Yolk color measurement using image processing and deep learning

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Abstract. A high yellow yolk color of laying hens is required by customers. As yolk color measurement is determined by visual perception, color score may be expressed differently. The objective of this study was to develop the recognition of yolk color using red green blue (RGB) image and deep learning. The three hundred and fifty-three RGB images were obtained. The rectified linear unit (ReLU) and softmax were used as the activation function. An optimizer was configured with Adam, and categorical crossentropy was used as a loss function. The results showed that the loss had decreased to 0.45 and 0.63, whereas the accuracy had increased and reached 0.80 and 0.76 for training dataset and testing dataset, respectively. For evaluation, the loss value was 0.27 and 0.63, whereas the accuracy value was 0.90 and 0.76 for training dataset and testing dataset, respectively. The average f1-score was 0.76, whereas the highest precision (1.00) was observed in color score 5, 6 and 8. In conclusion, RGB image can be used as an alternative method to classify yolk color score with lower cost of analysis for egg producers in the near future.

1. Introduction
Yolk color is one of the most important parameter of egg quality, which related to market requirements in commercial egg production. In developing countries, customers prefer yolk with containing a high pigment of yellow-orange colors [1]. For yolk measurement, the scale consists of 15 different color stripes ranging from light yellow to dark orange and red according to the Yolk Color Fan\(^\circ\) (Roche) scale [2]. In practical, the yolk color measurement is determined by visual perception, however, the colors might be perceived differently depending on each evaluator [3]. To solve this problem, portable spectrocolorimeter has been developed to measure yolk color as a new rapid method with high accuracy [2]. However, this instrument is very expensive and also needs a cost for maintenance. Alternatively, the content of pigments can be determined by chemical extraction, but this method is still time-consuming, and it is not easy to set up all instruments for monitoring yolk egg at the farm [4].

Computer vision and artificial neural networks (ANN) have been applied to evaluate egg quality [5, 6]. Digital camera and image processing were an alternative method to spectrocolorimeter for color measurement [7, 8]. The red, green and blue (RGB) obtained from digital-image is the main color component, which has been used to determine the quality of apples [9], wheat [10] and potato chips.
[11]. Interestingly, RGB image and ANN were used to monitor the defective eggs [5]. Recently, deep learning such as convolution neural networks (CNN) has been introduced to identify and classified poultry eggs [12] and double-yolked duck egg [13]. To our knowledge, no research was done with deep learning for yolk color measurement. This method will result in a standardization technique with lowering human error by individual visual perception. The digital image also plays a key role in economic advantages in reducing cost of analysis with less time-consuming. Therefore, the objective of this study was to develop the recognition of yolk color using image processing and deep learning.

2. Material and Methods

2.1. Dataset
Twenty laying hens (Lohmann Brown-classic) were individual kept in metabolic cages (40 cm wide × 40 cm deep × 30 cm high), equipped with feeding trough, nipple, and a wire mesh floor. The research unit was an evaporative cooling system (EVAP) with an automated temperature control at 25-28°C. The experimental diets were formulated to meet the nutrient requirement according to strain recommendation (17% protein, 2,725 kcal/kg). The pigment was supplemented to the experimental diet at levels of 0, 30, 60 and 90 g/ton, respectively. At the onset of the experiment, the animals were 55 weeks old and the trial lasted 3 weeks. The three hundred and fifty-three eggs were collected to determine yolk color with the Yolk Color Fan® (Roche) scale. This scale comprises 15 color stripes ranging from very light yellow through orange to red.

2.2. Image acquisition and image processing
The three hundred and fifty-three RGB images of yolk egg were obtained from iPhone 8 with a solution 3024 × 4032 pixels. Images were taken in the mini-photography box (22 cm wide × 24 cm deep × 24 cm high) with high brightness with LED. Images of yolk color were classified by sight of three evaluators, who have been trained to analyze egg quality and yolk color. The yolk image was extracted from an original image (Figure 1), and then resized to 160 × 160 pixels (Figure 2).

![Figure 1. An original yolk image.](image1.png)

![Figure 2. An extracted yolk image.](image2.png)
The histograms of RGB were determined using library OpenCV-Python version 3.2.0.8 (Figure 3). For better performance, all images were normalized to be a range between [-1, 1] as follows: image = (image/127.5) – 1.

![Figure 3. The histogram of red green blue (RGB) image of yolk colors.](image)

In Figure 4, the extracted yolk images were grouped into 11 classes (0-10) ranging from very light yellow (score 5) to dark yellow (score 15). For each class, the extracted yolk images were divided into training dataset and testing dataset at a ratio of 80:20.

