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Growth Performance in Laying Ducks Fed Protein Diets Supplemented by Fresh Black Soldier Fly Larva

Aam Gunawan[1]*, Abd. Malik[1], Fitri Noor Hayati[1], Afridolin Sonya Goa[1], Ahmad Junaedi[2], and Dwi Wahyu Candra[2]

[1]*Department of Animal Husbandry, Faculty of Agriculture, Islamic University of Kalimantan Muhammad Arsyad Al Banjari Banjarmasin Jl. Adhyaksa No. 2 Kayu Tangi Banjarmasin Indonesia-70123*
[2]*Dinas Pendidikan, Kabupaten Tanah Laut, Kalimantan Selatan Indonesia-70814*

*Corresponding author's E-mail: aamgunawan@yahoo.com

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ABSTRACT

Live black soldier fly (BSF) maggots serve as an alternative feed for ducks and other poultry, boasting a protein composition similar to fish meal. The current study aimed to evaluate the effect of live BSF maggot supplementation as a protein source on increasing duck daily production, feed conversion ratio, and egg quality. A total of 120 female Alabio ducks aged 7 months were randomly divided into 24 cages with four treatments and six replications. Each cage consisted of five ducks. Performance parameters such as daily egg production, feed conversion ratio, and egg mass production were evaluated, along with the quality of duck eggs, including egg weight, yolk weight, yolk crude protein, and albumen crude protein. The results revealed that protein levels did not significantly affect feed consumption during the laying phase for ducks. However, the comparison of duck day production between treatment groups indicated that ducks receiving lower protein levels (13.43%) exhibited lower production, compared to those with higher protein levels (18.29%). Furthermore, feed protein content had a notable impact on egg weight, yolk weight, and albumen crude protein. The study demonstrated a significant increase in egg yolk weight, while the percentages of egg yolk weight and eggshell weight showed no significant differences. In conclusion, this research suggests that supplementing duck diets with live BSF maggots can enhance egg quality and performance parameters.

Keywords: Black soldier fly, Duck, Egg quality, Maggot, Performance, Source of protein

INTRODUCTION

Between 2014 and 2017, there was a noticeable surge in global duck production. The countries experiencing the most significant increases in duck population during this period were China, Vietnam, Bangladesh, Indonesia, Russia, Myanmar, France, India, and Thailand (Kovitvadhi et al., 2019). Ducks play an important role in Asian countries, especially Indonesia, contributing significantly to the consumption of animal-origin protein, encompassing both meat and eggs (Hutahaean et al., 2022). Ducks exhibit resilience in challenging environments, immunity to diseases, and a capacity to adjust to locally available feed. Additionally, they have a symbiotic production system and are highly profitable (Adzitey and Adzitey, 2011). Feed is a crucial aspect of the livestock industry, accounting for up to 70% of total production expenses (Singh et al., 2009). As a result, it is necessary to explore various options to minimize feed costs. In the case of large-scale duck farms, the practice of utilizing commercial feed, imported feed ingredients, and other supplements is commonplace to reduce production expenses (Ismoyowati et al., 2018). However, it is not economically viable for small-scale duck farmers in rural areas. Therefore, it is necessary to seek alternative protein source feed ingredients that can overcome this problem while providing sustainability for large or small-scale farming businesses (Biasato et al., 2018). Live black soldier fly (BSF) maggot is a cheap protein source that can be easily procured and can be used as an alternative feed ingredient, which can reduce feed costs (El-Kaiaty et al., 2022; Mlaga et al., 2022). Maggot is not only a source of high protein (52.79%) but also contains fat (more than 35%), rich in minerals such as Calcium (5-8%) and

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Phosphor 0.6%-1.5% (Makkar et al., 2014; Herawati et al., 2020). In addition, the use of BSF maggot in feed can provide benefits in terms of nutritional content and the environment. In comparison to traditional protein sources, insect farming proves to be more practical, with lower greenhouse gas and ammonia emissions, contributing to a reduced environmental impact (Makkar et al., 2014; De Marco et al., 2015). According to Gunawan et al. (2022), adding BSF larva feed increases the carcass weight of the duck, making BSF maggot a popular alternative protein source for poultry feed (Gariglio et al., 2021). Furthermore, BSF maggot is an insect with nutrient quality and an environmentally friendly production system (Hanboonsong et al., 2013; Makkar et al., 2014; Sánchez-Muros et al., 2014). The results of research by several researchers have indicated that insects also can be used as a food source of protein, which can contribute to solving food problems for humans and livestock as especially for poultry and various types of birds (Bukkens, 1997; Makkar et al., 2014; De Marco et al., 2015).

