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Effect of Cricket Meal (*Gryllus bimaculatus*) on Production and Physical Quality of Japanese Quail Egg

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ABSTRACT

Feed cost contributes 80% of the total cost of production in quails. The utilization of cricket meal as a protein source can be a solution to reduce feed costs. The cricket has a high nutritive value, especially protein content, and is one of potential insects to be used as a source of alternative protein to replace fish meal in animal diet. This study aimed to evaluate the effect of cricket meal on the production and physical quality of japanese quail egg (*Coturnix coturnix japonica*). The experiment used 200 five-week-old female quails with an average body weight of 125.4 g. The completely randomized design (CRD) was employed for the experiments with 5 treatments and 4 replications (10 birds per replication). The dietary treatments were T0: diet without cricket meal, T1: diet containing 2% cricket meal to replace 25% of fish meal, T2: diet containing 4% cricket meal to replace 50% of fish meal, T3: diet containing 6% cricket meal to replace 75% of fish meal, and T4: diet containing 8% cricket meal to replace 100% of fish meal. Results revealed that utilization of cricket meal in the quail ration significantly increased egg production (P<0.05) and positively affected physical quality of quail eggs, such as egg weight, egg white weight, eggshell weight, and yolk score. It can be concluded that cricket meal can partially or fully replace fish meal in the diet of layer quails.

***Keywords:** cricket meal; egg production; fish meal; quail*

INTRODUCTION

In many parts of the world, Japanese quail is popular in the poultry sector for meat and egg production, and is often consumed as a protein source. Japanese quail has high productivity with capability to lay up to 350 eggs (Hrncar *et al.,* 2014) per year with average egg weight range of 6-16 g/egg (Tserveni-Goussi & Fortomaris, 2011). Quail eggs have higher nutritional value than the other types of egg. They are also rich in minerals such as calcium, phosphorus, and iron (Tolik *et al*., 2014). An important factor of quail production is a good maintenance management, including the availability of feed. Feed availability must be guaranteed in terms of quality, quantity, and continuity (Rahmasari *et al.,* 2014). In the livestock industry, feed is a major cost factor. In fact, feed cost contributes 60%-80% of the total production costs (Abu *et al.,* 2015). The cost of production increases if feed cost and price in the market increase. In Indonesia, the instability of feed price is unavoidable because some of feedstuff such as soybean meal and fish meal as the main protein ingredients are still imported. According to the Indonesia Statistical Information Service, feed industry in Indonesia requires about 100,000-120,000 tons of fish meal per year, and 80,000 tons are fulfilled from imports. One of the solutions to reduce the cost of feed for poultry is by replacing fish meal with edible insect.

Recently, researchers have proposed the utilization of insect as protein sources (Wang *et al*., 2005; Premalatha *et al*., 2011). Insects have been considered as promising alternative feed resources especially as a protein source (Jayanegara *et al.,* 2017). Insect has better protein in terms of quality and quantity than conventional protein sources (Makkar *et al.,* 2014). Insects also contain vitamins and minerals such as calcium and energy for their high-fat contents, making them one of the preferred commodities for food and feed (Van Huis *et al.,* 2013; Sanchez-Muros *et al*., 2014). Food and Agricultural Organization (FAO) has recommended insects as alternative protein sources in animal feed with relatively good amino acid profiles ((Van Huis *et al.,* 2013; Sanchez-Muros *et al.,* 2014). One of the types of insects which can be used as an alternative feed source in quail diet is cricket. In Indonesia, cricket is usually sold in local market as pet feed (Fuah *et al.,* 2015). In fact, cricket has been consumed by human as food in several regions. It belongs to the order *Orthoptera* and family *Gryllidae* (Kvassay, 2014; Van Huis *et al*., 2013). Cricket was reported to contain amino acids as much as 3.68% arginine, 1.94% histidine, 4.79% lysine, 5.52% leucine, 3.09% isoleucine, 1.93% methionine, and 1.01% cystine (Wang *et al*., 2005), 13.5% crude fat (Miech *et al*., 2017), 67.70% crude protein, and 14.6% crude fiber (Jayanegara *et al.*, 2017). Moreover, cricket was also reported to contain 8.7% chitin (Wang *et al.*, 2004). In addition to having a good nutritional content, crickets are potential alternative feed sources in Indonesia because they are readily available.

