Original Research

Journal of Advanced Veterinary Research
(2024) Volume 14, Issue 6, 959-963

Supplementing broiler diets with black soldier fly (*Hermetia illucens*) as a protein source: Performance, carcass traits, viscera organ, and economic perspectives

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ARTICLE INFO

Recieved: 05 March 2024

Accepted: 19 May 2024

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Keywords:

Black soldier fly
Broiler
Carcass
Performance
Profitability
Viscera organ

ABSTRACT

Black soldier fly (BSF) larva meal has the potential to become an alternative source of protein for broiler rations due to its high protein content. This study aimed to evaluate broiler chicken performance, carcass characteristics, viscera organs, and economic aspects when substituting poultry concentrate protein with different levels of BSF larva meal. A total of 200 Cobb broiler chicks were randomly put into four treatments and five replications, with ten birds per replicate then reared for 35 days. The treatment diets given in the finisher period consisted of R0 (a commercial finisher diet), R1 (R0+0% BSF larva meal), R2 (R0+7.5% BSF larva meal), and R3 (R0+15% BSF larva meal). The result showed that the treatment diet had a significant effect ($P<0.05$) on BW, ADG, and FI during the finisher period, while FCR did not have a significant effect ($P>0.05$). No significant differences in carcass characteristics and income over feed cost were observed among treatments. However, the inclusion of BSF larva meal (7.5% and 15%) significantly increased ($P<0.05$) gizzard weight compared to the R0 treatment. The use of 15% BSF larva meal in the finisher diet is a viable alternative protein source for broiler chickens, positively impacting gizzard percentage while maintaining comparable carcass characteristics and feed conversion efficiency. Additionally, it offers cost-saving potential compared to non-BSF diets.

Introduction

Broiler chickens are vital to food security as they are specifically for meat production due to their rapid growth and efficiency. However, the significant challenge of high feed costs, comprising a substantial portion of overall production expenses, has resulted in less-than-optimal chicken meat production. The rising demand for protein sources in livestock feed, along with concerns about feed availability, environmental pressures, population growth, and the increasing demand for protein, has led to the escalating expenses associated with animal-based protein feed ingredients. Consequently, current research in the field of animal nutrition is focused on exploring alternative protein sources through the utilization of insects.

Researchers worldwide have extensively studied insects as a protein source (Elahi *et al*., 2022). According to Khan (2018), insect-based protein offers economic viability, environmental sustainability, and plays a significant ecological role. Insect utilization stands out for its remarkable efficiency, as insects can be bred and produced on a large scale. Insect farming also has the potential to mitigate the environmental impact of organic waste. Black soldier fly (BSF) (*Hermetia illucens*), a member of the Diptera family known as Stratiomyidae, naturally inhabits tropical, subtropical, and warm temperate regions in the Americas. BSF larva showed promising potential for incorporation into animal feed, especially in poultry diets (Veldkamp and Bosch, 2015). These flies can grow and reproduce quickly, with remarkable feed efficiency, making them well-suited for cultivation on organic waste substrates. Indonesia's tropical climate provides an ideal environment for BSF cultivation.

According to Jayanegara *et al*. (2017), BSF larva meal contained 44.9% crude protein, 29.1% crude fat, 16.4% crude fiber, and 8.1% ash. Its amino acid composition surpasses plant-based proteins, particularly in sulfur-containing amino acids like methionine and cysteine. Rambet *et al*. (2016) reported that BSF meal holds the potential to replace fish meal in broiler chicken feed without any adverse effects on dry matter digestibility. The high protein content of BSF can reduce the need for concentrate, enabling small-scale farmers to engage in self-mixing and cost reduction. This study was conducted to evaluate the performance, carcass characteristics, and viscera organs of broiler chickens fed with different levels of BSF larva meal as a substitute for poultry concentrate protein and to assess the cost savings achieved through this substitution.

Materials and methods

Black soldier fly larva meal preparation

Black soldier fly (*Hermetia illucens*) was supplied by PT. Biomagg Indonesia. Organic waste served as the substrate for cultivating the BSF larva. Harvesting of the BSF larva commenced at 15 d of age, starting from egg hatching. The harvested BSF larva underwent a cleaning process before being placed in an oven at 60°C for 12 hours. The BSF larva were processed using a pressing machine, resulting in their coarse state, which was then further refined through grinding to achieve a fine or powdered consistency. The producer withheld details on the substrate, processing techniques, and larvae material production due to confidentiality.

