt_{iL}.x + 1) \quad (1)$$

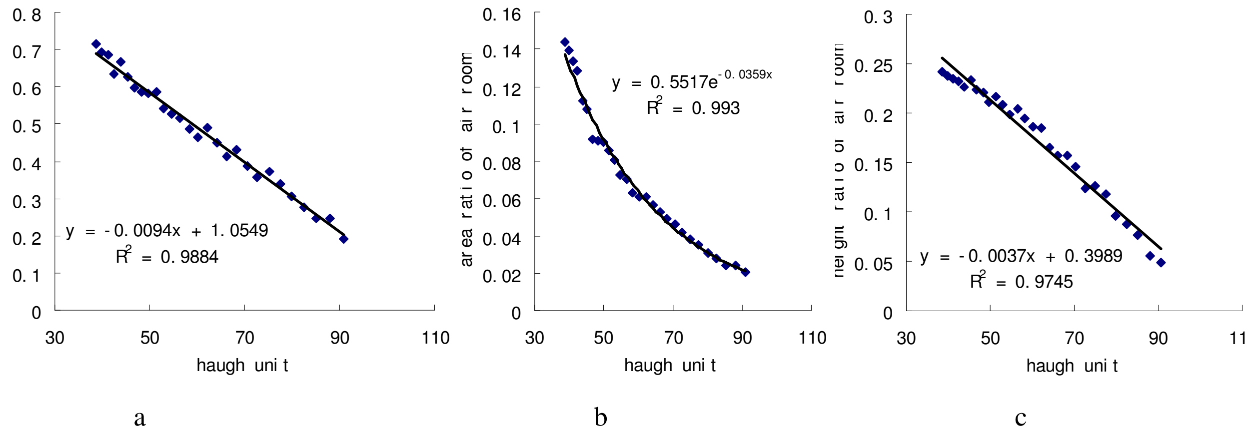


Figure 10. Relationship between ratio and Haugh unit (a-Area ratio of egg yolk and Haugh unit, b-Area ratio of air room and Haugh unit, c-Height ratio of air room and Haugh unit).

Where Pt_{iL} and Pt_{iR} , is the left and right edge point of the *ith* line of feature region respectively, $Pt_{iR}x - Pt_{iL}x + 1$ is the sum of pixels of the *ith* line, Pt_0 and Pt_1 are the highest and lowest point of the feature region respectively. Yolk area and air room area can be calculated by the same method.

Calculation of pixel length: Air room is located in the blunt end of egg, whose height is the length in long axis direction when the image is put upright. The specific algorithm is presented as follows:

Step 1: Calculate the image centroid according to the formula (2):

$$\overline{X} = \frac{M_Y}{M} = \frac{\int_a^b x[f(x) - g(x)]dx}{\int_a^b [f(x) - g(x)]dx} \quad (2)$$

The calculation procedures are as follows:

(1) The x-value was got after scanning any point in a image, then the pixel integral $\int xdA$ was obtained;

(2) The surface density of plane image is regarded as unit 1 and the image mass is calculated by integration which is equal to image area in value;
(3) The quotient of the two values was obtained;
(4) Scan and calculate all pixel points, then sum the feed-back results to calculate the abscissas value of centroid.
Step 2: The long axis passing centroid was defined as the vertical axis. Then scan the long axis from bottom to top using Newton's Dichotomy, from which the longitudinal coordinate values of top and bottom points were obtained. The difference of the above two values is the length of the whole egg.

The height of air room could be calculated by the same method. Finally, the obtained data are shown in Table1.

Data analysis and modeling

In this section, three correction equations between Haugh unit and characteristic parameters were established by classical statistical analysis method.

The relationship between the area ratio of egg yolk and Haugh unit is shown in Figure 10-a. The obtained equation is as follows:

$$y_1 = -0.0094x + 1.0549, R^2 = 0.9884,$$

Where x is Haugh unit, y_1 is the area ratio of egg yolk;

The relationship between the area ratio of air room and Haugh unit is shown in Figure 10-b. The obtained equation is as follows:

$$y_2 = 0.5517e^{-0.0359x}, R^2 = 0.993,$$

Where x is Haugh unit, y_2 is the area ratio of air room;

The relationship between the height ratio of air room and Haugh unit is shown in Figure 10-c. The equation is as follows:

Table 1. Data of characteristic parameters.