Crickets have been tested as feed ingredients in bird and fish diets and as milk replacer in goat and sheep diets. With their benefits and potentials, cricket meal has been considered to replace fish meal as the main source of protein in poultry ration. However, data on the use of cricket as feed for quails are still limited. This study presents the evaluation of cricket meal uses in quail diets and its effect on production and physical quality of eggs.

MATERIALS AND METHODS

Experimental Animal and Feed

A total of 200 five-week-old female quails (Japanese Quail) were placed in 20 pens (60 x 60 x 40 cm pen). The quails were randomly divided into 5 treatments with 4 replications. Feed compositions and nutrient contents of treatment diets used in the experiment are presented in Table 1. The experimental diets were formulated to meet the minimum requirements for Japanese quail based on NRC (2004). All quails received feed treatments twice per day and fresh water was available *ad-libitum*. The ambient temperature and humidity in the experimental cages and the mortality rate of the experimental quails were recorded daily.

Preparation of Cricket Meal

This study used female field crickets (*Gryllus bimaculatus*), obtained from cricket farm in North Bekasi, Indonesia. The age of field cricket was 6 weeks. After collecting crickets, the samples were stored in a freezer at -20°C overnight. Next, the samples were thawed under running tap water and rinsed. The entire crickets were oven-dried at 60 °C for 48 h. Further, the dried samples were ground by using a blender, to obtain the cricket powder.

Table 1 Feed compositions and nutrient contents of treatment diets

	Treatments				
	T0	T1	T2	T3	T4
Ingredients					
Maize grain (%)	57.6	57.6	57.6	57.6	57.6
Rice bran (%)	6.2	6.2	6.2	6.2	6.2
CGM (%)	5.2	5.2	5.2	5.2	5.2
Soybean meal (%)	12.0	12	12.0	12.0	12
Fish meal (%)	8.0	6.0	4.0	2.0	0.0
Cricket meal (%)	0.0	2.0	4.0	6.0	8.0
Palm oil (%)	3.0	3.0	3.0	3.0	3.0
DCP (%)	0.99	0.99	0.99	0.99	0.99
$CaCO_3$ (%)	5.85	5.85	5.85	5.85	5.85
NaCl (%)	0.4	0.4	0.4	0.4	0.4
Premix (%)	0.5	0.5	0.5	0.5	0.5
L-Lysine (%)	0.1	0.1	0.1	0.1	0.1
DL-Methionine (%)	0.16	0.16	0.16	0.16	0.16
Total	100.0	100.0	100.0	100.0	100.0
Nutrients					
Gross energy (kcal/kg)	2955.60	2965.58	2975.55	2985.53	2995.51
Crude protein (%)	18.33	18.40	18.47	18.54	18.61
Crude fat (%)	6.71	6.10	6.36	6.61	6.86
Crude fiber (%)	2.68	2.93	3.10	3.28	3.45
Methionine (%)	0.56	0.57	0.54	0.50	0.46
Lysine (%)	1.13	1.00	0.89	0.79	0.68
Cystine (%)	0.30	0.28	0.26	0.23	0.21
Methionine + Cystine (%)	0.86	0.85	0.79	0.73	0.68
Linoleic acid (%)	1.51	1.90	1.90	1.89	1.88
Ca (%)	2.74	2.87	2.74	2.61	2.48
P (%)	0.65	0.58	0.51	0.44	0.37
Na (%)	0.23	0.23	0.22	0.21	0.20
Cl (%)	0.32	0.32	0.31	0.30	0.29

Note: The result from analysis at Indonesian Research Insitute for Animal Production. T0: diet without cricket meal (CM), T1: diet containing 2% CM to replace 25% of FM, T2: diet containing 4% CM to replace 50% of FM, T3: diet containing 6% CM to replace 75% of FM, and T4: diet containing 8% CM to replace 100% of FM.

