Fitness of logistics model for predicting quails egg production reared in a tropical environment with dietary betaine supplementation

A Masykur¹, A N Azizah², N Widyas², S Prastowo¹,³ and A Ratriyanto¹,³,∗

¹Master Program of Animal Science, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami 36A Surakarta 57126, Indonesia
²Department of Animal Science, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami 36A Surakarta 57126, Indonesia
³Center for Biotechnology and Biodiversity Research and Development, Universitas Sebelas Maret, Surakarta, Indonesia

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

Abstract. Betaine is a methyl group donor and organic osmolyte, optimizing quail's performance, particularly in a tropical environment. This study determined the fitness of the logistic model to predict the quail egg production with dietary betaine supplementation. Two hundred and four quails were divided into two dietary treatments, and six replicates with 17 quails each. The treatment diets were control (CTR) and 0.12% betaine supplementation (BET). Egg production data were collected for eleven weeks, and a T-test was performed. Next, the data is plotted to get the actual egg production curve. The fit of the logistic model is calculated according to the coefficient of determination (R²). Quail that received betaine supplementation produced more eggs than control (P<0.05). The actual egg production curve shows the effect of betaine supplementation seen after the fourth week. The logistic model predicts CTR to reach peak production faster than BET but to have lower peak production than BET (56.63% vs. 63.56%). Prediction of egg production both CTR and BET showed high accuracy with a relatively high R² (0.88; CTR and 0.87; BET). Thus, the logistic model accurately predicted quails egg production reared in a tropical environment with betaine supplementation.

1. Introduction

Tropical environments have relatively high ambient temperatures, which adversely affect the physiology and performance of poultry [1,2]. Physiological responses caused by high environmental temperatures, for example, suppressed immune responses and changes in electrolyte balance and osmotic pressure of body cells [3,4]. In addition, high environmental temperatures can reduce blood flow to the digestive tract and ovaries, thereby reducing nutrient absorption and performance of laying birds [5].

The presence of betaine as a feed additive is expected to alleviate the adverse effects caused by the tropical environment on livestock performance. Betaine is a digestibility enhancer capable of stabilizing the intestinal cell structure and enabling optimal digestion and absorption of nutrients [6,7]. Ratriyanto et al. [8] reported that betaine could increase nutrient digestibility in quail placed under high ambient temperatures. In addition, betaine releases its methyl group through the transmethylation process to
synthesize important metabolic substances such as carnitine, creatine, phosphatidylcholine, and epinephrine which are essential in protein and energy metabolism [9].

Performance evaluation needs to be done by paying attention to time-dependent variables, for example, by applying a nonlinear regression model. The logistic regression model has been known to predict the production of quail eggs that received a modified diet with high accuracy [10–12]. Thus, this study aimed to determine the suitability of the logistic model to predict the egg production of quail receiving betaine supplementation in the diet.

2. Materials and methods

2.1. Experimental design and diets

A total of 204 Japanese quail was divided into two diet treatments and six replications, resulting in twelve experimental units. Each experimental unit contained 17 quails. The two treatment diets were a basal diet as control (CTR) and a basal diet supplemented with 0.12% betaine (BET). The nutrient composition of the basal diet is presented in Table 1. Hen day production data was collected for 11 weeks consisting of an adaptation period (1st-3rd week) since the quail was 40 days old and the treatment period (4th-11th week) since the quail was 62 days old.

Table 1. Nutrient contents of basal diet.

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

2.2. Data analysis

The T-test was conducted to determine the difference in the average egg production. Next, the egg production data is plotted to get the actual egg production curve. Logistic regression is used to predict egg production and displays a predictive curve for egg production [13] with the 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, and \( t \) = time of production.

The fitness of the prediction model [14] is determined based on the coefficient of determination (R^2) with the equation:

\[ R^2 = 1 - \frac{\text{SSE}}{\text{SST}_c} \]

where SS = sum squared errors and SSTc = corrected total sum of square.

All data analyzes were performed using the custom scripts in R (R Core Team).