Several research findings by different investigators suggest that insects can serve as a valuable protein source, offering a potential solution to food shortages for both humans and livestock, especially for poultry and various types of birds (Bukkens, 1997; Makkar et al., 2014; De Marco et al., 2015). Furthermore, Gunawan et al. (2018) and Gariglio et al. (2019) indicated an increase in carcass weight when ducks were provided with live maggots and supplemented with defatted larva meal from BSF. This is related to the elevated levels of protein, amino acids, minerals, and vitamins found in the BSF (Spranghers et al., 2017). However, data on the benefits or potential of using live maggot substitution as a source of protein to increase the production and quality of duck eggs are still limited. The objective of the research was to explore the effect of supplementation of fresh BSF larva on the growth performance of laying ducks fed low and high-protein diets.

MATERIALS AND METHODS

The present study was performed and approved by the Animal Care and Use Committee of the Faculty of Agriculture. Kalimantan Islamic University with number 007/U.CC/FP/V/23.

Rearing black soldier fly live

As a source of feed protein, this study used live BSF maggot in the prepupal stage (age 2-3 weeks) obtained through cultivation with a mixture of palm kernel cake media, hatchery waste, and bakery factory waste. The BSF maggot breeding was carried out using closed cages made of plastic nets. The enclosure had dimensions of 3 meters in width, 2.5 meters in height, and 5 meters in length. The breeding process began by placing plastic basins containing prepupae inside a closed enclosure made of plastic mesh, with dimensions measuring 3 meters in width, 2.5 meters in height, and 5 meters in length. These prepupae were left undisturbed for 2-3 weeks to allow the maggots to undergo transformation into pupae, eventually developing into BSF flies. Following this phase, the BSF flies mated and laid eggs on the prepared substrate.

After an additional 2-3 weeks, the substrate containing the matured maggots was harvested, employing sunlight for drying purposes. Due to the maggots' sensitivity to light and their tendency to aggregate in one location, they were carefully gathered and weighed, constituting the feed for the ducks. The prepupae phase was harvested twice daily, in the morning and evening, resulting in a total weight of 2.4 kg. Each cage plot received a daily live maggot supplement of 40 g. The nutrient content of BSF maggot is detailed in Table 1.

Experimental period

This research was conducted at the teaching farm and livestock production laboratory within the Faculty of Agriculture at Uniska Banjarmasin, Indonesia. The ambient temperature during the study ranged from 27.5 to 31.5°C, with humidity levels fluctuating between 72% and 84%. A total of 120 female *Alabio* ducks, sourced from breeders with an average weight of 1.75±0.14 kg and aged 7 months, were randomly distributed into 24 cages. Each cage, constructed from bamboo and wire, measured 220 cm x 145 cm and housed 5 ducks. The ducks were procured from the local livestock market in Amuntai District, Inodnesia.

The cage floor was layered with husks and equipped with feed and drinking water facilities. The ducks were provided with a daily feed allowance of 150 g/head, featuring varied protein contents. Drinking water was available ad libitum. The ducks were kept for seven weeks, with one week dedicated to feed adaptation, and no vaccinations were administered during the research. Lighting in the cages was maintained for 24 hours, utilizing 12 hours of sunlight and 12 hours of electric light. The initial production rate at the study's outset was recorded at 43.93%. The details of the ingredients and nutritional formulas employed in the study can be found in Table 2.

Table 1. Nutrient content of dry maggot and fresh black soldier fly

Nutrient	Dry maggot	Fresh maggot
	------------------- (%) -----------------	
Water content	0	68.32
Ash	17.57	5.56
Crude protein	46.15	14.62
Crude fat	22.13	7.01
Nitrogen free Extract	10.97	3.47
Crude fiber	3.19	1.01
Calcium	1.49	0.47
Phosphor	0.85	0.26
Gross energy (Kcal/kg)	4,622	1,464

Table 2. Ingredient and basic formula of nutrition for the research

Ingredient of feed	Basic formula of nutrition	
	Low protein	High protein
	------------------ (%) -------------------	
Concentrate for duck	17.00	17.00
Rice bran	24.10	21.40
Corn	58.90	43.60
Fish meal	0	18.00
Total	100	100
Nutrient content[1]		
Dry matter	93.80	94.16
Ash	8.86	9.73
Crude protein	13.43	18.29
Crude fat	4.32	3.52
Carbohydrate	53.84	49.29
Crude fiber	12.69	16.39
Metabolizable energy (Kcal/kg)	3,079	3,020

[1]Analysis by Building Research and Standardization Industry.