Birds and experimental diet

This study was conducted in the Field Laboratory Block C and the Laboratory of Poultry Nutrition, Faculty of Animal Science, IPB University. A total of 200 one-day-old Cobb broilers were allocated into four groups with five replicate cages (100x100 cm) containing ten birds each. Each

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cage was equipped with a feeder, a drinker, and rice hulls as bedding material. The birds were then reared from day-old chick (DOC) day one until 35 days of age. During the starter period (0–21 days), the birds were provided with a commercial starter diet and during the finisher period (22–35 days), the chickens were provided with the treatment diets. The finisher diet included a commercial finisher diet as control (R0) and R0 with BSF larva meal with 0%, 7.5%, and 15% (R1, R2 and R3). The formulation and nutrient composition of the treatment diet and its nutrient content are shown in Table 1. Feeding followed brooding management practices outlined in the guidelines of Medion (2020), and water was provided *ad libitum*. The birds were kept warm using a 60-watt lamp to maintain temperature and provided with lighting at night and on rainy days.

Table 1. Formula and nutrient content of the treatment diet

Items	Treatments			
	R0	R1	R2	R3
Feed ingredient (%)				
Commercial finisher	100	40	32.5	25
Corn	0	50	50	50
Rice bran	0	10	10	10
BSF	0	0	7.5	15
Nutrient content				
Dry matter (%)	87.0	87.1	87.3	87.4
Ash (%)	4.7	4.9	5.5	6.1
Crude protein (%)	19	19	19.73	20.5
Ether extract (%)	4.6	8.4	8.4	8.4
Crude fiber (%)	4.5	4.7	5.5	6.3
ME (kcal kg^{-1})	3000	3001	3062	3123
Calcium (%)	0.9	1.1	1.1	1.2
Phosphor (%)	0.7	0.8	0.8	0.7
Phosphor available (%)	0.5	0.5	0.5	0.5
Lysin (%)	1.2	1.2	1.1	1.1
Methionine (%)	0.5	0.5	0.5	0.5

R0: commercial diet; R1: R0 + 0% BSF larva meal; R2: R0 + 7.5% BSF larva meal; R3: R0 + 15% BSF larva meal.

Sample analysis and parameters observed

In this study, the birds' body weight (BW) and their feed intake (FI) were measured weekly. These data were used to calculate average daily gain (ADG), daily feed intake, and feed conversion ratio (FCR). The FCR was calculated as daily feed intake per average daily gain. Mortality rates were also recorded.

At 35 days of age, random sampling was conducted, with one broiler chicken selected from each repetition, resulting in a total of five chickens for each treatment. The birds were weighed before slaughter. Following slaughter, the birds were plucked to remove their feathers and weighed to determine the total carcass weight. Commercial cuts, including breast, thigh, wings, and back, were measured. Additionally, the weight of the viscera organs, including the heart, liver, gizzard, and caecum, was also determined. The percentage of commercial cuts and viscera organs was calculated as the organ weight per slaughter weight multiplied by 100.

Income over feed and chick cost (IOFCC) was an economic assessment in this study. The IOFCC was calculated as the difference between total revenue, which resulted from selling live chickens at the price of day-old chicks (DOC), and the total cost of feed used during the rearing of the birds until harvest.

Experimental design and statistical analysis

The experimental design was a Complete Randomized Design (CRD) consisting of 4 treatments with five replications. Each replication consisted of 10 birds. All data were analyzed by one-way analysis of variance (ANOVA) using SPSS ver. 20 (IBM Statistics Inc.), and if it was significant (P<0.05), then further tested using the Duncan Multiple Range Test.

Results

Performance

The chicken broiler performance during the starter period (1 to 21 days) and finisher period (22 to 35 days) is presented in Table 2. Based on the results, the performance, including BW, ADG, FI, and FCR, did not significantly differ. The mortality rate at the starter period was 1.5% or three birds. The result showed that the treatment diet had a significant effect (P<0.05) on BW, ADG, and FI at the finisher period, while FCR did not have a significant effect (P>0.05). Treatment R0 had the highest BW, ADG, and FI compared to other treatments.