2.3. Deep learning model and training
The image augmentation was used by rotating in 90° and flipping in horizontal and vertical position. The sequential model was applied to classified the different scores of yolk color. All images were flattened into one-dimension in input layer. The fully connected neural network was designed in second and third layers with 1024 nodes. The rectified linear unit (ReLU) was also used as the activation function in the second and third layers, while the softmax activation function was used in the last layer with 11 nodes to convert output into a probability distribution. A dropout with a probability of 0.20 was performed after activating in the second and third layers, respectively to avoid overfitting. The epochs of training were 500 with batch size of 64 and learning rate of 0.0001. An optimizer was configured with Adam, and categorical crossentropy was used as a loss function. In addition, an accuracy was included to consider the best fit of the model. The f1-score and confusion matrix were determined using Scikit-learn library in Python programming. Finally, two hundred and eighty-three images of extracted yolk color were used for training, while the remaining seventy images of extracted yolk color were used for testing dataset.

2.4. Birds and Management
The experiment was reviewed and approved by the Animal Care and Use for Scientific Research Committee, Kasetsart University, and care of the animals throughout this experiment was in accordance with the corresponding Ethical Principles for the Use of Animal for Scientific Purposes [14].
3. Results and discussion

The training histories of loss and accuracy were shown in Figure 5. The blue line indicated the results of training dataset, whereas the orange line indicated the results of testing dataset. The loss values had decreased to 0.45 and 0.63 for training dataset and testing dataset, respectively. In opposite, the accuracy had increased and reached 0.80 and 0.76 for training dataset and testing dataset, respectively. With regard to evaluation, the loss value was 0.27 and 0.63, whereas the accuracy value was 0.90 and 0.76 for training dataset and testing dataset, respectively.

Figure 4. The 11 classes (0-10) of yolk egg ranging from very light (score 5) to dark yellow (score 15).
Figure 5. Loss values and accuracy values for training dataset and testing dataset.

The average f1-score was 0.76, whereas f1-score per class was 1.00, 1.00, 0.89, 1.00, 0.57, 0.33, 0.86, 0.74, 0.47, 0.74 and 0.80, ranging from score 5 to 15, respectively. The confusion matrix of yolk color prediction is shown in table 1. The highest precision (1.00) was observed in score 5, 6 and 8, whereas the lowest precision (0.50) was observed in score 10 and 13, and there ranged from 0.67 to 0.82 for other scores. Furthermore, the highest recall (1.00) was observed in score 5, 6, 7, 8 and 15, whereas the lowest recall (0.25) was observed in score 10.

Table 1. The confusion matrix of yolk color prediction

| Color score | Predicted score | Recall |
|-------------|----------------|--------|
| Actual score | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| 5           | 4  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1.00 |
| 6           | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1.00 |
| 7           | 0  | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1.00 |
| 8           | 0  | 0  | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 0  | 1.00 |
| 9           | 0  | 0  | 1  | 0  | 2  | 1  | 0  | 0  | 0  | 0  | 0.50 |
| 10          | 0  | 0  | 0  | 0  | 1  | 1  | 2  | 0  | 0  | 0  | 0.25 |
| 11          | 0  | 0  | 0  | 0  | 0  | 0  | 9  | 1  | 0  | 0  | 0.90 |
| 12          | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 7  | 3  | 0  | 0.70 |
| 13          | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 4  | 4  | 0.44 |
| 14          | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0.77 |
| 15          | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 4  | 1.00 |

The objective of measuring yolk color is to classify the quality by visual perception [3]. However, the color perceived from human eye might be different depending on individual examiner. Alternatively, spectrocolorimeter has been introduced and widely accepted to use for monitoring egg yolk quality [2]. Unfortunately, the instrument is still expensive and it is slow the adoption by producers [7]. In this present study, image processing and deep neural networks showed a better fit model for improving accuracy with reducing error. Likewise, RGB images and ANN showed a high accuracy for determining the defective eggs of dirt stained eggs and crack detection [5]. Furthermore, RGB colors have been succeeded to determine the quality of apples [9] and potato chips [11] as well as to evaluate the senescence rates in spring wheat [10].
4. Conclusion
Our result suggested that image processing can be applied to extract RGB image of yolk color, which was used to develop the model of color recognition. The deep learning is one of machine learning methods based on artificial neural networks that used to train dataset of RGB image for improving accuracy with low error measurement. Therefore, image processing and deep learning is an alternative method used to classify yolk color for egg producers. For further research, the greater data of RGB image of extracted yolk color are also needed to be collect for training dataset and testing dataset. The modified deep learning architecture may improve an accuracy of the model, which may be applied to monitor egg quality in the near future.

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