Experimental design

The research design employed a completely randomized design with four treatments and six replications. Treatment P1 involved the supplementation without live maggots (0 g/day) with a low-protein diet (13.43%). In Treatment P2, live maggots were supplemented at 40 g/day alongside a low-protein diet (13.43%). Treatment P3 comprised supplementation without live maggots (0 g/day) with a high-protein diet (18.29%), while Treatment P4 involved the supplementation with live maggots (40 g/day) with a high-protein diet (18.29%). The study aimed to explore the effects of these treatments on the growth performance of laying ducks fed both low and high-protein diets. Each treatment was replicated six times to ensure the statistical robustness of the results, contributing to a comprehensive analysis of the study outcomes.

Measurement of parameters

Performance

Throughout the six weeks of observation, feed consumption was measured weekly. Duck day production was assessed daily for the entire 42-day observation period, calculated by dividing the daily egg production by the number of ducks present in each cage and multiplying the result by 100%. The feed conversion ratio (FCR) was determined by dividing the food consumption by the weight of the eggs produced. Additionally, the egg mass was obtained by multiplying the duck day production by the average egg weight.

Egg quality

The daily weighing of egg weights was conducted individually for each cage. To determine the yolk weight, a random egg sample was selected from each cage, and the yolk weight of the entire egg was calculated by dividing the yolk weight by the egg weight and then multiplying by 100%. The shell weight was obtained by isolating the eggshell and measuring its weight separately. Analysis of the crude protein content in both the yolk and albumen was performed using the Kjeldahl method, following the procedure outlined by Jamal et al. (2020).

Statistical analysis

The observational data underwent analysis of variance, and if the results indicated a significant effect ($p < 0.05$), further testing was conducted using an orthogonal contrast test with SPSS 24 for Windows (George and Mallery, 2016). To discern differences among the treatment groups, contrasts were organized based on contrast components. These components were designated as follows: contrast component 1 involved comparisons between P1, P2 versus P3, P4; contrast component 2 encompassed contrasts between P1, P3 versus P2, P4; and contrast component 3 focused on comparisons between P2 and P3. Statistical significance was set at p values less than 0.05 ($p < 0.05$).

RESULTS

Performance

The impact of different protein levels and live Black Soldier Fly (BSF) supplementation on duck performance, including feed consumption, duck day production, feed conversion ratio (FCR), and egg mass, is detailed in Table 3. The results of the analysis of variance revealed no significant differences ($p > 0.05$) among the treatments in terms of feed consumption and feed conversion ratio for the layer-phase ducks. However, significant effects were observed in duck day production and egg mass. Further examination through the orthogonal contrast test revealed that in contrast component 1 (P1, P2 versus P3, P4), ducks receiving low protein levels (13.43%) exhibited significantly lower duck day production ($p < 0.05$), compared to those receiving high protein levels (18.29%). Conversely, contrast component 2 (P1, P3 versus P2, P4) did not show a significant effect on duck day production during the 6-week observation period ($p > 0.05$), indicating that the supplementation of 40 g/head/day live BSF had no significant impact on duck day production ($p > 0.05$). Nevertheless, contrast component 3 (P2 versus P3), while not statistically significant, hinted at a positive effect of adding live BSF maggots ($p > 0.05$). This implies that a low-protein diet supplemented with 40 g/head/day of BSF maggots could potentially match the performance of a high-protein diets, demonstrating a noteworthy finding in the study.