Table 3 shows the effect of the treatment diet on broiler performance in all phases (1 to 35 days). The treatment diets significantly affected BW,

Table 2. Effect of treatment diet on growth performance of broiler chicken at starter period (1 to 21 days) and finisher period (22 to 35 days)

Items	Treatment diet			
	R0	R1	R2	R3
	Starter phase			
BW DOC (g bird^{-1})	38.68±0.3	38.58±0.9	38.66±0.5	38.86 ± 0.50
BW at 21 days (g bird^{-1})	972.36±23.3	957.88±31.7	950.14±30.4	953.06±35.7
ADG (g bird^{-1})	933.68±23.5	919.30±32.5	911.48±30.7	914.20±35.7
FI (g bird^{-1})	1262.96±11	1258.80±18	1262.92±14	1238.12±32
FCR	1.35±0.04	1.37±0.03	1.38±0.03	1.35±0.03
Mortality (%)	0	0	1.5	0
	Finisher phase			
BW at 35 days (g bird^{-1})	2194.93±83a	2015.00±61b	2070.5±103b	2050.18±111b
ADG (g bird^{-1})	1222.57±66a	1222.57±66a	1120.36±80b	1097.12±76b
FI (g bird^{-1})	1097.12±76b	1756.68±32b	1832.8±71ab	1742.64±132b
FCR	1.58 ± 0.09	1.66 ± 0.09	1.63 ± 0.07	1.58 ± 0.02
Mortality (%)	0.5	0	0	0
BW at 35 days (g bird^{-1})	2194.93±83a	2015±61b	2070.5±103b	2050.18±111b

Means in the same row with different superscripts significantly different (P<0.05). R0: commercial diet; R1: R0 + 0% BSF larva meal; R2: R0 + 7.5% BSF larva meal; R3: R0 + 15% BSF larva meal. BW DOC: Body weight at day-old chicks, BW: Body weight; ADG: Average daily gain; FI: Feed intake; FCR: Feed conversion ratio

ADG, and FI (P<0.05). Observing all phases showed that the commercial diet (R0) resulted in the highest BW, ADG, and FI. Dietary BSF in different levels did not improve broiler performance, which is similar to BW, ADG, and FI in treatments R1, R2, and R3. The FCR also did not differ among treatment diets.

Carcass characteristics and viscera organ

The results revealed no differences in weight or percentage of carcass yield and commercial cuts, and viscera organ among treatment diets (P>0.05) (Table 4). The inclusion of 7.5% and 15% BSF larva meal (R2 and R3) did not improve carcass weight and commercial cuts percentage (breast, thigh, wings, and back). The carcass percentage in this study ranged from 70.74 to 73.81%. Dietary BSF larva meal 7.5−15% in broiler diet did not affect either weight or percentage of heart, liver, and caecum but increased gizzard weight (P<0.05).

Economic aspects

The economic aspects, reflected by IOFCC, aim to determine the profitability obtained from income in broiler farming. The price of BSF larva meal was assumed to be equivalent to that of soybean meal due to the fluctuating production costs of BSF meal and the limited production of BSF larva meal in Indonesia. The effects of treatment diets on the economic aspect are displayed in Table 5. The feed costs for R2 and R3 treatments were 1.25% and 2.51% lower than the R1 treatment, respectively. The inclusion of 7.5% and 15% BSF larva meal (R2 and R3) in broiler rations resulted in higher IOFCC, increasing it by 3.58% and 11.10%,

Table 3. Effect of treatment diet on growth performance of broiler chicken (1 to 35 days).

Items	Treatment diet			
	R0	R1	R2	R3
BW at 35 days (g bird^{-1})	2194.93±83a	2015±61b	2070.5±103b	2050.18±111b
ADG (g bird^{-1})	2156.25±83a	1976.42±61b	2031.4±103b	2011.32±111b
FI (g bird^{-1})	3210.54±65a	3015.48±36b	3095.7±81ab	2980.76±157b
FCR	1.58 ± 0.09	1.66 ± 0.09	1.63 ± 0.07	1.58 ± 0.02
Mortality (%)	1	2	1	0

Means in the same row with different superscripts significantly different (P<0.05). R1: commercial diet; R1: R0 + 0% BSF larva meal; R2: R0 + 7.5% BSF larva meal; R3: R0 + 15% BSF larva meal. BW: Body weight; ADG: Average daily gain; FI: Feed intake; FCR: Feed conversion ratio.