Experimental Design

The experiment was designed based on the completely randomized design (CRD) principles with 5 dietary treatments and 4 replications (10 birds per replication- per treatment). The treatments were T0: diet without cricket meal, T1: diet containing 2% cricket meal to replace 25% of fish meal, T2: diet containing 4% cricket meal to replace 50% of fish meal, T3: diet containing 6% cricket meal to replace 75% of fish meal, and T4: diet containing 8% cricket meal to replace 100% of fish meal (Table 1).

Parameters and Statistical analysis

The parameters measured in this study were egg production performance and physical qualities of eggs produced. The production performance parameters consisted of feed consumption, feed conversion rate, egg production, and egg mass production. The egg quality measurements consisted of egg weight, egg white weight, egg white percentage, yolk weight, yolk percentage, eggshell weight, eggshell percentage, eggshell thickness, Haugh unit, and yolk score.

In this experiment, the results were analyzed by calculating the mean ± standard deviation. Data were subjected to analysis of variance (ANOVA). If treatment means indicated a significant effect at 5% probability, the analysis was continued with a post-hoc test by Duncan's multiple range test using SPSS software version 21 procedure (SPSS, 2012).

RESULTS

The inclusion of cricket meal in the diets significantly increased egg production, egg mass production and quality in case of weights of whole egg, egg white, and eggshell, although it decreased eggshell thickness. The averages of feed consumption, feed conversion, egg production, and egg mass production are shown in Table 2. The averages of feed consumption in this experiment were not affected by the treatment diets. There was no significant difference was found between cricket meal treatments and control treatment during the entire experimental period. Table 2 also showed that the increased cricket meal used in the diet slightly decreased feed conversion. However, the difference was not significant as compared to control meal treatments. In contrast, the egg productions and egg mass productions with cricket meal treatment were significantly increased (P<0.05) compared to the control. The order of averages of egg productions from the lowest to the highest were T0 < T2 < T1 < T4 < T3, respectively. The control quails without cricket supplementation had the lowest egg production compared to quails treated with cricket meal. Further, egg mass production is related to egg production and egg weight and is also influenced by protein content and feed quality. Based on the statistical analysis it was found that the averages of egg mass production were affected by cricket meal treatment, andquails fed with T3 diet (diet containing 6% cricket meal to replace 75% of fish meal) had the highest egg mass production than the other treatments.

The physical qualities of eggs in Japanese quails treated with cricket meals are presented in Table 3. During the experimental period, the average of egg weight, egg white weight, eggshell weight, eggshell thickness, and yolk score were significantly different (either higher or lower) between the control and cricket meal treatments (P<0.05). In this study, quails fed diets with cricket meal treatments produced higher egg weights than control quails, and the differences were significant. The average egg weight in quails in the T4 group was the highest among all treatments, although the average feed consumption was not significantly different. The averages weight of egg white in this experiment were affected by the treatment diets, and the differences were found between control quail group and quails treated with cricket meal. The weight of egg white in the control group that received fishmeal was significantly lower than that of quails that received the diet containing the largest amount of cricket meal.

The eggshell is the outer-layer of egg that protect the membrane. In this study, the average weight of eggshell in the T4 group was higher than in the control group, and the differences were statistically significant (P<0.05). Meanwhile, quails treated with the cricket meal had significantly lower averages of eggshell thickness compared to the control group without cricket meal treatment (T0 group). Furthermore, egg yolk color score in this study was increased by utilizing cricket meal in the diet. Quails in the T4 group (fed diet containing 8% cricket meal to replace 100% of fish meal) showed the highest score of egg-yolk color among all treatments. In this study, the averages scores of egg yolk color were significantly (P<0.05) different among treatments.