In the orthogonal contrast test number 1 (P1, P2 versus P3, P4), the egg mass production analysis indicated a significant difference ($P < 0.05$) between ducks subjected to low protein levels (13.43%) and those treated with high protein levels (18.29%). Contrast component 2 (P1, P3 versus P2, P4) did not reveal any significant impact on egg mass during the 6-week observation period, suggesting that the supplementation of 40 g/head/day live BSF had no significant effect on egg mass production. However, in contrast to component 3 (P2 versus P3), although not statistically significant, the addition of live BSF maggots demonstrated a notably positive effect. This implies that a low-protein diet, supplemented with 40 g/head/day of BSF maggots, has the potential to match the egg mass production of ducks fed a high-protein diet (P4). On the other hand, the feed conversion ratio (FCR) across all treatments did not yield significant results between diets with low and high protein content ($p > 0.05$). Additionally, feed consumption did not show any significant differences between diets with low and high protein content ($p > 0.05$).

Egg quality

The results of this study about egg qualities in the research are shown in Table 4. As can be seen, treatment with live BSF maggot and protein content diet (14.62%) had a significant effect on egg weight ($p < 0.05$). Furthermore, egg weight in the orthogonal contrast test number 1 (P1, P2 versus P3, P4) showed that ducks in the treatment group with low protein (P2) levels (13.43%) indicated lower egg weight results ($p < 0.05$) than high protein level treatment group (18.29%). In the orthogonal contrast test number 3 (P2 versus P3), it was observed that ducks in the treatment with low protein levels (13.43%) supplemented with live maggots exhibited similar egg weights to the high protein level treatment group (18.29%). The protein level of the diet had a significant effect ($p < 0.05$) on yolk weight, as did maggot supplementation. Orthogonal contrast test number 2 revealed a significant difference ($p < 0.05$) between P1, P3 versus P2, P4, resulting in increased yolk weight. However, the percentage of yolk weight and shell weight did not show a significant effect ($p > 0.05$) among P1, P3 versus P2, P4. Furthermore, the protein level of the diet significantly increased the crude protein of albumen (contrast number 1), and maggot supplementation, as indicated by orthogonal contrast test number 2, significantly elevated the crude protein of albumen ($p < 0.05$).

DISCUSSION

In Indonesia, ducks are typically raised for meat production, egg production, or dual purposes encompassing both. The predominant share of production costs in duck farming is attributed to feed expenses, with a particular emphasis on the raw materials serving as a protein source. Consequently, there is a crucial need to mitigate dependency on conventional protein source feed ingredients by exploring alternative, cost-effective by-products. A strategic approach involves combining commercial feed with live maggots to formulate optimal and efficient diets for duck layers. This innovative combination not only addresses economic considerations but also enhances the nutritional profile, reflecting a promising initiative to optimize duck farming practices in Indonesia. The feed intake of ducks in all treatments was comparable. This is likely due to the uniform metabolizable energy content in the provided diets (Table 2). One of the parameters observed in this research was feed intake. The results of feed intake showed that there was no difference between the low protein ratio treatment and the high protein ratio treatment.

These findings are consistent with the observations of Fouad et al. (2018b) who reported a positive effect on laying ducks when the feed energy ranged from 2,600 to 3,100 kcal AME/kg. Furthermore, a study by Wickramasuriya et al. (2016) demonstrated that an increase in energy levels from 2,600 to 3,300 kcal AME/kg in native Korean ducks led to enhanced productive performance. On the other hand, daily duck egg production in the treatment group with low protein levels (13.43%) was lower than that in the treatment group with high protein levels (18.29%). This finding aligns with the results reported by Fouad and El-Senousey (2014), who stated that the production and reproduction performance of laying ducks was influenced by the adequacy of protein and energy. Providing live BSF maggots in the diet turned out to be of great benefit to duck egg weight. Giving live BFS maggots containing high protein has an impact on *Alabio* duck egg weight. However, giving live BFS maggots to the low protein content treatment (13.43%) also resulted in low egg weight results when compared to the high protein treatment group (18.29%).