Table 4. Effect of treatment diet on carcass yield, commercial cut percentage, and viscera organ percentage of broiler chicken at 35 d.

Items	Treatment diet			
	R0	R1	R2	R3
Slaughter weight (g)	2361.60±260.30	1993.40±153.40	2141.40±167.50	2129.40±134.70
Carcass weight (g)	1744.00±199.00	1438.40±138.60	1517.20±158.40	1562.40±97.80
Carcass percentage (%)	73.80±1.30	72.00±2.00	70.70±2.30	73.30±1.90
Commercial cuts percentage (%)				
Breast	38.00±1.40	35.70±2.50	32.50±7.30	36.90±0.70
Thigh	30.70±0.90	30.60±0.50	32.90±1.00	29.80±0.70
Wings	11.40±0.70	11.40±1.40	16.40±1.20	12.000.40
Back	19.90±1.10	22.30±3.10	18.20±3.10	21.30±1.20
Viscera organ percentage (%)				
Heart	0.45±2.77	0.45±4.35	0.44±3.95	0.47±6.57
Liver	1.72±1.67	1.73±3.28	1.73±3.28	1.65±1.15
Gizzard	1.14±2.53	1.77±1.77	1.54±2.51	1.34±2.32
Caecum	0.29±1.68	0.30±3.68	0.30±1.63	0.36±12.16

R0: commercial diet; R1: R0 + 0% BSF larva meal; R2: R0 + 7.5% BSF larva meal; R3: R0 + 15% BSF larva meal.

Table 5. Effect of treatment diet on economic aspects.

Items	Treatment diet			
	R0	R1	R2	R3
Intake of starter diet (kg bird^{-1})	1.26	1.26	1.26	1.24
Intake of finisher diet (kg bird^{-1})	1.93	1.76	1.83	1.74
Feed cost for starter diet (Rp kg^{-1})	7,500	7,500	7,500	7,500
Feed cost for finisher diet (Rp kg^{-1})	6,900	5,804	5,721	5,638
Processing cost (Rp kg^{-1})		800	800	800
Total feed cost (Rp bird^{-1})	22,811	21,043	21,424	20,505
DOC cost (Rp bird^{-1})	4,500	4,500	4,500	4,500
Body weight (kg bird^{-1})	2.19	2.02	2.07	2.05
Chicken cost (Rp)	17,000	17,000	17,000	17,000
Income (Rp bird^{-1})	37,313.80	34,255	35,198.50	34,853
IOFCC (Rp kg^{-1})	4,557	4,324	4,479	4,804

R0: commercial diet; R1: R0 + 0% BSF larva meal; R2: R0 + 7.5% BSF larva meal; R3: R0 + 15% BSF larva meal. IOFCC: income over feed and chick cost.

respectively, compared to the 0% BSF meal (R1). Treatment R3 (15% BSF larva meal) had the highest IOFCC among all the treatments.

Discussion

During the starter period, broiler performance did not differ significantly among the treatment diets due to the uniformity of the starter commercial diet provided to the broilers. However, treatment R0 (commercial finisher diet) resulted in the highest BW, ADG, and FI during the finisher period. The low BW in R1, R2, and R3 treatments is due to differences in the composition of feed ingredients and their nutrient content. According to the Cobb management guide (2018), broiler chicken maintenance of the Cobb strain for 35 days resulted in a standard BW of 2191 g bird^{-1}. The BW outcomes of treatments R2 and R3 in this study were lower by 5.49% and 6.43%, respectively, compared to the Cobb standard. This could be attributed to the environmental temperature within the research pen, where the conditions during the finisher period ranged from 26.16to 30.61°C. These conditions contradicted the Cobb temperature management standards (2018), which state that the environmental temperature for chickens aged 22−24 days should be 24–26°C and decrease to 21°C for chickens over 28 days of age.

