Non-linear prediction model for egg production of quails the tropics with methionine supplementation

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Abstract. This study aimed to predict the egg production of quails receiving methionine supplementation. Two hundred and four quails were divided into two treatment diets, and six replicates with 17 quails each. The treatment diets were control (P0) and 0.12% methionine supplementation (P1). Egg production data were collected for eleven weeks, and a T-test was performed. Next, the data was plotted to get the actual egg production curve. We used a logistic regression model to predict the egg production pattern and calculated the model's fitness with the coefficient of determination (R²). The results showed that methionine supplementation increased egg production by 9.43% (p<0.01). Based on the actual production curve, the increase in initial production to peak production of P1 was slower than P0, but P1 had a higher egg production than P0. The logistic model predicts that peak production of P1 was higher than P0 (62.74% vs. 56.79%), although the production rate of P1 was lower than P0 (0.21 vs. 0.36). In addition, the accuracy of both P0 and P1 models was 0.88 and 0.92, respectively. Thus, the logistic model can predict quail egg production in the tropics due to diet modification with high accuracy.

1. Introduction
The tropical environment has a relatively high ambient temperature, limiting birds' ability to absorb nutrients in the diet, such as protein [1]. It is necessary to modify the diet for tropical areas with optimal nutritional content, such as through supplementation of feed additives that play a role in protein metabolism, namely the amino acid methionine [2,3].

Methionine is an essential amino acid containing sulfur and has a vital role for poultry as a methyl donor in forming cystine, creatine, and carnitine [4]. Metabolites of the amino acid methionine are used in various fundamental biological processes, including protein deposition and the synthesis of S-adenosyl methionine [3]. Saki et al. [5] reported that increasing the methionine content from 0.24 to 0.34% increased the production of laying hens by 37.71%.

So far, diet modifications in poultry were commonly evaluated using analysis of variance accompanied by post-hoc [6]. The disadvantage of this analysis is that it cannot explain time-dependent variables; thus, the information contained in this study has not been explored. Another evaluation that can overcome this disadvantage is using a non-linear mathematical model [7,8]. This model can provide
predictions of egg production with high accuracy [8–12]. Currently, there is no information on the application of non-linear models to predict egg production in quail supplemented with methionine. Therefore, this study aimed to predict the egg production of quails receiving methionine supplementation.

2. Materials and methods

2.1. Experimental design and diets
A total of 204 Japanese quail were divided into two dietary treatments and six replicates, resulting in twelve experimental units. Each experimental unit contained 17 quails. The two treatment diets were a basal diet as control (P0) and a basal diet supplemented with 0.12% methionine (P1). The nutrient composition of the basal diet is presented in Table 1.

Table 1. Nutrient contents of basal diet

| Nutrients                  | Content |
|----------------------------|---------|
| Metabolizable energy (kcal/kg) | 2,800   |
| Crude protein (%)          | 18.00   |
| Calcium (%)                | 3.40    |
| Available phosphorus (%)   | 0.50    |
| Lysine (%)                 | 1.02    |
| Methionine (%)             | 0.40    |

Egg production data was collected for eleven weeks consisting of three weeks adaptation period (from 40 days old) and eight weeks of treatment (from 62 days old).

2.2. Data analysis
A T-test was applied to determine the effect of treatment on egg production. Then, the data was plotted to get the actual egg production curve. In addition, we used a non-linear logistic regression model to predict egg production [13]. The fitness of the prediction model was determined based on the coefficient of determination (R²). The equation for the logistic regression prediction model was as follows:

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

where:
\[ Y_t \] = production at time-\( t \)
\[ \alpha \] = peak production
\[ \beta \] = carrying capacity
\[ k \] = production rate
\[ t \] = time of production
All data analysis uses the custom script program R [14].

3. Results and discussion

3.1. Treatment comparison
The result of the T-test of quail egg production in this study is shown in Table 2. In the adaptation period (weeks 1-3), P0 produced more eggs than P1 (p<0.01). After that, during the treatment period (weeks 4-11), egg production of P1 was 9.43% higher than P0 (p<0.01).
Table 2. T-test results of quail egg production during the study.

| Treatment | Period | Amount of Data (week) | Minimum (%) | Maximum (%) | Mean (%) ± SD | p Value |
|-----------|--------|-----------------------|-------------|-------------|--------------|---------|
| P0        | Adaptation | 3                     | 0           | 84.62       | 31.55±23.53  | < 0.01  |
| P1        | Adaptation | 3                     | 0           | 70.59       | 24.51±18.99  |         |
| P0        | Treatment  | 8                     | 26.67       | 100.00      | 56.23±15.27  | < 0.01  |
| P1        | Treatment  | 8                     | 23.53       | 100.00      | 61.53±15.75  |         |
| P0        | Whole     | 11                    | 0           | 100.00      | 49.50 ± 20.99| 0.19    |
| P1        | Whole     | 11                    | 0           | 100.00      | 51.43 ±23.46 |         |

P0 basal diet as control; P1 basal diet with 0.12 methionine supplementation; SD standard deviation

Figure 1. Actual egg production curve

Based on the actual egg production curve, there was an increase in egg production until peak production has reached, then remained relatively constant until the end of the study (Figure 1). These results are in line with those reported by Narinc et al. [15], in which quails start laying eggs when they reach sexual maturity, then quickly reach peak production and decline over time. The different egg production patterns were shown by P0 and P1. P0 got peak production faster at week four by 63.20%, and then egg production decreased until week eleven. Although the increase in egg production of P1 was slower than that of P0, at the sixth week until the end of the observation, P1 had a more constant and higher egg production. The decrease in egg production both P0 and P1 occurred at week 7, but P1 was able to produce higher and more constant egg production to increase in the following week.