The results of the study were in line with the results of research by Fouad et al. (2018a) As observations, the laying performance of ducks, encompassing egg production, egg weight, and (FCR), is impacted by the presence of feed with a sufficient protein content (Finke, 2013). The study results indicated that the treatment with live BSF maggot and the protein level of the diet affected egg weight. This was understandable because giving live maggots to the feed will add nutritional value in the form of feed protein it has an impact on increasing egg production and weight. Dong et al. (1997) reported that using local feed resources like live BSF maggot was efficient in feeding Muscovy ducks. Contrastingly, Finke (2013) emphasized the rich protein and amino acid content of live BSF larvae. Furthermore, various studies (Spranghers et al., 2017) have pointed out that insects, in general, possess high levels of essential amino acids and exhibit a superior amino acid profile compared to traditional protein sources (Tran et al., 2015). Regarding the current study, it was noted that the introduction of live BSF maggots had a significant impact on the weight of duck egg yolks, as indicated by other parameters. The results of this study were in line with the research of Gunawan, et al (2018) which reported that the provision of live BSF maggots at 10% of the amount of diet given can result in a higher percentage of carcass but produce a lower percentage of carcass pieces than 0% BSF maggot (without maggot).

Table 3. Performance parameters of local ducks were given different diets

Variable	Diet				SEM	P-value	Orthogonal contrast[1]		
	P1	P2	P3	P4			1	2	3
Feed consumption (g/head)	127.18	137.28	133.88	140.68	1.99	0.090	-	-	-
Duck day production (%)	53.01	61.19	64.36	62.78	1.61	0.048	*	ns	ns
Feed conversation ratio (FCR)	5.31	6.39	5.48	4.24	0.34	0.174	-	-	-
Egg mass (g/head/day)	31.52	37.17	41.64	40.75	1.41	0.034	*	ns	ns

P1: Diet Crude Protein 13.43%; P2: Diet Crude Protein 13.43% + 40 g maggot; P3: Diet Crude Protein 18.29%; P4: Diet Crude Protein 18.29% + 40 g maggot. ns = no significance ($p > 0.05$); * ($p < 0.05$). [1]Comparison of orthogonal contrast; 1: P1, P2 versus P3, P4 (Diet -1 -1 1 1); 2: P1, P3 versus P2, P4 (Diet -1 1 -1 1); 3: P2 versus P3 (Diet 0 -1 1 0).

Table 4. Egg quality parameters of local ducks were given different diets

Variable	Diet				SEM	P-value	Orthogonal contrast[1]		
	P1	P2	P3	P4			1	2	3
Egg weight (g)	59.30	62.84	64.31	64.71	0.77	0.045	*	ns	ns
yolk weight (g)	18.77	20.78	20.70	21.26	0.27	0.001	*	*	ns
Yolk weight of whole egg (%)	31.64	33.06	32.19	32.81	0.23	0.120	-	-	-
Shell weight (g)	6.12	6.59	6.66	6.93	0.11	0.079	-	-	-
Crude protein of yolk (%)	13.81	12.94	13.81	13.79	0.31	0.730	-	-	-
Crude protein of albumen (%)	11.48	13.02	12.55	13.54	0.20	0.000	*	*	ns

P1: Diet Crude Protein 13.43%; P2: Diet Crude Protein 13.43% + 40 g maggot; P3: Diet Crude Protein 18.29%; P4: Diet Crude Protein 18.29% + 40 g maggot. ns = no significance ($p > 0.05$); * ($p < 0.05$). [1]Comparison of orthogonal contrast; 1: P1, P2 versus P3, P4 (Diet -1 -1 1 1); 2: P1, P3 versus P2, P4 (Diet -1 1 -1 1); 3: P2 versus P3 (Diet 0 -1 1 0).

CONCLUSION

Based on the results of the study it can be concluded that giving live BSF maggot to laying ducks can improve performance parameters such as day egg production and FCR and can improve egg quality parameters.

DECLARATIONS

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Authors' contributions

Aam Gunawan served as the principle researcher of the project and conducted data analysis. Abd. Malik contributed to the design and drafting of the article. Fitri Noor Hayati and Afridolin Sonya Goa were responsible for data collection, and Ahmad Junaedi and Dwi Wahyu Candra oversaw the rearing of experimental livestock. All authors thoroughly reviewed and approved the final version of the manuscript for publication in the current journal.

Competing interests

All authors have no conflicts of interest.

Ethical considerations

Ethical issues, including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were checked by all authors.

Availability of data and materials

The primary data for this study is available from the corresponding author.