Incorporating 7.5% and 15% BSF larva meal (R2 and R3) in the finisher diet did not significantly affect BW and ADG compared to the 0% BSF larva meal (R1). This suggested that the presence of chitin in treatments R2 and R3 did not influence on feed digestibility. Chitin is a polysaccharide compound poorly digested by broilers' digestive systems. According to Soetemans *et al*. (2020), the chitin content in BSF constituted 7.8−9.5% of DM. The age of the BSF larva influences the chitin content. As BSF age increases, the chitin content from its exoskeleton also increases. This study used a 15-day-old BSF larva with low chitin content, as the exoskeleton had not fully developed. The chitin content in treatments R2 and R3 was 0.65% and 1.30%, respectively. The BW of this study differs from previous research, which reported that the broiler fed with 13% and 20% BSF larva meal had significantly higher BW compared to fed with non-BSF larva meal. The BW obtained in this study tended to be higher than the results of Hwangbo *et al*. (2009), with the same percentage of larva meal, which was 15%, resulting in 1785 g bird^{-1}.

The FI during the finisher period also did not exhibit significant differences among the treatment diets. The color of feed is one of the factors that affect feed consumption. Poultry possesses a heightened visual sensitivity to colors, particularly within the orange spectrum. Incorporating BSF larva meal in broiler diet imparts a dark color to the diets. The higher the proportion of BSF larva meal used, the darker the black color becomes. The utilization of 15% BSF larva meal in the diet resulted in a dark greyish color, while broilers are attracted to bright colors such as yellow and orange (Gulizia and Downs, 2021). Consequently, FI in treatment R3 tended to decrease compared to the commercial diet (R0). This study is in line with Makinde (2015) who indicated that the utilization of BSF larva meal at levels exceeding 10% might lead to reduced feed consumption due to reduced palatability, attributed to the unattractive dark coloration of the feed from the perspective of broilers.

High environmental temperatures combined with high levels of dietary fat also could induce oxidative stress in poultry, potentially affecting the feed consumption of broiler chickens. Additionally, elevated levels of crude fat can trigger feed oxidation, making it prone to rancidity, which, in turn, may reduce feed quality and livestock palatability (Hidayat, 2018). Therefore, fat separation (defatting) was carried out in this study with mechanical (physical) techniques to prevent these issues. According to the Cobb management guide (2018), broiler chickens of the Cobb strain typically have a standard feed consumption of 2160 g bird^{-1} during the finisher period. The variation in feed consumption observed here could be attributed to differences in the environmental temperature within the pens. In this study, the temperature inside the pens ranged from 26.16–30.61°C, whereas the comfortable temperature range for chickens during the finisher period is around 20–26°C (Cobb, 2018). Uncomfortable temperatures can influence feed consumption because, at high temperatures, chickens tend to reduce their feed intake and increase their water consumption to maintain their normal body temperature.

The inclusion of BSF larva meal (R2 and R3 treatments) in the finisher diet resulted in comparable FCR to the commercial diet (R0) but lower than the non-BSF diet (R0). This finding aligns with a previous study that indicated higher BSF inclusion levels led to lower FCR. Treatment R3 resulted in a low FCR of 1.58. This means that to produce 1 kg of chicken meat, 1.58 kg of feed were required, costing Rp 9170.32 kg^{-1}. In contrast, the R1 treatment had a high FCR at 1.66, requiring 1.66 kg of feed to produce 1 kg of chicken meat, costing Rp 9359.08 kg^{-1}. These results indicate that using of 15% BSF larva meal can achieve FCR on par with the commercial diet. The FCR in the finisher period in this study was lower than the Cobb standard of 1.72 (Cobb, 2018), and treatment R3 outperformed a study by Hwangbo *et al*. (2009), which reported an FCR of 1.65. A low FCR suggests better feed efficiency in converting feed into meat.

The performance of chickens aged 1−35 days yielded varying results compared to the Cobb standard. According to the Cobb management guide (2018), the standard BW, ADG, FI, and FCR were 2191 g bird^{-1}, 2149 g bird^{-1}, 3352 g bird^{-1}, and 1.53, respectively. Based on Table 3, chickens fed with commercial feed (R0) demonstrated higher values in standard BW, ADG, and FCR but lower values in FI compared to the Cobb standard (2018). Chickens fed with BSF-treated feed exhibited lower performance than the Cobb management standard (2018). The combination of broiler chicken rearing using commercial broiler starter feed and BSF-treated feed during the finisher period influenced the overall performance of broiler chickens.