3. Results and discussion

3.1. Treatment comparison

Table 2 shows the mean and the results of the T-test for egg production, both CTR and BET. In the adaptation period, egg production of both CTR and BET was relatively the same \((p>0.05)\). Differences occurred in the treatment period, and BET produced more eggs than CTR. Overall, for 11 weeks, BET egg production increased by 4.1% than CTR \((p<0.05)\).
Table 2. Mean of quail egg production during the study.

| Treatment | Period       | Amount of data (week) | Minimum (%) | Maximum (%) | Mean (%) ± SD | p Value |
|-----------|--------------|-----------------------|-------------|-------------|---------------|---------|
| CTR       | Adaptation   | 3                     | 0           | 84.31       | 31.54±23.51   | 0.17    |
| BET       | Adaptation   | 3                     | 0           | 70.59       | 27.80±20.22   |         |
| CTR       | Treatment    | 8                     | 25.00       | 100.00      | 56.23±15.27   | <0.05   |
| BET       | Treatment    | 8                     | 18.75       | 100.00      | 63.26±14.33   |         |
| CTR       | Whole        | 11                    | 0           | 100.00      | 49.49±20.99   | <0.05   |
| BET       | Whole        | 11                    | 0           | 100.00      | 53.59±22.58   |         |

CTR= basal diet as control, BET= basal diet with 0.12 betaine supplementation, SD= standard deviation

Based on the actual egg production curve shown in Figure 1, there was a rapid increase in production from the first egg-laying to peak production in all treatments. The CTR's egg production pattern describes a faster peak production than BET at the 4th week, reaching 62.75%. Meanwhile, in BET, peak production is achieved at the 11th week, reaching 69.50%. Especially at week seven, there was a decrease in production in all treatments, but BET was able to show a higher production than CTR and more constant to increase further in the following week.

![Figure 1. Actual egg production curve.](image)

Egg production is determined by the number of eggs in one clutch (number of eggs in successive days) and the period between clutches when oviposition does not occur (laying eggs). The number of eggs in the clutch is influenced by the circadian cycle synchronizing between the oviduct rhythm and the resting period of laying eggs [15,16]. Genetic factors play an important role in egg production patterns, but this can still be modified by environmental factors such as nutrition in the diet [17]. The high production of BET represents a better metabolic rate than CTR. Betaine as a digestibility enhancer can optimize digestion and absorption of nutrients [5–7], optimizing quail performance. In addition, betaine, which also acts as a methyl donor, contributes significantly to increasing the protein synthesis process [18] through the transmethylation mechanism [19,20].

Betaine also stimulates the anterior pituitary to secrete follicle-stimulating and luteinizing hormones, which promote follicular growth and ovulation to increase egg production, respectively [21–23]. In line with this study, Ezzat et al. [22] reported that a diet with 0.1% betaine supplementation enhanced egg production by 6.7% and was in line with other studies conducted on laying hens [21,23,24] as well as in quail [5,8,25].
3.2. Logistic regression model

The results of the logistic regression analysis are presented in Table 3. The peak production of BET was higher than CTR. Peak production is the highest average during the egg-laying period; thus, higher average egg production will result in higher peak production [16]. In addition, based on the production rate in Table 3, CTR is predicted to reach peak production faster than BET because it has a higher production rate than BET (0.35 vs. 0.26). The peak production and the resulting production rate are in line with the actual egg production yields in Table 2.

| Treatment | $\alpha$  | $\beta$  | $k$  | $R^2$  |
|-----------|-----------|-----------|------|--------|
| CTR       | 56.63     | 41.52     | 0.35 | 0.88   |
| BET       | 63.56     | 28.63     | 0.26 | 0.87   |

CTR = basal diet as control, BET = basal diet with 0.12 betaine supplementation, $\alpha$ = peak production (%), $\beta$ = carrying capacity, $k$ = production rate, $R^2$ = coefficient of determination.

In addition, we visualized the logistic regression analysis results into the predictive curves of egg production for CTR and BET in Figures 2 and 3. Figure 2 clarifies that CTR rises faster and reaches peak production after producing the first egg than BET. However, CTR egg production variation was higher than BET, as evidenced by the actual egg production points in Figure 2, which tended to be more spread out and away from the prediction line than BET production in Figure 3.

