Substitution of fish meal with black soldier fly larvae *(Hermetia illucens)* meal to eggs production and physical quality of quail *(Coturnix coturnix japonica)* eggs

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**Abstract.** This study was aimed to identify the effect of black soldier fly larvae (BSFL) meal addition to the quail *(Coturnix coturnix japonica)* egg production and physical quality. The material used in this study was a 6-week-old female quail totaling 120 birds kept for seven weeks. This study employed an experimental method and a completely randomized design. The addition of BSFL meal consisted of four different treatments with five replications of each treatment, i.e. P0: Ration without addition BSFL meal; P1: 3.18% BSFL meal (6.67% fish meal crude protein); P2: 6.37% BSFL meal (3.34% fish meal crude protein); P3: 9.56% BSFL meal (0% fish meal crude protein). The observed variables were egg production and the physical quality of quail eggs. The results of the study indicated that BSFL meal addition in quail did not significantly affect (P > 0.05) on egg weight, haugh unit, egg yolk index and egg yolk color. Conversely, the addition of BSFL meal significantly affected (P < 0.05) on egg production and eggshell thickness. The egg production of treatment eggs P0 and P1 was significantly higher (P < 0.05) than P2 and P3. The egg production of P0 and P1 was significantly higher (P < 0.05) than P2 and P3. The eggshell thickness of P0, P1 and P2 were significantly higher (P < 0.05) than P3. The addition of BSFL meal at the concentration of 9.56% substituting 100% fish meal in quail feed did not affect negatively the egg weight, haugh unit, yolk index, and yolk color.

1. **Introduction**

The availability of quality feed that is safe for livestock and sufficient throughout the year is an effort to increase the productivity and quality of quails. The price of high-quality protein-source feed ingredients is increasingly expensive due to rising prices of imported raw materials, such as fish meal and meat and bone meal (MBM). This dependence on imports ultimately makes the price of quail feed more expensive. On the other hand, the cost of feed is known to contribute 70-80% of the total production cost. Increasing prices of protein sources and the threat of animal feed security, environmental pressures, human population growth and increasing demand for protein on the market have made animal-based protein prices more expensive [1]. Therefore, the current feed study is aimed at finding alternative sources of protein by utilizing insects. According to [2], protein originating from insects is more economical, environmentally friendly and has an important role naturally. Insects are...
reported to have high feed conversion and can be maintained and mass produced. In addition, insect cultivation can reduce organic waste that has the potential to pollute the environment [3].

Insects are an alternative source of protein that can be used in monogastric animal feed and as a natural feed of poultry [4]. As cold-blooded creatures, insects can convert high feed and relatively short life cycles [5]. Various types of insects have the potential to be used to produce useful biomass, but what has begun to be widely investigated are larvae from Black Soldier Fly (BSF) (*Hermetia illucens*), maggot/house fly larvae (*Musca domestica*) and hongkong caterpillars (*Tenebrio molitor*) [6]. Based on various studies, the crude protein content of BSF larvae ranges from 31.9% to 47.6% [7–9]. BSF larvae also have an amino acid composition that resembles the amino acid composition of soybean meal or fish meal [10].

According to [11] states that the use of BSF larvae meal can replace fish meal up to 13.15% (replacing 100% fish meal) in a quail laying ration. This was confirmed by [12] stating that the use of BSF larvae meal was able to replace fish meal up to 6.75% (replacing 100% fish meal) in quail rations in the starter and finisher phases and resulted in better weight gain.

Based on this potential, research on the use of BSF larvae meal in poultry feed as an alternative source of conventional protein, how much influence the use of BSF larvae protein in replacing fish meal protein on egg production, physical quality of quail eggs.

### 2. Research methods

The material used in this study was six weeks old female quail as many as 120 animals were obtained from breeders in Gowa Regency. Each quail is placed in a 30×35×26 cm³ battery cage made of ram wire. Each enclosure consists of 6 quails, equipped with a feed container, drinking water container and incandescent lamp (60 watts) which are placed outside the cage as lighting the cage, thermohygrometer, slide calipers, glass table, tripod micrometer, roche yolk color fan and digital scales.