Dietary BSF did not significantly affect carcass weight and carcass percentage. The similar results observed in carcass percentage in this study may be attributed to featherweight, internal organ weight, and non-carcass weight. Featherweights recorded in this study were R0 179.6 g, R1 153 g, R2 174 g, and R3 185.4 g, with no differences among the treatment diets. Carcass percentage in this study ranged from 70.74–73.81%. These results were consistent with those of Rumondor *et al*. (2016), who reported a carcass percentage range of 68.47% to 73.17% relative to live weight. Factors influencing carcass percentage include body weight, feed intake, and sex (Pahlepi *et al*., 2015).

Commercial cuts of broiler chicken typically encompass the breast, thigh, wing, and back. The inclusion of BSF larva meal in broiler chicken's finisher diet did not affect commercial cuts. The proportions of chicken breast, thigh, and wings in this study were within the normal range. According to Lesson and Summers (2005), chicken breast constitutes the primary component of broiler chicken and generally exhibits greater mass compared to wings, back, and thigh. The thigh represents a muscular portion of chicken meat. In this study, the proportion of chicken breast and thighs ranged from 32.50–38.00% and 29.86–32.90%, respectively. These results were similar to a study by Megawati (2011), who reported percentages of 34.11–38.12% for chicken breast and 29.73–30.77% for thigh. Wings comprise numerous bones and feathers, thus exhibiting a lower proportion. The back is characterized by a lower meat content and a predominance of bones. In this study, the proportions of commercial cuts for wings and back ranged from 11.40–16.40% and 18.20–22.08%, respectively. Tumiran *et al*. (2019) reported similar proportions of 9.40–10.72% for chicken wings and 18.33–22.07% for the back. Marzani *et al*. (2016) stated that carcass weight significantly impacted the carcass percentage, with chicken breast and thigh dominating the growth phase relative to wings.

The utilization of BSF at 7.5% and 15% as substitutes for concentrates was found not to affect the hepatic detoxification of toxic compounds and the excretion by the liver. The percentage of the liver was 1.60–1.73% of the carcass weight, which had a similar value to Hafsan *et al*. (2018), reported that the percentage of liver ranged from 1.9–2.2%. Based on the observations, no hepatic enlargement, shrinkage, or discoloration was detected. Therefore, the hepatic organ in this study can be characterized as being in a normal state. The normal liver had a reddish brown or light brown, smooth surface, and no liver damage was identified (Novita *et al*., 2016). The liver plays an essential role in the body due to its multifaceted functions, including decomposing hazardous substances absorbed from the intestines or other body parts. Thus far, no toxic substances have been identified in BSF besides its notable high chitin and fat content (Citra *et al*., 2019). Factors influencing liver weight encompass body weight, species, gender, age, and pathogenic bacteria.

Based on Table 4, the percentage of heart weight obtained in the study ranged from 0.44% to 0.46%. These findings were lower than those reported by Santi (2018), which indicated a heart weight percentage of 0.51–0.56%. The disparity in results was attributed to the heart's function in pumping blood to support metabolic processes. Accumulation of toxins in the cardiac muscle can lead to heart enlargement. The heart is highly vulnerable to toxins and anti-nutrient substances, and cardiac enlargement may result from the accumulation of toxins in the heart muscle (Mawadah *et al*., 2018). No signs of enlargement were observed in broiler chickens subjected to different treatments, aligning with the statement by Mawadah *et al*. (2018) that BSF was known to be devoid of toxic substances. The inclusion of BSF larva meal in the diet had no adverse effects on broiler production and health.

Gizzard weight increased in treatment R1 (0% BSF), while it decreased in R2 (7.5% BSF) and R3 (15% BSF) diets due to dietary composition variations, particularly the inclusion of BSF. The increment in gizzard weight was attributed to the high crude fiber content in the treatment diet, which mechanically and enzymatically stimulated gizzard activity. BSF contains chitin, a non-digestible animal fiber, but its chitin content had yet to fully develop in the 15-day-old BSF used in the study (Khempaka *et al*., 2011). Coconut meal also contained high crude fiber (25%), comprising 13% cellulose, 40−50% galactomannan, and 61% mannans, which were likely responsible for gizzard enlargement (Ariandi *et al*. 2015). The gizzard weight percentage ranged from 1.14–1.77%, consistent with Pangesti *et al*. (2016), suggesting normal gizzard function. Dietary BSF had no significant effect on the weight and percentage of the caecum. Table 4 shows that the percentage of caecum within the study ranged from 0.29 to 0.36%. This aligns with Karthika *et al*. (2019), who reported caecum percentages ranging from 0.38 to 0.63%. The caecum serves as a fermentative digestive organ in chickens.

