Predicting yolk and albumen weight using egg weight of quails (Coturnix coturnix japonica) fed diet supplemented with betaine

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Abstract. Betaine as a methyl donor is proven to increase the synthesis of egg components which presence in poultry diet is suspected to modify the composition of the eggs. Eggs are multi-purpose animal product. It is utilized in various ways; either as a whole or separated between its yolk and albumen. For the later purpose, the knowledge about egg composition is essential. This study aimed to build models to predict the yolk and albumen weight using egg weight of quails (Coturnix coturnix japonica) fed diet supplemented with betaine. In total, 239 data obtained from 3 assay diets were subjected to analysis of variance, correlation, regression and cross validation. The assay diets consisted of a basal diet containing 16.5% protein fed without or with supplementation of 0.06 and 0.12% betaine. The supplementation of 0.12% betaine increased egg, yolk and albumen weight (p<0.01). The correlation of egg weight–yolk weight and egg weight–albumen weight ranged between 0.65–0.69 and 0.69–0.79, respectively. The regression models showed high predictability between 92.7–94.5% for yolk weight prediction and 96.0–97.2% for egg weight prediction based on egg weight. Thus, egg weight is a good predictor to predict the yolk and albumen weight of quail eggs.

1. Introduction

Coturnix coturnix japonica quails start to lay eggs at the age of 35–42 days [1] and produce 200–300 eggs in a year with average egg weight of 10 grams [2]. The interior quality of the egg is affected by nutrient content in the diet [3]. The yellow yolk is composed of lipoproteins while albumen composed of proteins. Protein requirements for laying quails according to recommendation of Nutrition Research Council [4] is 20% while Indonesian National Standard recommends 17% protein. Due to high temperature in Indonesia, it is required to adjust protein content in the diet because the too high protein stimulates heat stress, leads to reduces protein synthesis [5]. An alternative to avoid heat stress is feeding low-protein diet and supplementation with feed additive that play a role in protein metabolism, for example betaine.

Betaine donates its methyl group to synthesize various important metabolically substances such as carnitine, creatine and phosphatidylcholine, thus betaine plays a role in energy and protein metabolism [5]. Betaine increases the efficiency of energy and protein utilization, leads to improve egg quality [6]. In addition, betaine supplementation in the diet has been shown to increase yolk and albumen weight in quails [7,8].

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Eggs are multi-purpose animal product. It is utilized in various ways; either as a whole or separated between its yolk and albumen. For the later purpose, the knowledge about egg composition is essential. Yolk and albumen weight are generally determined by breaking the eggs [9]. This method is complicated, takes a lot of time and causes economic losses due to broken eggs [10]. Predictions of yolk and albumen weight with the regression equation using egg weight as predictor allow to measure these variables without breaking the eggs [11]. Several studies have been conducted to determine the correlation between egg weight and yolk weight as well as albumen weight. Kul and Seker [9] showed a positive correlation between egg weight and yolk or albumen weight in quails. However, there is a lack of information on the predictability with cross validation method, particularly in quails received betaine supplementation. Therefore, this study aimed to build models to predict the yolk and albumen weight using egg weight of quails (Coturnix coturnix japonica) supplemented with betaine.

2. Materials and methods

2.1. Experimental design and diet formulation
In total, 225 laying quails (Coturnix coturnix japonica) were distributed to 3 dietary treatments with 5 replicates of 15 quails each. The basal diet was formulated to meet the nutrient requirements of laying quails according to Nutrition Research Council [4] except the protein which was formulated below the standard (16.5%), as presented in Table 1. The other 2 assay diets were obtained by supplementing 0.06 and 0.12% betaine. Betaine supplementation was performed according to the procedure of Ratriyanto et al. [8]. The dietary treatments were given for two periods (2×28 days). The data were collected at last 3 days of the first and second periods, namely days 26, 27 and 28. The eggs were individually weighed and then cracked. The yolk was separated from the albumen using yolk separator. The albumen weight was calculated by reducing the egg weight with the yolk and shell weight [8].

