Employing logistic model to predict the egg production of quails receiving digestibility enhancer supplementation

A Ratriyanto¹,²*, S Prastowo¹,², N Widyas¹, C Huda¹, A Masykur² and L A Pradista²

¹Department of Animal Science, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia
²Master Program of Animal Science, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia

Corresponding author: ratriyanto@staff.uns.ac.id

Abstract. This study aimed to predict the egg production of quails supplemented with a combination of betaine and silica+. Three hundred and fifty laying quails were divided into two dietary treatments and seven replicates of 25 quails. The treatments consisted of control (T0), and supplementation with digestibility enhancer mixture consisted of 0.12% betaine and 200 ppm silica+ (T1). Egg production data were collected for three periods of 28 days, and they were subjected to T-test. The data were plotted to obtain the egg production curve. A logistic regression model was employed to identify the trend of the egg production pattern. The T1 groups produced more eggs than T0 groups (P<0.05), which attributed to the higher egg production during period II and III (P<0.01). The egg production curves indicated that production rose sharply soon after the beginning of lay. The T1 groups had a higher peak production than T0 (76.43% vs 69.20%). Furthermore, production rate was 0.17 and 0.18 and prediction accuracy was 97% and 98% for T0 and T1, respectively. Thus, the logistic model proved to be employed to analyse the biological impact of egg production in quails with a high prediction accuracy.

1. Introduction
Female quail (Coturnix coturnix japonica) start the production phase at about 45 days of age, with egg production reaching 250–300 eggs per year [1]. Egg production in quail is strongly influenced by several factors such as feed, climate, health, and genetics [2]. One of the efforts to optimize it can be done by modifying the nutrient content of the diet, such as by the supplementation of betaine and silica+, which function as digestibility enhancer feed additives to optimize the nutrient digestion and absorption [3].

Betaine acts as a methyl donor in the transmethylation reactions to form important substances such as carnitine, creatine, phosphatidylcholine, and epinephrine [4]. Betaine also acts as an organic osmolyte for epithelial cells and the microflora of the digestive tract [5]. Furthermore, the addition of silica+ in the diet increases the efficiency of the diet and reduces the conversion of ammonium gas (NH₄⁺) to NH₃, leads to reducing stress due to ammonia evaporation [6].

Evaluation of the egg production performance in quail can be known accurately by using a nonlinear mathematical model [7]. The application of this nonlinear model to predict the production of quail eggs given a combination of betaine and silica+ supplementation in diet has never been done...
previously. Based on the above description, this study discovered the application of nonlinear models to predict the egg production pattern of quail given a combination of betaine and silica+ supplementation in the diet.

2. Materials and methods

2.1. Experimental design and diet
A total of 350 quails was distributed into two different diets: control (T0) and control + 0.12% betaine and 200 ppm silica+ (T1). Each treatment was repeated 7 times consisting of 25 quail per replication. The nutrient content of experimental diets is presented in Table 1. Egg production data were collected for 3 periods (3×28 days) and started from 42 days of age.

| Nutrients                | T0    | T1    |
|--------------------------|-------|-------|
| Metabolisable energy (kcal/kg) | 2800  | 2795  |
| Crude protein (%)        | 20.00 | 19.9  |
| Calcium (%)              | 3.35  | 3.35  |
| Phosphorus (%)           | 0.46  | 0.46  |

2.2. Data management and analysis
The data collected are used to display the egg production curve. Furthermore, to compare the effect of the treatment, the data were subjected to T-test. The data analyses was performed using a custom script in the R program [8].

2.2.1. Logistic regression model. In the egg production curve, there are fluctuations caused by uncontrollable factors. To obtain the ideal sigmoid curve for egg production, it can be done by utilizing a non-linear mathematical model. We used a logistic regression model to identify egg production patterns through the egg production curve with the following equation:

\[ Y_t = \frac{\alpha}{1 + \beta \exp[kt]} \]

where:
- \( Y_t \) = production at time-\( t \)
- \( \alpha \) = peak production
- \( \beta \) = carrying capacity
- \( k \) = production rate
- \( t \) = time of production

3. Results and discussion

3.1. Treatments comparison
Egg production of quail from two different diets were compared. The comparison of the results can be seen in Table 2. The result showed that T1 groups produced more eggs than T0 groups (\( P<0.05 \)), which attributed to the higher egg production during period II and III (\( P<0.01 \)). It was found that T1 had 4.26% higher egg production than T0 (\( P<0.05 \)). Egg production began to show a significant difference (\( P<0.05 \)) starting from 2nd period or 7th week.

A positive response to the combination of betaine and silica+ supplementation indicated by an increase in egg production (Figure 1). Betaine as a methyl donor plays an important role in protein and energy metabolism in the transmethylation process [9–11], as a substitution for the role of methionine [10] and organic osmolyte [12] in assisting the growth and survival of intestinal cells and microbes leading to optimal nutrient absorption. Betaine supplementation in the diet increased weekly
quail egg production between 9.4-16.3% [1]. Also, silica+ is silicon dioxide which can accelerate biochemical processes in the digestive tract [13]. It is hypothesized that the combination of betaine and silica+ supplementation optimized the nutrient absorption and increased the egg production.

### Table 2. Effect of two different diets on quail egg production

| Treatments | Min (%) | Max (%) | Mean±SD | P value² |
|------------|---------|---------|---------|----------|
| 1st Period |         |         |         |          |
| T0         | 0.00    | 78.26   | 28.35±22.08 | 0.59     |
| T1         | 0.00    | 91.67   | 29.61±24.49 |          |
| 2nd Period |         |         |         |          |
| T0         | 36.36   | 90.91   | 65.79±10.73 | 2.94 x 10⁻¹¹ |
| T1         | 44.00   | 96.00   | 72.94±9.90  |          |
| 3rd Period |         |         |         |          |
| T0         | 40.91   | 95.45   | 71.88±10.20 | 3.48 x 10⁻⁹ |
| T1         | 50      | 100     | 77.98±9.74  |          |
| 1st-3rd Period |   |         |         |          |
| T0         | 0.00    | 95.45   | 54.96±24.62 | 0.01     |
| T1         | 0.00    | 100     | 59.22±27.12 |          |

¹ standard deviation
² Significant if P<0.05

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3.2. Logistic regression model

Logistic regression was employed to predict the trend from actual egg production in both control (Figure 2) and a combination of betaine and silica+ supplementation (Figure 3).

The egg production curves indicated that the production rose sharply soon after the beginning of lay. The pattern and parameter of logistic regressions illustrated the increase in egg production to reach peak production were similar for the two treatments. The T1 groups had a higher peak production than T0 (76.43% vs 69.20%). The increase in peak production following the combination of betaine and silica+ supplementation according to the model was also fit with the actual data. The instability of egg production at control (T0) in reaching peak production was indicated by a lower production rate. Furthermore, production rate was 0.17 and 0.18 and prediction accuracy was 97% and 98% for T0 and T1, respectively. The accuracy of logistic regression models for T0 and T1 were 0.98 and 0.97, respectively, which categorized as high coefficient of determination (R²) (≥0.60) [14].
Finally, our findings confirmed that the logistic model proved to be employed to analyse the biological impact of egg production in quails with a high prediction accuracy.

![Graph of egg production over days for control group]

**Figure 2.** Non linear curve of control group

![Graph of egg production over days for supplemented group]

**Figure 3.** Non linear curve supplemented group

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