The price of the finisher diet with 7% and 15% BSF larva meal (R2 and R3), along with additional processing costs, was cheaper than the finisher diet without BSF larva flour (0% BSF/R1). The cost savings in the broiler diet for R2 and R3 treatments during the finisher period occurred due to a reduction in concentrate usage. The total feed costs for treatments using BSF larva meal were cheaper than the total commercial feed costs, with treatments R1, R2, and R3 showing sequential percentage reductions in total feed costs of 7.75%, 6.08%, and 10.10%, respectively. The comparison between treatments R1, R2, and R3 with R0 demonstrated that substituting 15% BSF larva meal reduced the highest total feed costs by up to 10.10%. The high IOFCC in the R3 treatment was attributed to the fact that BW in the R3 treatment was not significantly different from R1 and R2, but R3 had the lowest feed conversion compared to treatments R1 and R2. The addition of BSF larva meal in the feed could not match the income generated from commercial feed. The value of IOFCC is influenced by several factors, including feed consumption, final weight, chicken selling price, and feed price (Sukiman et al., 2023).

Conclusion

BSF larva meal can serve as an alternative protein source without negatively affecting the performance of broiler chickens. The inclusion of BSF larva meal up to 15% in the finisher diet improved gizzard percentage, producing similar effects to a commercial finisher diet on carcass characteristics and feed conversion. Moreover, the incorporation of 15% BSF larva meal demonstrated the potential to reduce feed costs compared to a non-BSF diet.

Acknowledgments

The authors would like to thank the Laboratory of Poultry Nutrition staff for their assistance. This research was funded by the Ministry of Education, Culture, Research, and Technology, the Republic of Indonesia, through the Applied Research of Higher Education (PTUPT) grant 2021.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ariandi, Yopi, Meryandini, A., 2015. Enzymatic hydrolysis of copra meal by mannanase from Streptomyces sp. Bf3.1 for the production of mannooligosaccharides. Hayati Journal of Biosciences 22, 79−86.

Citra V.K., Hermana, W., Mutia, R., 2019. Digestive organs and status of escherichia coliin quail intestine givendefatted maggot (*Hermetia illucens*) meal as a substitute formeat bone meal. Jurnal Ilmu Pertanian Indonesia 24, 237-246.

Cobb, 2018. Broiler performance & nutrition supplement. Available from: https://www.cobb-vantress.com/assets/5a88f2e793/Broiler-Performance-Nutrition-Supplement.pdf (accessed 12 February 2024).

Elahi, U., Xu, C., Wang, J., Lin, J., Wu, S., Zhang, H., Qi, G., 2022. Insect meal as a feed ingredient for poultry. Animal Bioscience 35, 332−346.

Gulizia, J.P., Downs, K.M., 2021. The effects of feed color on broiler performance between day 1 and 21. Animals 11, 1511−1518.

Hafsan, Bayu, G., Hidayat, S.A., Agustina, L., Natsir, A., Ahmad, A., 2018. Carcass weight and percentage of organ in broiler with supplementation of phytase from Bukholderia sp. Strain HF.7. Prosiding Seminar Nasional Biologi 20, 479−484.

Hidayat, C., 2018. The utilization of insects as feedstuff in broiler diet. Wartozoa 28, 161−174.

Hwangbo, J., Hong, E.C., Jang, A., Kang, H.K., Oh, J.S., Kim, B.W., Park, B.S., 2009. Utilization of house fly-larva BSFs, a feed supplement in the production of broiler chickens. Journal of Environmental Biology 30, 609−614.

Jayanegara, A., Yantina, N., Novandri, B., Laconi, E.B., Nahrowi, Ridla, M., 2017. Evaluation of some insects as potential feed ingredients for ruminants: chemical composition, in vitro rumen fermentation and methane emissions. Journal of the Indonesian Tropical Animal Agriculture 42, 247−25.

Karthika, K., Sunilkumar N.S., Dixy, B.A., Sebastian, H., 2019. Comparative studies on the morphometry and percent organ weights of digestive tract in commercial broiler and layer chicken. The Pharma Innovation Journal 8, 994−997.

