Egg production trajectories of quails fed moderate energy and protein levels supplemented with digestibility enhancer

A Ratriyanto1,2, F Rosyidi1, S Prastowo1,2 and N Widyas1

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

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

Abstract. Betaine is proven as a digestibility enhancer that improves egg production. This study investigated the egg production trajectory of quails receiving betaine supplementation. The experimental population comprised of 204 quails (Coturnix coturnix japonica) which were allotted to two treatments and six replicates with 17 quails each. The quails were given a basal diet containing 2,700 kcal/kg of metabolizable energy and 18% crude protein, without (Control) and with 0.12% betaine supplementation (Betaine). Egg production were collected from adaptation (age 42-62) and treatment period (age 63-118), and they were subjected to T-test. The data were plotted to obtain the egg production trajectory. A logistic regression model was employed to see the trend of the egg production patterns. There was no significant difference in egg production during adaptation period. Furthermore, during treatment period, the egg production enhanced (p<0.01) following betaine supplementation (59.54±13.11% vs 63.72±13.52%). This finding was confirmed by egg production trajectory curves. Results from logistic regression showed that the trend for both treatment groups were similar with slightly different fitness. Coefficient determination (R2) for both groups were 0.96 and 0.95, respectively. Betaine supplementation was able to improve quail egg production; however, the trend of trajectory was similar from that without supplementation.

1. Introduction

Japanese quails have a high sexual precocity, in which the egg production starts with the age of sexual maturity at about 42 days [1]. Egg production rapidly reaches the level of peak production, following a linear trend after a while and gradually decreases over time [2]. It has been reported that annual egg numbers in quails ranged between 250 and 300 [3]. Egg production trajectory is genetically programmed, but it may be modified by environmental factors such as nutrition [4,5]. In a region with high environmental temperature, such as in the tropics, feeding with high content of protein and energy in the diet would not have a positive impact on improving the productivity, but rather reduce the performance of poultry due to the high metabolic heat production and undigested nutrients [6]. Thus, a precise feed formulation with appropriate crude protein and metabolizable energy level is required. This condition provides an opportunity to adjust the nutrient content to the hot climate regions to produce optimal performance [7].

Dietary supplementation with feed additive may improve productive performance in laying quails. Betaine (trimethyl glycine) is a natural feed additive acts as a methyl group donor in protein and
energy metabolisms and as an organic osmolyte [8,9]. As an osmolyte, betaine stabilizes intestinal cells and supports microbial growth which subsequently improves the nutrient digestibility [5,8]. However, animal feedstuffs commonly contain a low level of betaine, thus, supplementation appears essential for enhancing poultry performance [10]. Previous studies showed that dietary betaine supplementation to the diet enhanced the nutrient digestibility in laying hens [9,11] and laying quails [12,13], associated with increased in egg production [9,11–13]. Furthermore, improvement in peak production has also been observed in quails receiving betaine supplementation [14].

Egg production both in laying hens and quails follow the specific trajectory curve. Deviation from the trajectory can indicate anomalies, thus the information on egg production trajectory is very useful for control and evaluation mechanism [15–18]. Several studies have been performed on modeling egg production trajectory curves in laying hens, but only few have been done in quails [3]. Furthermore, there is no study on the comparison of fit of different egg production models in quails receiving betaine supplementation. The objective of this paper is to observe the egg production trajectory of quails fed diet supplemented with betaine and to measure fitness of the regression model.

2. Materials and methods

2.1. Experimental design and diet formulation

The experimental population comprised of 204 female laying quails (Coturnix coturnix japonica) aged 25 days originated from a quail breeding farm to ensure the homogeneity of the strain and age. The birds were randomly allotted into two diets and six replicates with 17 quails each. The birds were housed in colony battery cages with the same size, namely 70 cm length, 50 cm width and 30 cm height.

During pre-laying period, the birds were fed starter diet, while during laying period the birds were fed layer diet. The basal diet for laying phase was formulated based on corn and soybean meal to contain 18% crude protein and 2,700 kcal/kg metabolizable energy (Table 1). The assay diet was obtained by supplementing 0.12% betaine to the basal diet at the expense of corn, as previously done by Ratriyanto et al. [19]. During the adaptation period (day 42-62) the birds were fed a basal diet, while during the treatment period (day 63-118) the birds were fed either basal diet without betaine supplementation (Control) or with betaine supplementation (Betaine). The diets were given twice a day, at 07.00h and 13.30h, each with the same proportion.

| Nutrient            | Content |
|---------------------|---------|
| Metabolizable energy (kcal/kg) | 2700    |
| Crude protein (%)   | 18.03   |
| Calcium (%)         | 3.40    |
| Phosphorus (%)      | 0.50    |
| Lysine (%)          | 1.01    |
| Methionine (%)      | 0.40    |

2.2. Data collection and analyses

The actual egg production data was visualized into a trend line plot. The idealized trajectory curve, which is identical with actual eggs production trajectory curve, can be approached by utilizing
non-linear mathematical models. A logistic regression was employed to build the hypothesized production trajectory with the following formula:

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

Where: \( Y_t \) = production at time \( t \), \( \alpha \) = peak of production, \( \beta \) = carrying capacity, \( k_t \) = production rate, \( t \) = time of production

The goodness of fit of the models were then assessed through the coefficient of determination parameter \( R^2 \) [2]. In addition, all data analyses were performed using custom scripts of R program [20].