REFERENCES

Adzitey F and Adzitey S (2011). Duck production: Has a potential to reduce poverty among rural households in Asian communities–a review. Journal of World's Poultry Research, 1(1): 7-10. Available at: https://jwpr.science-line.com/attachments/article/4/JWPR,%20A3,%207-10,%202011.pdf

Biasato I, Gasco L, De Marco M, Renna M, Rotolo L, Dabbou S, Capucchio MT, Biasibetti E, Tarantola M, Sterpone L et al. (2018). Yellow mealworm larvae (*Tenebrio molitor*) inclusion in diets for male broiler chickens: Effects on growth performance, gut morphology, and histological findings. Poultry Science, 97(2): 540-548. DOI: https://www.doi.org/10.3382/ps/pex308

Bukkens SGF (1997). The nutritional value of edible insects. Ecology of Food and Nutrition, 36(2-4): 287-319. DOI: https://www.doi.org/10.1080/03670244.1997.9991521

De Marco M, Martínez S, Hernandez F, Madrid J, Gai F, Rotolo L, Belforti M, Bergero D, Katz H, Dabbou S et al. (2015). Nutritional value of two insect larval meals (*Tenebrio molitor* and *Hermetia illucens*) for broiler chickens: Apparent nutrient digestibility, apparent ileal amino acid digestibility and apparent metabolizable energy. Animal Feed Science and Technology, 209: 211-218. DOI: https://www.doi.org/10.1016/j.anifeedsci.2015.08.006

Dong NTK, Ogle B, and Preston TR (1997). Effect of level of local supplements for fattening Muscovy ducks by poor farmers in remote villages in Mekong delta of Vietnam. Livestock Research for Rural Development, 9(1): 27. Available at: https://www.lrrd.cipav.org.co/lrrd9/1/dong91.htm

El-Kaiaty AM, Atta AER, Dawa DT, and El-sayed TR (2022). The impact of black soldier fly (*Hermetia illucens*) as feed supplementation on productive and physiological performance of broiler chickens. World's Veterinary Journal, 12(2): 133-140. DOI: https://www.doi.org/10.54203/scil.2022.wvj17

Finke MD (2013). Complete nutrient content of four species of feeder insects. Zoo Biology, 32(1): 27-36. DOI: https://www.doi.org/10.1002/zoo.21012

Fouad AM and El-Senousey HK (2014). Nutritional factors affecting abdominal fat deposition in poultry: A review. Asian-Australasian Journal of Animal Sciences, 27(7): 1057-1068. DOI: https://www.doi.org/10.5713%2Fajas.2013.13702

Fouad AM, Chen W, Ruan D, Wang S, Xia W, and Zheng C (2018a). Effects of dietary lysine supplementation on performance, egg quality, and development of reproductive system in egg-laying ducks. Journal of Applied Animal Research, 46(1): 386-391. DOI: https://www.doi.org/10.1080/09712119.2017.1308868

Fouad AM, Ruan D, Wang S, Chen W, Xia W, and Zheng C (2018b). Nutritional requirements of meat-type and egg-type ducks: What do we know?. Journal of Animal Science and Biotechnology, 9(1): 1. DOI: https://www.doi.org/10.1186/s40104-017-0217-x

Gariglio M, Dabbou S, Biasato I, Capucchio MT, Colombino E, Hernández F, Madrid J, Martínez S, Gai F, Caimi C et al. (2019). Nutritional effects of the dietary inclusion of partially defatted *Hermetia illucens* larva meal in Muscovy duck. Journal of Animal Science and Biotechnology, 10: 37. DOI: https://www.doi.org/10.1186/s40104-019-0344-7

Gariglio M, Dabbou S, Gai F, Trocino A, Xiccato G, Holodova M, Gresakova L, Nery J, Oddon SB, Biasato I et al. (2021). Black soldier fly larva in Muscovy duck diets: Effects on duck growth, carcass property, and meat quality. Poultry Science, 100(9): 101303. DOI: https://www.doi.org/10.1016/j.psj.2021.101303

George D and Mallery P (2016). IBM SPSS statistics 23 step by step: A simple guide and reference, 14th Edition. Routledge., New York. DOI: https://www.doi.org/10.4324/9781315545899

Gunawan A, Erlina S, Samudera R, Syarif DM, Noor MY, and Lantu A (2018). Effect of supplement maggot black soldier fly live on the percentage of carcass and weight of carcass of male Alabio ducks. IOP Conference Series: Earth and Environmental Science, 207: 012021. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/207/1/012021/pdf