The feed ingredients used to prepare the experimental diet consisted of yellow corn, soybean meal, rice bran, coconut cake, fish meal, premix, lysine, methionine, CaCO₃, DCP and BSF larval meal. The composition and composition of quail rations in the study are presented in table 1.

| Type of ration        | Treatment | P0   | P1   | P2   | P3   |
|-----------------------|-----------|------|------|------|------|
| Corn (%)              |           | 46.90| 50.10| 52.50| 52.10|
| Soybean Meal (%)      |           | 12.51| 14.65| 15.60| 16.44|
| Fine Bran (%)         |           | 18.73| 13.80| 12.80| 12.90|
| Coconut Cake          |           | 6.76 | 6.10 | 4.30 | 3.50 |
| Fish Meal (%)         |           | 10.00| 6.67 | 3.33 | 0.00 |
| BSF Larvae Meal (%)   |           | 0.00 | 3.18 | 6.37 | 9.56 |
| Premix (%)            |           | 0.10 | 0.10 | 0.10 | 0.10 |
| L-Lysine (%)          |           | 0.30 | 0.30 | 0.30 | 0.30 |
| DL-Methionine (%)     |           | 0.10 | 0.10 | 0.10 | 0.10 |
| CaCO₃ (%)             |           | 2.00 | 2.00 | 1.20 | 1.20 |
| DCP (%)               |           | 2.60 | 3.00 | 3.40 | 3.80 |
|                       |           | 100  | 100  | 100  | 100  |

This study used a completely randomized design CRD [13] with four treatments and five replications based on the following treatments: P0= Ration without the addition of BSF larvae meal; P1= BSF Larvae meal 3.18% (6.67% fish meal crude protein); P2= BSF Larvae meal 6.37% (3.34% fish meal crude protein); P3= BSF Larvae meal 9.56% (0% fish meal crude protein).
Tabel 2. Nutrition ration based on analysis.

| Type of ration      | Treatment |        |        |        |
|---------------------|-----------|--------|--------|--------|
|                     | P0        | P1     | P2     | P3     |
| Energy Metabolism (kcal/kg) | 2,723.51  | 2,743.67 | 2,786.49 | 2,772.86 |
| Crude protein (%)   | 20.46     | 20.47  | 20.16  | 20.01  |
| Coarse Fiber (%)    | 3.66      | 3.68   | 3.25   | 3.33   |
| Coarse Fat (%)      | 5.97      | 5.80   | 6.20   | 6.47   |
| L-Lysine (%)        | 0.42      | 0.35   | 0.40   | 0.54   |
| DL-Methionine (%)   | 0.45      | 0.46   | 0.45   | 0.43   |
| Phosphor (%)        | 1.14      | 1.03   | 0.96   | 0.95   |
| Calcium (%)         | 3.03      | 2.42   | 1.99   | 1.84   |

Analysis of Feed Chemistry Laboratory at Universitas Hasanuddin Makassar (2019).

2.1. Research implementation

Maintenance is carried out for seven weeks. Feeding and drinking water were done ad libitum. The provision of treatment ration was given two times a day in the morning at 07.00 WITA and in the afternoon at 16.00 WITA. The provision of drinking water is given once a day in the morning at 07.00 WITA. Giving ND vaccine through drinking water during the day, before giving quail vaccine fasted for 4 hours. Every week, food consumption and mortality are recorded. Egg collection and recording is done every day at 17.00 WITA in the afternoon. The eggs are then weighed and counted the number of eggs obtained.

2.2. Research variable

- Egg production: egg production is calculated by dividing the number of eggs produced by the quail population [14]. With the formula egg production (%): Number of eggs (eggs) / Number of quails still alive (tails) \times 100%
- Egg weight: The weight of the egg is weighed using a digital scale unit gram (g)
- Egg yolk: Measure the yolk using the Yolk Color Fan. The egg yolk color score has a 1-15 color standard, the higher the yolk color score, the better the egg quality [15].
- Egg thickness: Measurement of eggshell thickness is done at the blunt end, middle (equator), and the tapered end of the egg is then averaged [16].
- Yolk index: The components used to measure the yolk index are the yolk height and yolk diameter [17]. The values obtained are entered in the formulation as follows egg yolk index: Egg yolk height / Yolk diameter
- The Haugh Unit (HU) value is used to determine the thickness of the egg-based on the logarithmic relationship between albumen height (mm) and egg weight (g). Albumen height (mm) was measured using a tripod micrometer, then calculated using the formula [18].