3. Results and discussion

3.1. Comparison of experimental diets effect on egg production

The daily egg productions of Control and Betaine groups were compared (Table 2). The comparison results showed that during adaptation period the egg production indicated no significant difference between two treatments. During this period, all groups of quails generated similar egg production since they received the basal diet. Furthermore, at the onset of laying period, the egg production fluctuates as indicated by the high standard deviation. The rate of egg production changes over time, and can be represented in terms of a production trajectory curve [21].

| Diets             | Observation days | Egg Production (%) | P value |
|-------------------|------------------|--------------------|---------|
|                   |                  | Min    | Max    | Mean ± SD        |         |
| **Adaptation period** |                  |        |        |                  |         |
| Control           | 21               | 0.00   | 64.71  | 29.41 ± 19.60    | 0.24    |
| Betaine           | 21               | 0.00   | 76.47  | 26.35 ± 22.75    |         |
| **Treatment period** |                  |        |        |                  |         |
| Control           | 56               | 23.53  | 93.33  | 59.54 ± 13.11    | <0.01   |
| Betaine           | 56               | 29.41  | 93.75  | 63.72 ± 13.52    |         |
| **Whole period**  |                  |        |        |                  |         |
| Control           | 77               | 0.00   | 93.33  | 51.74 ± 19.70    | 0.12    |
| Betaine           | 77               | 0.00   | 93.75  | 53.92 ± 23.06    |         |

Betaine supplementation enhanced the egg production during the experimental period (P<0.01). It was observed that average egg production during this period was 59.54 ± 13.11% and 63.72 ± 13.52 for Control and Betaine group, respectively. The improvement of egg production observed in this study was in agreement with that in previous observations [12,13]. The results from t-test in Table 2 were supported by the eggs production trajectory in Figure 1. Although the egg productions were fluctuating among days, but the trajectory for both diets were similar. Egg production trajectory curves describe the relationship between the number of eggs and time of the laying period [2]. During the treatment period, supplementation of betaine enhanced average egg production compared with those without supplementation. The egg production trajectories indicated that production rapidly reached 50% soon after the onset of lay. Then, egg production rose sharply and reached the peak production.

The mode of actions of betaine in improving productive performance have been thoroughly investigated [8,9,11,22]. Betaine improves nutrient digestibility and absorption in the small intestine leading to higher nutrient availability, which subsequently improves the egg production [23]. Furthermore, betaine also increases the ovary and reproductive tract size as well as stimulates the secretion of estrogen, progesterone, follicle-stimulating hormone and luteinizing hormone, leading to enhances egg production [9,24].
Figure 1. Actual egg production trajectory of the Control and Betaine groups

3.2. Logistic regression and fitness
Several models can be employed to predict egg production trajectory in poultry [2,3,15]. Non-linear logistic regression was employed to obtain the hypothesized trajectory of egg production for Control and Betaine groups (Figure 2A and B). Logistic regression was applied due to its simplicity and it can interpret and describe the biological data accurately [25].

Figure 2. Non-linear trajectories of Control group (A) and Betaine group (B)
The parameters estimated from logistic regression model were similar for both diets, as indicated by the similar peak production, production rate and carrying capacity, although the fitness was slightly differed (Table 3). Logistic regression models fit with the data as indicated by coefficient determination ($R^2$) for Control and Betaine groups were 0.96 and 0.95, respectively, categorized as high coefficient of determination [26]. Most of the studies on egg production modeling belong to laying hens, although Narinc et al. [3] showed that several models can be applied to predict egg production in Japanese quails. They observed that actual egg production fits with the predicted values using Gamma, McNally, Modified compartmental and Adams-Bell regressions with coefficient of determination between 0.88 and 0.92 [3]. Similarly, a study in laying hens showed that the actual egg production fits with the logistic regression [15].

Table 3. Parameter estimates of the logistic regression model

| Parameters         | Control     | Betaine    |
|-------------------|-------------|------------|
| Peak production   | 59.69       | 59.69      |
| Carrying capacity | 14.20       | 14.20      |
| Production rate   | 0.25        | 0.25       |
| $R^2$             | 0.96        | 0.95       |

4. Conclusion

The birds received betaine supplementation generated higher egg production than the non-supplemented birds. Furthermore, betaine supplementation showed similar egg production trajectory with the control. Logistic regression can be employed to predict the trajectory of quails’ egg production with high accuracy ($R^2 = 0.95-0.96$).

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