Khan, S.H., 2018. Recent advances in role of insects as alternative protein source in poultry nutrition. Journal of Applied Animal Research 46, 1144−1157.

Khempaka, S., Chitsatchapong, C., Molee, W., 2011. Effect of chitin and protein constituents in shrimp head meal on growth performance, nutrient digestibility, intestinal microbial populations, volatile fatty acids, and ammonia production in broilers. Journal of Applied Poultry Research 20, 1−11.

Lesson, S., Summers, J., 2005. Commercial poultry nutrition. 3rd ed. Nottingham Press, Nottingham.

Makinde, J.O., 2015. Maggot meal: a sustainable protein source for livestock production-a review. Advances in Life Science and Technology 31, 35−41.

Marzani, R., Samadi, Herawati., 2016. Effect of substitution amtabis fermented with aspergillus niger on the weight and the percentage of carcass broiler. Jurnal Ilmiah Mahasiswa Pertanian Unsyiah 1, 835−842.

Mawadah, S., Hermana, W., Nahrowi., 2018. Effect of feeding deffated BSF meal (*Hermetia illucens*) on production performance of laying quail (*Coturnix coturnix japonica*). Jurnal Ilmu Nutrisi Teknologi Pakan 16, 47−51.

Medion, 2020. Manajemen brooding ayam broiler. https://www.medion.co.id/manajemen-brooding-ayam-broiler/ (accessed 12 February 2024).

Megawati, D.H., 2011. Percentage of carcasses and commercial cut of broiler chickens fed vegetable and commercial diet. Undergraduate Thesis, Bachelor of Animal Science, Bogor Agricultural University.

Novita, R., Herlina, B., Marwanto., 2016. The influence of application of katuk leaf (Sauropus androgynus) as feed additive on the diet on carcass weight and giblet quail (*Coturnix coturnix japonica*). Jurnal Sain Peternakan Indonesia 11, 126−133.

Pahlepi, R., Hafid, H., Indi, A., 2015. Final carcass weight and abdominal fat percentage of broiler chickens by administering betel leaf extract (*Piper betle* L.) in drinking water. Jurnal Ilmu dan Teknologi Peternakan Tropis 2, 1−7.

Pangesti, T.U., Natsir, H.M., Sudjarwo, E., 2016. The effect used of jackfruit seed meal (*Artocarpus heterophyllus*) in diet on broiler giblet weights. Jurnal Ternak Tropika 17, 58−65.

Rambet, V., Umboh, J.F., Tulung, Y.L.R., Kowel, Y.H.S., 2016. Energy and protein digestibility of broiler chicken consuming maggot (*Hermetia illucens*) meal substituting fish meal in the diets. Zootek Journal 36, 13−22.

Rumondor, G., Maaruf, K., Tulung, Y.R.L., Wolayan, F.R., 2016. The effects of substitution of fish meal with maggot meal of black soldier (*Hermetia illucens*) in ration on broiler's carcass and abdominal lipid percentage's. Zootek Journal 36, 131−138.

Santi, M.A., 2018. The effect of Indigofera zollingeriana top leaf meal protein substitution with soybean meal protein in the diet on giblet of broilers. Jurnal Peternakan 2, 15−20.

Soetemans, L., Uyttebroek M., Bastiaens, L., 2020. Characteristics of chitin extracted from black soldier fly in different life stages. International Journal of Biological Macromolecules 165, 3206−3214.

Sukiman, D.L., Mutia, R., Martin, R.S.H., Nahrowi, Utari, T.A., Shofiah, M., Nugroho, J.E., 2023. Utilization of liquid probiotics from black soldier fly larvae (*Hermetia illucens*) fermentation on broiler chickens performance. Jurnal Ilmu Nutrisi Teknologi Pakan 21, 164−170.

Tumiran, M., Rompis, J.E.G., Mandey, J.S., Nangoy, F.J., Landok, J.J.M.R., 2019. The effect of feed restriction and source of different crude fiber on carcass weight and commercial pieces of broiler with Cobb strain. Zootec Journal 39, 122−133.

Veldkamp, T., Bosch, G., 2015. Insects: A protein-rich feed ingredient in pig and poultry diets. Animal Frontiers 5, 45−50.