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HU = 100 \log (H + 7.57 - 1.7W^{0.37})
\]

Note:
HU = Haugh Unit
W = total egg weight (g)
H = high viscous egg white (mm)
3. Results and discussion

Substitution of fish meal with BSF larvae meal significantly \( (P<0.05) \) on egg production and quail egg thickness but no significant effect \( (P>0.05) \) on egg weight, haugh unit egg value, egg yolk index and yolk color eggs (table 3).

| Variable                        | Treatment  | P0         | P1         | P2         | P3         |
|---------------------------------|------------|------------|------------|------------|------------|
| Egg Production (%)              |            | 64.53±8.37a | 66.40±2.72a | 51.13±5.82b | 44.80±2.78b |
| Egg Weight (g)                  |            | 10.70±0.32 | 10.72±0.19 | 10.59±0.46 | 10.58±0.37 |
| Egg Shell Thickness (mm)        |            | 0.202±0.004a | 0.208±0.004a | 0.202±0.004a | 0.192±0.004b |
| Egg Haugh Unit Value            |            | 87.71±0.51 | 88.12±0.39 | 87.87±0.43 | 87.89±0.48 |
| Egg Yolk Index                  |            | 0.45±0.01  | 0.44±0.01  | 0.44±0.01  | 0.44±0.01  |
| Egg Yolk Color                  |            | 7.71±0.46  | 7.60±0.16  | 7.91±0.14  | 8.00±0.61  |

Note: The same superscript in the same line shows no significant difference at the Duncan test level of 5% \( (P<0.05) \).

3.1. Egg production

Based on the results of the analysis of variance showed that BSF larval meal substitution significantly affected \( (P<0.05) \) on quail egg production. This is in line with ration consumption data, P3 treatment with the lowest ration consumption of 18.97 g/head/day, its egg production is lower compared to treatments P0, P1, and P2. Lower ration consumption will cause the consumption of nutrients in the ration also lower [11]. Egg production is generally influenced by strains, age, consumption of rations and drinking water, and consumption of minerals and protein ration [19]. According to [20] low feed consumption and energy consumption during the production phase will result in decreased egg production and mass. The results of this study correlated with the consumption of rations, the higher the administration of BSF larvae that affected the production of quail eggs.

The results of this study are in line with [21] the higher the substitution of BSF larvae meal to replace fish meal will have an impact on decreasing the level of ration consumption in broiler chickens, this is thought to be due to the low palatability of chickens to conventional protein sources from BSF larvae origin. Another cause is thought to be because the color of the rations using BSF larvae is less attractive which gives a dark effect on the ration so that the chicken is less interested in consuming it [22,23]. This is in accordance with [24], the use of BSF larvae substitution up to 100% replacing fish meal has a bad effect on egg production, but the use of BSF larvae meal can be used in replacing meat and bone meal up to 100% if the ration is supplemented with methionine. The use of BSF larvae meal in the ration should be supplemented with methionine because this is the amino acid content of methionine in BSF larvae low [23,25].

3.2. Physical quality of quail eggs

3.2.1 Egg weight. Based on the results of the analysis of variance showed that the substitution of fish meal with BSF larvae meal had no significant effect \( (P>0.05) \) on egg weight (table 2). Egg weighing in this study is in line with [11], stating that the weight of quail eggs using BSF larvae meal substitution ranges between 10.10-10.99 g / item. This shows that the use of BSF larvae substitution up to 9.56% which replaced 100% of fish meal protein in the ration did not affect the weight of the eggs produced.