Table 2. The average of feed consumption, feed conversion, egg production, and egg mass production of laying quail during 8 weeks of treatment

Variables	Treatments				
	T0	T1	T2	T3	T4
Feed consumption (g/quail/d)	18.05± 1.60	18.72±1.78	20.77± 2.41	19.43± 1.84	19.27± 0.84
Feed conversion	4.64± 1.14	3.58±0.34	4.62± 0.85	3.40± 0.17	3.45± 0.60
Egg production (%)	35.48± 6.16^{b}	47.39±3.45^{a}	41.96± 9.73^{ab}	51.73± 6.70^{a}	49.12± 7.23^{a}
Egg mass (g/b)	225.87±44.07^{b}	293.23±4.08^{ab}	256.23±40.41^{ab}	319.75±16.95^{a}	319.38±48.56^{a}

Note: T0: diet without cricket meal (CM), T1: diet containing 2% CM to replace 25% of FM, T2: diet containing 4% CM to replace 50% of FM, T3: diet containing 6% CM to replace 75% of FM, and T4: diet containing 8% CM to replace 100% of FM. Means in the same row with different superscripts differ significantly (P<0.05).

Table 3. The average of physical quality egg of laying quail during 8 weeks of treatment

Variables	Treatments				
	T0	T1	T2	T3	T4
Egg weight (g)	8.85± 0.17[b]	9.10±0.22[b]	9.27±0.27[ab]	9.23±0.31[ab]	9.63±0.31[a]
Egg white weight (g)	4.21± 0.46[b]	4.77±0.55[a]	5.08±0.70[a]	5.01±0.67[a]	5.23±1.12[a]
Egg white percentage (%)	44.94± 7.98	49.79±3.36	52.92±5.72	51.86±4.23	50.53±8.18
Yolk weight (g)	2.95± 0.52	3.19±0.50	3.28±0.60	3.31±0.60	3.34±0.78
Yolk percentage (%)	35.78±15.06	33.20±3.05	34.10±4.34	34.16±3.96	32.17±5.63
Eggshell weight (g)	1.02± 0.07[b]	1.07±0.13[b]	1.26±0.16[ab]	1.11±0.10[ab]	1.35±0.09[a]
Eggshell percentage (%)	11.41± 1.14	11.85±1.16	13.12±1.33	10.86±0.49	13.20±0.39
Eggshell thickness (mm)	0.20± 0.01[a]	0.18±0.00[b]	0.16±0.01[b]	0.18±0.03[b]	0.16±0.01[b]
Haugh unit	87.39± 4.54	87.49±2.40	87.79±1.72	85.15±0.87	85.94±1.18
Yolk score	4.81± 0.19[b]	5.17±0.21[ab]	5.61±0.26[a]	5.42±0.17[a]	5.36±0.52[a]

Note: T0: diet without cricket meal (CM), T1: diet containing 2% CM to replace 25% of FM, T2: diet containing 4% CM to replace 50% of FM, T3: diet containing 6% CM to replace 75% of FM, and T4: diet containing 8% CM to replace 100% of FM. Means in the same row with different superscripts differ significantly (P<0.05).

DISCUSSION

Cricket meal is a material potentially used as an alternative source of protein in animal diet. Protein is one of the most important criteria for normal animal growth and reproduction. Cricket meal contains 55.41% crude protein and good essential amino acids content. In this study, the utilization of cricket meal in quail diet did not affect feed consumption and feed conversion. Feed consumption is an indicator to assess the palatability of feed ingredients. The results of this study indicated that cricket meal was acceptable to be consumed by quails, with the averages (consumption) values obtained were higher than the control treatment. According to Dewi & Setiohadi (2010), feed consumption is easily influenced by several factors such as feed quality, feed quantity, palatability, as well as age and size of bird. Feed conversion is also an indicator of an animal's ability to efficiently use ration to produce meat and eggs (Hilmi *et al.*, 2015). Low feed conversion values indicate good levels of efficiency. The utilization of cricket meal did not affect feed efficiency. Makund (2006) reported that the highest feed conversion value in quail was 3.34. Feed conversion was influenced by several factors such as egg production, egg weight, nutritional content of rations, and ration palatability (Leeson & Summers, 2005; Campbell *et al.*, 2009).