| Nutrients                  | Content |
|----------------------------|---------|
| Metabolizable energy (kcal/kg) | 2,800   |
| Crude protein (%)          | 16.50   |
| Crude fat (%)              | 5.09    |
| Crude fiber (%)            | 4.58    |
| Crude ash (%)              | 5.00    |
| Calcium (%)                | 3.40    |
| Phosphorus (%)             | 0.61    |
| Lysine (%)                 | 1.13    |
| Methionine (%)             | 0.41    |

2.2. Management and analysis of the data
The data used in the analyses included egg, yolk and albumen weight. The data were separated between control (without supplementation) and those supplemented with 0.06 and 0.12% betaine. The data were subjected to analysis of variance, correlation, regression and cross validation. All data analyses were performed using custom scripts of R program [12].

2.2.1. Analyses of variance
Analysis of variance was performed to determine the effect of treatments on egg, yolk and albumen weight. If the treatments showed significant effect, it was continued with Duncans test [13].

2.2.2. Correlation
Correlation was calculated to determine the relation between egg weight and yolk or albumen weight, and to determine the regression model. The correlation of egg weight–yolk weight and egg weight–albumen weight were calculated according to Ott et al. [14] as follows:
\[ R_{EW,YA} = \frac{\text{Cov}(EW,YA)}{\sigma_{BT} \sigma_{YA}} \]

\[ \text{cov}(EW,YA) = \frac{\sum^n_i (EW,YA)}{n} \]

\[ \sigma = \sqrt{\frac{\sigma^2}{n}} \]

\[ \sigma^2 = \frac{\sum^n_i (x-\mu)^2}{n} \]

Where: \( R_{EW,YA} \) = correlation of egg weight–yolk weight or egg weight–albumen weight; \( \text{Cov}(EW,YA) \) = covariant between egg weight–yolk weight or egg weight–albumen weight; \( \sigma_{BT} \) = standard deviation of egg weight; \( \sigma_{YA} \) = standard deviation of yolk or albumen weight; \( n \) = number of data; \( x \) = data; \( \mu \) = average.

2.2.3. Regression
Regression model was built to predict yolk and albumen weight using egg weight data according to Gujarati [15]:

\[ y_i = \alpha + \beta x_i \]

Where: \( Y_i \) = response (yolk weight, albumen weight); \( \alpha \) = intercept; \( \beta \) = slope of independent variable; \( x_i \) = egg weight.

2.2.4. Cross validation
The model built was compared to the predictor's ability by using the accuracy of the prediction model. Predictability was obtained by applying the cross validation method, which determine the performance of a prediction model [11] by using most of the data to create a prediction model and save the rest for validation process [16]. Cross validation applied a regression formula obtained in another data to measure the accuracy of the formula to predict another set of data. The cross validation was tested by taking a certain amount of data (test set) and the remaining data are training set (Figure 1).

Figure 1 shows the data 2–10 were the training set that will be used to create a regression equation, then to predict the test set of the data 1. The actual value of the test set data and predicted value based on the regression was then compared to determine the predictability of the regression equation.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 1= test set, 2-10 = training set |

Figure 1. Illustration of cross-validation method.

3. Results and discussion

3.1. Actual weight of the egg, yolk and albumen
Average weight of the egg of all treatments ranged from 8.77 to 9.35 grams (Table 2), which were categorized normal [1]. Yolk and albumen weight in this study are also in the normal range between
2.50–2.74 and 5.37–5.74, respectively. Supplementation of betaine enhanced the egg weight associated with enhanced in yolk and albumen weight. Betaine has been shown to improves nutrient digestion and involved in protein and energy metabolism, led to improvement in egg weight [8]. According to Horhoruw et al. [17] yolk and albumen weight increased as egg weight increased. Yolk composed mainly of lipids while albumen composed of protein, thus involvement of betaine in the metabolism increase the synthesis of yolk and albumen precursors. In this study, each variable (egg, yolk and albumen weight) was affected by betaine supplementation, thus further analyses were performed separately based on the treatment.