Factors affecting egg weight include natural patterns of egg and ration production. The natural pattern of egg production is that the eggs produced for the first time are laying small and are getting bigger until the weight of the egg is stable. Quail eggs weigh about 10 g (about 8% of the parent's body
weight) [25], [16] stated that the weight of quail eggs is between 8-10 g. According to [26], egg weight is usually uniform, only in double yolk eggs and other non-uniform eggs. Based on these statements, the weight of quail eggs in this study was normal, giving substitution of BSF larvae meal up to the level of 9.56% replacing 100% of fish meal did not affect egg weight.

3.2.2 Eggshell thickness. Based on the results of the analysis of variance showed that the substitution of fish meal with BSF larvae meal significantly (P<0.05) on the thickness of the quail eggshell. The thickness of the quail eggshell obtained in this study was higher compared to the study of [11] stating that the thickness of the quail eggshell using BSF larvae substitution ranged from 0.158 ± 0.007 to 0.170 ± 0.004 mm. The results of this study experienced a decrease in eggshell thickness in the P3 treatment, this was due to the lower calcium (Ca) content in the P3 treatment ration compared to the P0, P1 and P2 treatments.

The effect of the level of BSF larvae meal is evident, this is due to differences in calcium and phosphorus levels in each treatment ration and BSF larvae meal calcium is lower than fish meal. The thickness of the quail eggshell is influenced by the calcium (Ca) ration content [27].

3.2.3 Haugh unit (HU) value. Based on the results of a variety of analysis showed that the substitution of fish meal with BSF larvae meal did not significantly affect (P> 0.05) on haugh units (HU) of quail eggs. Based on the results of this study, in harmony with [11], stated that the average HU value of quail eggs using BSF larvae substitution ranged from 87.23 to 91.00. The results of this study are still higher than the results of research [28]afir states that the HU value of 70.69-72.36. The HU value did not significantly affect this because it was suspected that the protein content in the ration in each treatment had met the needs of quail.

According to [29] states that the protein content contained in the ration must be in accordance with the needs to obtain optimal HU values. Besides being caused by proteins that have to meet the needs, the value of HU is also determined based on the correlation of albumen height and egg weight. [30] states that AA quality eggs have an HU value of more than 72, A quality is 60-72, B quality is 31-60, and C quality is less than 31. Based on the research results obtained, the HU value of eggs given BSF larvae flour in the ration, which is 87.71 ± 0.89 - 88.12 ± 0.39 and is classified as AA quality.

3.2.4 Egg yolk index. Based on the results of the analysis of variance showed that the substitution of fish meal with BSF larvae meal did not significantly affect (P>0.05) on the yolk index. According to [27], states that the index value of quail yolks which are fed with the crude protein content of 20.01% is 0.422. Egg yolk index according to SNI 01-3926-2008 [31] consists of three levels of quality, namely quality I (0.458-0.521 mm), quality II (0.394-0.457 mm), and quality III (0.330-0.339 mm). The results of this study showed an index of egg yolks, 0.436 to 0.446. When compared with the SNI standard for the yolk index the results of this study are still quite good, which is at the quality II. The yolk index is a comparison between the height of the yolk and its diameter after the yolk is separated from the egg Whites [32].

Protein consumption is one of the factors that affect the thickness of the yolk, the thicker the egg will get heavier, this is in line with the opinion of [20] when eggs are not formed on certain days, protein accumulation occurs so that the availability of protein to form one egg the next day becomes more which in turn produces larger eggs. Other factors that influence the value of the egg yolk index are the age of the egg or duration of storage, storage temperature, and age of the parent that produces Long egg storage time causes diffusion of water from the egg white to the yolk, resulting in enlargement of the yolk and becoming softer due to the egg yolk vitellin membrane being unable to keep the yolk in its place [32].
3.2.5 Egg yolk color. Based on the results of the analysis of variance showed that the substitution of fish meal with BSF larvae meal did not significantly affect (P>0.05) on the color of quail eggs. The results of this study, the color of egg yolk is higher than [11] research ranging from 4.97-5.69. [33] states, if the yolk color reaches a score of 7-8 on the Roche scale, then the eggs will be classified as good quality. The color of the egg yolk does not significantly affect the food ingredients containing carotenoid pigments, especially beta-carotene and xanthophyll pigments, which are relatively similar.