Methionine supplementation to quail diets optimized egg production in this study. Methionine plays a vital role through the transmethylation mechanism by donating its methyl group to increase the protein synthesis process [2], which directly impacts egg production. In addition, methionine supplementation was able to optimize follicular development in ovarian performance. This finding agreed with Bunchasak and Silapasorn [16], who reported that methionine supplementation 0.26 - 0.44 in the diet of laying hens could increase ovarian weight and egg production. Methionine is also beneficial to the immune system under various catabolic conditions that directly affect protein synthesis [17,18].

3.2. Non-linear prediction model
The results of the logistic regression analysis are presented in Table 3. Peak production is the highest average production during the laying period; thus, higher average egg production is expected to result in higher peak production. The predicted result was in line with the actual egg production in Table 2.
Quail receiving methionine supplementation produced a higher mean and predicted peak egg production.

The speed of both increasing and decreasing egg production represents the production rate [19]. The production rate of P1 has a lower value than P0; this indicates a more stable rate of increase and decrease in egg production. According to the actual egg production curve, P1 was slower to reach peak production but resulted in a more stable egg production pattern than P0.

**Table 3.** Logistic regression parameters and fitness of model

| Treatment | α     | β     | k    | R²  |
|-----------|-------|-------|------|-----|
| P0        | 56.79 | 44.36 | 0.36 | 0.88|
| P1        | 62.75 | 18.51 | 0.21 | 0.92|

P0: basal diet as control, P1: basal diet with 0.12 methionine supplementation, α: peak production (%), β: carrying capacity, k: production rate, R²: coefficient of determination

Furthermore, Figure 2 shows the predictive curve of egg production in control. At the beginning of egg production, the prediction line increases rapidly until the highest point is reached on the 20th day, then remains constant until the 77th day. In contrast to Figure 3, the prediction curve for egg production shows that the prediction line at the beginning of egg production increases slowly, and the highest point is reached on day 30, then remains constant until the 77th day. The actual egg production points at P0 tend to spread and move away from the prediction line, while at P1, the actual egg production points tend to clump together and approach the prediction line.

The logistic regression prediction model has been widely used to predict the production of quail eggs that received a modified diet with high accuracy [8,11,12]. The logistic regression prediction model produces a high accuracy value for P0 and P1, namely 0.88 and 0.92, respectively. Cason and Britton [9] and Anang et al. [19] explained that logistic regression has high accuracy in presenting the prediction of the egg production curve. Savegnago et al. [20] explained that the logistic regression model could provide parameter estimations with important biological interpretations for the poultry, such as peak egg production, egg production persistency, rate of decline in egg production after peak, age of spawning, and age of sexual maturity.

**4. Conclusion**

This study confirms that the logistic model can predict quail egg production in the tropics due to diet modification with high accuracy.

**References**

[1] Masykur A, Prastowo S, Widyas N and Ratriyanto A 2021 *IOP Conference Series: Earth and Environmental Science* **637** 012018

[2] Metzler-Zebel B U, Eklund M and Mosenthin R 2009 *Worlds. Poul. Sci. J.* **65** 419–42

[3] Ratriyanto A, Mosenthin R, Bauer E and Eklund M 2009 *Asian-Australasian J. Anim. Sci.* **22**
1461–76

[4] Eklund M, Bauer E, Wamatu J and Mosenthin R 2005 Nutr. Res. Rev. 18 31–48
[5] Saki A A, Naseri Harsini R, Tabatabaei M M, Zamani P and Haghigh M 2012 Rev. Bras. Cienc. Avic. 14 209–16
[6] Steel R G D, Torrie J H and Dickey D A 1996 Principles and Procedures of Statistics: A Biometrical Approach (New York: McGraw-Hill)
[7] Suparyanto A and Prasetyo L H 2004 J. Ilmu Ternak dan Vet. (Indonesian J. Anim. Vet. Sci. 9 17–25
[8] Ratriyanto A, Prastowo S, Widyas N, Huda C, Masykur A and Pradista L A 2021 IOP Conference Series: Earth and Environmental Science 637 012073
[9] Cason J A and Britton W M 1988 Poulttry Sci. 67 213–8
[10] Anang A, Indrijani H and Sundara T A 2007 J. Ilmu Ternak 7 6–11
[11] Ratriyanto A, Nuhriawangsa A M P, Masykur A, Prastowo S and Widyas N 2018 AIP Conference Proceedings 2014 020011
[12] Widyas N, Nugroho T, Hidayat B F, Masykur A, Prastowo S and Ratriyanto A 2019 IOP Conf. Ser. Mater. Sci. Eng. 633 012020
[13] Narinc D, Uckardes F and Aslan E 2014 Worlds. Poult. Sci. J. 70 817–28
[14] R Core Team 2019 R: A Language and Environment for Statistical Computing (Vienna: R Foundation for Statistical Computing)
[15] Narine D, Karaman E, Aksoy T and Firat M Z 2013 J Poult. Sci. 92 1676–82
[16] Bunchasak C and Silapasorn T 2005 Int. J. Poult. Sci. 5 301–8
[17] Tsiagbe V, Cook M, Harper A and Sunde M 1987 Poult. Sci. 66 1138–46
[18] Bunchasak C 2009 J. Poult. Sci. 46 169–79
[19] Anang A, Indrijani H and Sujana E 2017 J. Indones. Trop. Anim. Agric. 42 66