Table 2. Description of data.

| Variables       | Treatments   | Total Data | Min. | Max. | Mean±SD         |
|-----------------|--------------|------------|------|------|-----------------|
| Egg weight      | Control      | 80         | 7.63 | 10.38| 8.77 ± 0.55a   |
|                 | Betaine 0.06%| 79         | 7.78 | 9.97 | 8.99 ± 0.52b   |
|                 | Betaine 0.12%| 80         | 8.50 | 10.32| 9.35 ± 0.48a   |
| p value         |              |            | < 0.01|
| Yolk weight     | Control      | 80         | 1.76 | 3.47 | 2.50 ±0.32b    |
|                 | Betaine 0.06%| 79         | 2.13 | 3.23 | 2.55 ±0.26b    |
|                 | Betaine 0.12%| 80         | 2.21 | 3.27 | 2.74 ±0.25a    |
| p value         |              |            | < 0.01|
| Albumen weight  | Control      | 80         | 4.38 | 6.41 | 5.37 ±0.38a    |
|                 | Betaine 0.06%| 79         | 4.68 | 6.53 | 5.53 ±0.43ab   |
|                 | Betaine 0.12%| 80         | 5.00 | 6.50 | 5.73 ±0.34a    |
| p value         |              |            | < 0.01|

<sup>a,b</sup> Different superscript in the same column and variable indicated significant difference (p < 0.01).

3.2. Correlation of egg weight–yolk weight and egg weight–albumen weight

Egg weight is a good predictor for some characteristics of egg quality such as yolk and albumen weight [9]. Kul and Seker [9] showed that quails egg weight had a positive correlation with yolk and albumen weight. Predicting the interior quality of the egg using egg weight data is considered easier and without breaking the egg.

There were positive correlations of egg weight–yolk weight and egg weight–albumen weight (Table 3). Correlations of egg weight–yolk weight are classified as moderate correlation (0.3–0.7) while correlations of egg weight–albumen weight are classified as high correlation with the correlation value above 0.7 [18]. Control treatment and supplementation of 0.12% betaine showed highest correlation of egg weight–yolk weight while and supplementation of 0.12% betaine showed highest correlation of egg weight–albumen weight. This result was in accordance with previous studies which observed positive correlation of weight–yolk weight and egg weight–albumen weight in quails and chickens [9,19].

Table 3. Correlation of egg weight–yolk weight and egg weight–albumen weight.

| Treatments   | Egg Weight–Yolk Weight | Egg Weight–Albumen Weight |
|--------------|------------------------|---------------------------|
| Control      | 0.69                   | 0.69                      |
| Betaine 0.06%| 0.65                   | 0.76                      |
| Betaine 0.12%| 0.69                   | 0.79                      |

3.3. Linear regression model and cross validation

The model built in this study was simple linear regression. The regression used dependent variable (y), that is yolk weight or albumen weight and independent variable (x), that is egg weight. Since there were 3 treatments in each variable, 6 regression models were built in this study (Table 4).

The R² measures the capability of the model in explaining variations in the dependent variable [15]. R² ranged between 0 and 1, with the higher value indicating the better the independent variable in providing all the information needed to predict the dependent variable. All the 6 models were then subjected to K–fold cross validation resulting the predicted values of yolk and albumen weight. The
prediction accuracy were obtained by comparing the actual values with the prediction values [11] as presented in Table 5. Regression models had predictability ranged between 92.7–94.5% for yolk weight and 96–97.2% for albumen weight. The highest predictability for both yolk and albumen weight obtained by the supplementation with 0.12% betaine treatment. The predictability of all treatments was above 90%, thus its classified as very high accuracy.

4. Conclusion
Linear regression model with egg weight as a predictor was considered as good model for predicting yolk and albumen weight in quails fed diet supplemented with betaine. All models for predicting yolk and albumen weight generated very high predictability. Thus, egg weight is a good predictor to predict the yolk and albumen weight of quail eggs.

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