Gunawan A, Malik A, Rusmana D, Djaya MS, and Widaningsih N (2022). Fatty acid composition of black soldier fly maggot were reared in the mixture of laying hen manure with lemuru fish oil. IOP Conference Series: Earth and Environmental Science, 1020: 012020. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/1020/1/012020/pdf

Hanboonsong Y, Jamjanya T, and Durst PB (2013). Six-legged livestock: Edible insect farming, collection and marketing in Thailand. RAP publication., Thailand, pp. 1-48. Available at: https://www.fao.org/3/i3246e/i3246e.pdf

Herawati VE, Pinandoyo P, Windarto S, Rismaningsih N, Riyadi PH, Darmanto Y, and Radjasa OK (2020). Nutritional value and growth performance of sea worms (Nereis sp.) fed with Hermetia illucens maggot flour and grated coconut (*Cocos nucifera*) as natural feed. Biodiversitas Journal of Biological Diversity, 21(11): 5431-5437. DOI DOI: https://www.doi.org/10.13057/biodiv/d211151

Hutahaean L, Sirnawati E, Rohaeni ES, and Bakrie B (2022). Duck business development strategy in duck farming center area of Indramayu Regency, West Java Province of Indonesia. E3S Web of Conferences, 36: 1-10. DOI: https://www.doi.org/10.1051/e3sconf/202236101014

Ismoyowati I, Indrasanti D, and Sulistyawan IH (2018). The differences of feed quality and egg production performance of Tegal and Magelang ducks on farming in Central Java. Buletin Peternakan, 42(3): 197-202. DOI: https://www.doi.org/10.21059/buletinpeternak.v42i3.34465

Jamal S, Jamil DM, and Khidhir ZK (2020). Protein determination in some animal products from sulaymaniyah markets using kjeldahl procedure. Journal of Food and Dairy Sciences, 11(12): 343-346. DOI: https://www.doi.org/10.21608/jfds.2020.160394

Kovitvadhi A, Chundang P, Thongprajukaew K, Tirawattanawanich C, Srikachar S, and Chotimanothum B (2019). Potential of insect meals as protein sources for meat-type ducks based on *in vitro* digestibility. Animals, 9(4): 155. DOI: https://www.doi.org/10.3390/ani9040155

Makkar HPS, Tran G, Heuzé V, and Ankers P (2014). State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 197: 1-33. DOI: https://www.doi.org/10.1016/j.anifeedsci.2014.07.008

Mlaga KG, Attivi K, Agboka K, Osseyi E, and Tona K (2022). The long-term effects of dietary replacement of fish meal with black soldier fly (*Hermetia illucens*) larvae on nutritional content and eggshell quality in layer chickens. Journal of World's Poultry Research, 12(3): 181-191. DOI: https://www.doi.org/10.36380/jwpr.2022.21

Sánchez-Muros MJ, Barroso FG, and Manzano-Agugliaro F (2014). Insect meal as renewable source of food for animal feeding: A review. Journal of Cleaner Production, 65: 16-27. DOI: https://www.doi.org/10.1016/j.jclepro.2013.11.068

Singh VK, Chauhan SS, Ravikanth K, Maini S, and Rekhe DS (2009). Effect of dietary supplementation of polyherbal liver stimulant on growth performance and nutrient utilization in broiler chicken. Veterinary World, 2(9): 350-352. Available at: https://www.veterinaryworld.org/Vol.2/September/Effect%20of%20dietary%20supplementation%20of%20polyherbal%20liver%20stimul.pdf

Spranghers T, Ottoboni M, Klootwijk C, Ovyn A, Deboosere S, De Meulenaer B, Michiels J, Eeckhout M, De Clercq P, De Smet S et al. (2017). Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates. Journal of the Science of Food and Agriculture, 97(8): 2594-2600. DOI: https://www.doi.org/10.1002/jsfa.8081

Tran G, Heuzé V, and Makkar HPS (2015). Insects in fish diets. Animal Frontiers, 5(2): 37-44. DOI: https://www.doi.org/10.2527/af.2015-0018

Wickramasuriya SS, Yoo J, Kim JC, and Heo JM (2016). The apparent metabolizable energy requirement of male Korean native ducklings from hatch to 21 days of age. Poultry Science, 95(1): 77-83. DOI: https://www.doi.org/10.3382/ps/pev321