Cricket meal treatment significantly increased egg production during the study. These results indicate that cricket meal in quail diet are able to meet the nutrient adequacy required for quails. Brand *et al*. (2003) reported that the main factors for egg production are the amount of feed consumption and nutrient content in the feed consumed. Leeson & Summers (2005) reported that egg production is also affected by strain, age, consumption of rations and of water, and also consumption of minerals and protein. Complete nutritional content in cricket meal such as protein and amino acids are considered as a trigger in egg production. Protein contents, especially amino acids, influence the component of immune system (Abbasi *et al.*, 2014), and is related to the health of quail's intestine. Besides, chitin content in cricket may be useful in restoring the compositional balance of gut microbiome and improving colon function (Neyrinck *et al.*, 2011; Brownawell *et al.*, 2012). Chitin cannot be degraded and absorbed in the small intestine but can be fermented in the large intestine by microbes, acting as a prebiotic (Bovera *et al.*, 2015). This condition indicates that a healthy quail provides a better productivity.

Egg mass production is closely related to egg production and egg weight. Egg mass production is also influenced by quality and protein content, thus high and low egg mass are affected by these factors. Ricardo *et al.* (2015) reported that cricket contains amino acid such as arginine, proline, valine, methionine, tyrosine, leucine, and phenylalanine. Cricket also contains fatty acid such as palmitic acid, oleic acid, linoleic acid, and linolenic acid (Carolyne *et al.*, 2017). Mousavi *et al.* (2013) report that proper protein and amino acid contents in the ration provide the optimal productivity.

The egg weight of quails fed diet containing 8% cricket meal to replace all fish meal (T4) was significantly higher compared to the other treatments. According to Tserveni-Goussi & Fortomaris (2011), the range of averages egg weight is 6-16 g. Campbell *et al.* (2009) reported that the difference in the weight of eggs produced could be affected by age, size of bird, environmental temperature, and nutrients contents in the ration. Protein and amino acid contents in cricket meal are the reasons of the differing egg weight among treatments, especially when compared to control treatment. Leeson & Summers (2005) reported that amino acid contents, especially lysine and methionine, are major factors in determining egg weight. Jayanegara *et al.* (2017) reported that cricket contained 6.59% lysine and 1.88% methionine. Cricket meal can also improve the weight of egg white. The major constituents of egg white are water and protein, followed by the carbohydrates existing in free form, usually as glucose (Wu, 2014). The differences in the weight of egg white among dietary treatments are in line with the different egg weights in different treatments. A study reported by Zita *et al*. (2013) stated that egg white weight was also influenced by the egg weight.

The egg-yolk color plays an important role in perception of food (Bovskova *et al.*, 2014). The egg-yolk color is an important factor to determine the quality of egg. Many costumers also prefer golden-yellow to pale-yellow colors. Esfahani-Mashhour *et al.* (2009) reported that customer tastes are influenced by the characteristic quality of yolk color. The average egg yolk scores in this study showed that the utilization of cricket meal significantly increased the score of yolk color variable. Yolk color was influenced by xanthophylls (one of two major divisions of the carotenoid group) in diet (Khairani *et al.*, 2016). Xanthophylls give the color characteristic to the egg yolks. The quality of eggshell has an important role in egg production. Shells must be strong enough to prevent failure during packing and transportation (Ketta & Tumova, 2016). The quality of eggshell depends on the weight and size of the egg (Duman *et al.*, 2015). Overall, the weight of eggshell is affected by the cricket meal treatment. The average eggshell weight in this study is similar to a result reported by Rahmasari *et al.* (2014). In this study, cricket meal treatment had significant effect on decreasing eggshell thickness. Hincke *et al.* (2012) reported that eggshell protects and prevents physical damage. Eggshell thickness is related to the length of eggshell formation and is more affected by the genotype (Ketta & Tumova, 2016). Eggshell is influenced by some minerals such as calcium and phosphorus. Calcium is a major component in eggshell (Shen & Chen, 2003). The higher calcium concentration in the diet, the better eggshell quality and eggshell thickness (Leeson & Summers, 2005). The availability of calcium and phosphorus are affected by crude fiber content, and cricket meal treatment has higher crude fiber content compared to the control treatment. This study used whole cricket, which means that it is rich in chitin content. Chitin is a polysaccharide present exclusively in the exoskeleton of arthropods.

CONCLUSION

The total replacement of fish meal by cricket meal in quail diet increased egg production and egg quality (egg weight, egg white weight, and eggshell), but tended to decrease eggshell thickness.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with the other people or organization related to the material discussed in the manuscript.

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