According to [34] stated that feed consumed by livestock influences the color of egg yolks, namely feed ingredients that contain carotenoid pigments, especially beta-carotene and xanthophyll pigments. So we need nutrients that can improve egg yolk color scores. The egg yolk pigment which is physiologically absorbed will be absorbed by the intestinal digestive organs and spread to target organs that need it [35]. The lower egg production in the P3 treatment can be a factor in the higher yolk color score in the treatment compared to other treatments. According to [33] stated that the rate of egg production causes the diversity of egg yolk color when egg production increases, xanthophyll in the ration spreads to many egg yolks so that the color of the yolk decreases and vice versa.

4. Conclusions
Based on the results of data analysis and discussion in this study, it can be concluded that the addition of BSF larvae flour to level 9.56% in quail feed did not have a negative effect on egg weight, haugh unit egg value, yolk index, and yolk color.

References
[1] FAO 2013 Edible Insects: Future Prospects for Food and Feed Security (Rome: Food Agriculture Organization)
[2] Van Huis A 2013 Potential of insects as food and feed in assuring food security Annu. Rev. Entomol. 58 563–83
[3] Li Q, Zheng L, Qiu N, Cai H, Tomberlin J K and Yu Z 2011 Bioconversion of dairy manure by black soldier fly (Diptera: Stratiomyidae) for biodiesel and sugar production Waste Manag. 31 1316–20
[4] Makkar H P S, Tran G, Heuţé V and Ankers P 2014 State of the art on the use of insects as animal feed Anim. Feed Sci. Technol. 197 1–33
[5] Cullere M, Tasoniero G, Giaccone V, Miotti-Scapin R, Claeyss E, De Smet S and Dalle Zotte A 2016 Black soldier fly as dietary protein source for broiler quails: Apparent digestibility, excreta microbial load, feed choice, performance, carcass and meat traits Animal 10 1923–30
[6] Charlton A J, Dickinson M, Wakefield M E, Fitches E, Kenis M, Han R, Zhu F, Kone N, Grant M and Devic E 2015 Exploring the chemical safety of fly larvae as a source of protein for animal feed J. Insects as Food Feed 1 7–16
[7] St-Hilaire S, Cranfill K, McGuire M A, Mosley E E, Tomberlin J K, Newton L, Sealey W, Sheppard C and Irving S 2007 Fish offal recycling by the black soldier fly produces a foodstuff high in omega-3 fatty acids J. World Aquac. Soc. 38 309–13
[8] Diener S, Zurbrügg C, Gutiérrez F R, Nguyen D H, Morel A, Koottatep T and Toekner K 2011 Black soldier fly larvae for organic waste treatment–prospects and constraints. Proceedings of the Waste Safe 2nd International Conference on Solid Waste Management in the Developing Countries (Khulna, Bangladesh)
[9] Kroeckel S, Harjes A-G, Roth I, Katz H, Wuertz S, Susenbeth A and Schulz C 2012 When a turbot catches a fly: Evaluation of a pre-pupae meal of the Black Soldier Fly (Hermetia illucens) as fish meal substitute—Growth performance and chitin degradation in juvenile turbot (Psetta maxima) Aquaculture 364 345–52
[10] Veldkamp T, van Duinkerken G, van Huis A, Lakemond C M M, Ottevanger E, Bosch G and van Boeckel M A J S 2012 Insects as a Sustainable Feed Ingredient in Pig and Poultry Diets - a Feasibility Study (Wageningen (NED): Wageningen UR Livestock Research)
[11] Harlystiarini 2107 Pemanfaatan Tepung Larva Black Soldier Fly (Hermetia illucens) Sebagai
Sumber Protein Pengganti Tepung Ikan pada Pakan Puyuh Petelur (Cortunix cortunix Japonica) (Bogor: Institut Pertanian Bogor)

[12] Teguia A, Awah N J and Puene C 2002 Effects of replacing maize with dried leaves of desmodium spp on the growth performance of broiler chickens Bull. Anim. Heal. Prod. Africa 50 106-14

[13] Gaspersz V 1991 Metode Rancangan Percobaan (Bandung: Armico)