Figure 2. The logistic model curve of the control group. Figure 3. The logistic model curve of the betaine group.

The logistic model showed a high coefficient of determination, both CTR and BET, 0.88 and 0.87 respectively. The suitability of the relationship between the independent and dependent variables can be seen through the coefficient of determination. This study added information about applying logistics models in modeling egg production and quail growth that received modified diets. Previously, logistic regression has been used to predict the production of quail eggs that received a modified diet with high accuracy [10–12].

4. Conclusion

Based on the results of this study, the logistic model accurately predicts the egg production of quail reared in a tropical environment with betaine supplementation.

References

[1] El-Kholy M S, El-Hindawy M M, Alagawany M, Abd El-Hack M E and El-Sayed S A E G A E H 2017 Biol. Trace Elem. Res. 179 148–57
[2] Alagawany M, Farag M R, Abd El-Hack M E and Patra A 2017 Worlds. Poult. Sci. J. 73 747–56
[3] Farghly M F A, Alagawany M and Abd El-Hack M E 2018 Br. Poult. Sci. 59 205–10
[4] Lara L J and Rostagno M H 2013 Animals 3 356–69
[5] Ratriyanto A and Prastowo S 2019 J. Therm. Biol. 83 80–6
[6] Attia Y A, Abd El-Hamid E A El, Ahmed A A, Marfat A B, Mohammed A A-H, Osman K, Kazim S and Baha M A-S 2016 Springerplus 5 1–12
[7] Eklund M, Bauer E, Wamatu J and Mosenthin R 2005 *Nutr. Res. Rev.* **18** 31–48
[8] Ratriyanto A, Indreswari R and Nuhriawangsa A M P 2017 *Rev. Bras. Cienc. Avic.* **19** 445–54
[9] Kidd M T, Ferket P R and Garlich J D 1997 *Worlds. Poult. Sci. J.* **53** 125–39
[10] Ratriyanto A, Prastowo S, Widyas N, Huda C, Masykur A and Pradista L A 2021 *IOP Conference Series: Earth and Environmental Science* **637** 012073
[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] Narinc D, Karaman E, Aksoy T and Firat M Z 2013 *I Poult. Sci.* **92** 1676–82
[15] Sadeghi R, Pakdel A and Shahrbabak M M 2013 *World Appl. Sci. J.* **24** 463–6
[16] Ratriyanto A 2018 *Caraka Tani J. Sustain. Agric.* **33** 1–7
[17] Pavlidis H O, Price S E and Siegel P B 2002 *J. Appl. Poult. Res.* **11** 304–7
[18] Apicella J M, Lee E C, Bailey B L, Saenz C, Anderson J M, Craig S A S, Kraemer W J, Volek J S and Maresh C M 2013 *Eur. J. Appl. Physiol.* **113** 793–802
[19] Ratriyanto A, Mosenthin R, Bauer E and Eklund M 2009 *Asian-Australasian J. Anim. Sci.* **22** 1461–76
[20] Metzler-Zebeli B U, Eklund M and Mosenthin R 2009 *Worlds. Poult. Sci. J.* **65** 419–42
[21] Zou X 2002 *Chinese J. Anim. Sci.* **38** 7–8
[22] Ezzat W, Shoeib M S, Mousa S M M, Bealish A M A and Ibrahim Z A 2011 *Egypt. Poult. Sci.* **31** 521–37
[23] Gudev D, Popova S, Ralcheva, Yanchev I, Moneva P, Petkov E, Ignatova M, Popova-Ralcheva S, Yanchev I, Moneva P, Petkov E and Ignatova M 2011 *Bulg. J. Agric. Sci.* **17** 859–66
[24] Park J H, Kang C W and Ryu K S 2006 *Korean J. Poult. Sci.* **33** 323–8
[25] Ratriyanto A, Indreswari, R. Nuhriawangsa A and Haryanti A 2015 *Proc. The 6th International Seminar on Tropical Animal Production* ed Noviandi C T (Yogyakarta: Faculty of Animal Science, Universitas Gagaj Mada) pp 118–22