Day	Haugh unit	Area ratio of egg yolk	Area ratio of air room	Height ratio of air room
1	90.75	0.19346	0.020579	0.047962
2	87.93	0.24716	0.02425	0.055755
3	85.20	0.246192	0.024192	0.07645
4	82.54	0.274828	0.028158	0.087026
5	79.98	0.305108	0.03096	0.095875
6	77.49	0.340396	0.035239	0.117402
7	75.08	0.372678	0.037851	0.126012
8	72.74	0.355834	0.042105	0.12414
9	70.49	0.387794	0.046224	0.146132
10	68.29	0.432036	0.049491	0.157368
11	66.16	0.412694	0.052934	0.156606
12	64.11	0.448086	0.056604	0.165328
13	62.11	0.491824	0.06128	0.1843
14	60.18	0.465454	0.06096	0.185526
15	58.31	0.485436	0.063301	0.193904
16	56.50	0.51488	0.07014	0.203682
17	54.74	0.528608	0.07286	0.199108
18	53.03	0.541966	0.080697	0.207958
19	51.39	0.5876	0.085994	0.216942
20	49.79	0.581086	0.090122	0.210668
21	48.24	0.5876	0.090679	0.220208
22	46.74	0.598984	0.091988	0.223218
23	45.29	0.6269	0.107594	0.23358
24	43.87	0.6659	0.112238	0.226536
25	42.51	0.63298	0.128394	0.232006
26	41.19	0.6843	0.13379	0.235056
27	39.91	0.693244	0.13918	0.237716
28	38.67	0.714906	0.144192	0.241304

$$y_3 = -0.0037x + 0.3989, R^2 = 0.9745,$$

Where x is Haugh unit, y_3 is the height ratio of air room.

It can be concluded from the equations that: the single variable linear regression equation with high correlation coefficient can be established for the area ratio of egg yolk and Haugh unit, which is the same to the area ratio of air room and Haugh unit. However, the height ratio of air room has high exponential correlation with Haugh unit.

Model test and result analysis

Reliability test: In order to test the detection accuracy of the established models, 100 eggs with clean brown shell were randomly selected from different batch samples with the same variety and experimental procedure. After the egg images were acquired, Haugh unit representing freshness was obtained through experiment. Then the characteristic parameters were calculated and put into the corresponding model. The results of calculation based on model equations were compared with the measured results, which indicated that the accuracy rate of the three models of the area ratio of egg yolk, the area ratio of air room and the height ratio of air room was 93, 94 and 92% respectively.

Analysis of results:

(1) Yolk index of fresh egg is 0.38 - 0.44. And egg whose yolk index is higher than 0.30 can be considered qualified.

The yolk appears as a globular domain when the egg is very fresh. However, because of the moisture loss and the yolk membrane elasticity increase, egg yolk will gradually become flat. One of the expressions reflected from the morphology performance is that the yolk area in horizontal direction will change from small to large. The research results are consistent with the theory. Area ratio of egg yolk gradually increases with the prolongation of time and decrease of Haugh unit. The established linear equation is significant, which can present the relationship between morphological characters and egg freshness.

Main reasons for the misjudgement rate of 7% are as follows: As the objective and subjective factors, there would be errors in experimental measurement of the Haugh unit representing freshness, and these errors also exist in the establishment of the model. As a reference standard, the freshness itself has some errors. In addition, there are differences in the structure of the eggs, for example, the impact of the eggshell thickness to the image quality. These factors were not considered in this article, which could result some misjudgement.

(2) According to the egg quality grading standards set by United States Department of Agriculture (USDA), the edible egg is divided into four different levels. And different levels correspond with different Haugh unit ranges. The height ranges of air room at all levels are as follows: the air room height of egg at AA level(Haugh ≥ 72) is smaller than 7mm; the value at level A(60 ≤ Haugh ≤ 72) is smaller than 9mm; the value at level B,C (Haugh ≤ 60) is less than 1/3 of the whole egg's length. The established relationship between the ratios and the corresponding freshness are consistent with the theory. Main reasons of the misjudgement rate of detection (6 and 8%) are as follows: the air room will fluctuate up and down within several days. What's more, the change of air room has direct relation to the factors such as the stomatal density of egg shell.

(3) In this research the three models were tested respecttively. It should be noted the relationship between morphological characteristics and freshness may change slightly when the experimental samples are different, such as birth time, different hens.

Conclusion

This paper presents a non-destructive method on egg freshness detection by computer image processing. The main findings are summarized as follows:

(1) The egg yolk and air room were not obvious in the original transmitted light images, but which can be clearly viewed by the image processing method proposed in this paper.

(2) Area ratio of egg yolk, area ratio of air room, height ratio of air room, can not only reflect the morphological change of egg contents, but also eliminate impact of the external factors such as subjective or objective factors. These characteristic parameters are very sensitive to the changes of the egg yolk pixel area and the air room height.

(3) Research on image feature parameters of egg yolk and air room, is trying to find an indirect measurement of the freshness. The feature parameters ratios increase gradually with the prolongation of storage time, and the decrease of fresh degree.

(4)The established equations have high detection accuracy, whose accuracy rate is more than 90%. It shows that this method can be used in non-destructive detection of egg freshness.

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