[14] Zahra A A, Sunarti D and Suprijatna D E 2012 Effects of free choice feeding on the egg production performance of Coturnix coturnix japonica Anim. Agric. J. 1 1–11

[15] Muharliem 2010 Meningkatkan kualitas telur melalui penambahan teh hijau dalam pakan ayam petelur J. Ilmu dan Teknol. Has. Ternak 5 32–7

[16] Yuwanta T 2010 Telur dan Kualitas Telur (Yogyakarta: Gadjah Mada University Press)

[17] Sirait C H 1986 Telur dan Pengolahannya (Bogor: Pusat Penelitian dan Pengembangan Peternakan)

[18] Austic R E and Nesheim M C 1990 Poultry Production 4th Edition (Philadelphia London: Lea and Febiger)

[19] Leeson S and Summers J D 2005 Commercial Poultry Nutrition (Nottingham, UK: Nottingham University Press)

[20] Widjastuti T and Kartasudjana R 2006 The effect of restricted feeding and its implication on the performance of Coturnix coturnix japonica at the first production phase J. Indones. Trop. Anim. Agric. 31 162–6

[21] Dengah S P, Umboh J F, Rahasia C A and Kowel Y H S 2015 Pengaruh penggantian tepung ikan dengan tepung maggot (Hermetia illucens) dalam ransum terhadap performans broiler Zootec 36 51–60

[22] Atteh J O and Ologbenla F D 1993 Replacement of fish meal with maggots in broiler diets: effects on performance and nutrient retention Niger. J. Anim. Prod. 20 44–9

[23] Bamgbose A M 1999 Utilization of maggot-meal in cockerel diets Indian J. Anim. Sci. 69 1056-58

[24] Agunbiade J, Adeyemi O, Ashiru O, Awojobi H, Taiwo A A, Oke D B and Adekumnisi A A 2006 Replacement of fishmeal with maggot meal in cassava-meal based layer diet Japanese J. Poult. Sci 44 278–82

[25] Woodard A, Abplanalp H, Wilson and Vohra P 1973 Japanese Quail Husbandry in The Laboratory (California: Departement of Avian Science)

[26] North M O and Bell D D 1992 Commercial Chicken Production Manual (New York, USA: An A Vi Book Published)

[27] Sahara E 2011 Penggunaan kepala udang sebagai sumber pigmen dan kitin dalam pakan ternak J. Agribisnis dan Ind. Peternakan, AGRINAK 1 31–5

[28] Afirzalludin 2016 Pengaruh Penggantian Tepung Ikan dengan Tepung Maggot Black Soldier Fly (Hermetia illucens) terhadap Kualitas Internal Telur Puyuh (Coturnix coturnix Japonica) [Thesis] (Universitas Brawijaya)

[29] Roesdiyanto 2002 Kualitas telur itik tegal yang dipelihara secara intensif denganberbagai tingkat kombinasi metionin-lancang (Atlatna sp.) dalam pakan J. Anim. Prod. 4 77–82

[30] United States Departement of Agriculture (USD) Egg Grading Manual (Washington, DC: Agricultural Handbook)

[31] Badan Standardisasi Nasional 2008 Telur Ayam Konsumsi (Jakarta: Badan Standardisasi Nasional)

[32] Buckle K A, Edwards R A, Fleet G H and Wooto M 1987 Ilmu Pangan (Jakarta: Universitas Indonesia Press)

[33] Amrullah I K 2003 Nutrisi Ayam Petelur (Bogor: Satu Gunungbudi)

[34] Sujana E, Wahyuni S and Burhanuddin H 2006 Efek pemberian ransum yang mengandung tepung daun singkong, daun ubi jalar dan eceng gondok sebagai sumber pigmen karotenoid terhadap kualitas kuning telur itik tegal J. Ilmu Ternak Univ. Padjadjaran 6 53-56
[35] Suprijatna E, Kismiati S and Furi N R 2008 Penampilan produksi dan kualitas telur pada puyuh (Coturnix coturnix japonica) yang memperoleh ransum protein rendah disuplementasi enzim komersial JITAA 33 66–71