Research Article

A Comparative Study of Fresh Blood and Probio FM–Fermented Tofu Waste as Growth Media for Black Soldier Fly (*Hermetia illucens*) and Their Application in Laying Quail Feed

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Abstract | This study aimed to determine the optimal growth media formulation and Probio FM utilization level to produce Black Soldier Fly (BSF) maggot meal with the best nutritional quality, as well as to evaluate the effect of BSF maggot meal inclusion in laying quail diets on production performance. The research consisted of two experimental stages. The first stage investigated the interaction between fresh blood and fermented tofu waste ratios combined with different Probio FM levels as growth media for BSF larvae. A Completely Randomized Design (CRD) in a factorial pattern was applied, consisting of two factors and three replications. Factor A was the ratio of fresh blood to tofu waste (1:2, 1:3, and 1:4), and Factor B was the Probio FM level (25, 50, and 75 ml/kg of growth media). The parameters measured were dry matter, crude protein, and crude fat contents of BSF maggot meal. The results showed no significant interaction between the blood-to-tofu waste ratio and Probio FM level on dry matter, crude protein, or crude fat contents. The second stage employed a CRD with five dietary treatments: A (control diet without BSF maggot meal), B (diet with 1.5% BSF maggot meal), C (3%), D (4.5%), and E (6%), each with four replications. The analysis of variance indicated that the inclusion of BSF maggot meal had no significant effect ($P>0.05$) on feed intake and egg weight, but had a highly significant effect ($P<0.01$) on egg mass, egg production, and feed conversion ratio (FCR). In conclusion, the ratio of fresh blood to tofu waste at 1:4 combined with 25 ml/kg Probio FM produced BSF maggot meal with high dry matter, high crude protein, and optimal crude fat content. Furthermore, inclusion of 6% BSF maggot meal in the diet maintained the production performance of laying quails, with feed consumption of 22.90 g/head/day, quail-day egg production of 72.53%, egg weight of 10.13 g/egg, egg mass of 7.35 g/egg, and a feed conversion ratio of 3.15.

Keywords | Black soldier fly (*Hermetia illucens*), BSF maggot, Probio FM, Fermentation medium, Laying quail feed, Production performance

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INTRODUCTION

Feed represents the largest cost component in poultry production; therefore, the availability of stable, affordable, and sustainable alternative protein sources is crucial. The black soldier fly (BSF, *Hermetia illucens*) has emerged as a promising candidate due to its high efficiency in bioconverting organic waste into protein- and lipid-rich biomass. Its growth performance and biochemical composition are strongly influenced by the type of substrate used (Lopes *et al*., 2024). The nutritional quality of BSF maggot meal including crude protein, lipid content, and fatty acid profile can be modulated through growth media formulation. Variations in substrate composition result in significant differences in larval protein and fat contents as well as growth performance, making substrate composition control essential for standardizing maggot meal quality (Fuso *et al*., 2021). Furthermore, because BSF larvae consume protein-rich substrates, the crude protein content of the pupae also tends to be high (Purnamasari *et al*., 2023).

Abundant agro-industrial by-products that can be utilized as BSF growth media include fresh slaughterhouse blood and tofu waste. Fresh blood is known to be very rich in protein and certain essential amino acids, making it a relevant nitrogen source for BSF larvae. The nutritional composition of bovine blood meal contains high crude protein (79.3%) and low crude fiber (0.31%) (Ramadhan *et al*., 2021). Tofu waste, on the other hand, contains high levels of protein and fiber, thus having great potential as a growth substrate and feed source to support BSF larval development. Its nutritional composition includes 23.55% crude protein and 36.41% crude fiber (Amalia *et al*., 2021).

Fermentation of the substrate is a promising approach to enhance nutrient availability, stabilize beneficial microbiota, and improve the palatability of BSF growth media. The use of probiotic cultures for fermenting food waste has been shown to improve BSF production and nutritional quality, highlighting the importance of determining the optimal level of probiotic inoculum. One such probiotic is Probio FM.

Probio FM is a liquid probiotic containing several species of lactic acid bacteria (LAB) with bacterial populations ranging from 10^{10}–10^{11} cfu/ml (Nadhira *et al*., 2022). It is widely used in the fermentation of both ruminant and poultry feeds. Probio FM can be utilized to ferment fibrous feedstuffs such as grass straw, corn straw, soybean residue, and oil palm fronds, as well as concentrate ingredients such as rice bran (Saelan *et al*., 2023). In addition to improving feed quality, Probio FM also supports gut health and reduces ammonia emissions from animal waste (Yusrizal *et al*., 2015).

The urgency of this research arises from the continuously increasing prices of conventional protein feed ingredients such as fish meal and soybean meal, necessitating the exploration of alternative, waste-based resources. Slaughterhouse blood and tofu waste can be bioconverted into high-protein BSF maggot meal, providing a cost-effective and sustainable solution. Furthermore, BSF maggots reared on substrates containing tofu waste and fresh blood can be utilized in laying quail diets to evaluate their effects on production performance.

Based on these considerations, this study aimed to determine the optimal ratio of fresh blood and tofu waste, along with the best Probio FM level for fermentation, to produce BSF maggot meal with superior nutritional quality. Subsequently, the BSF maggot meal was applied in laying quail diets to assess its effects on production performance.

MATERIALS AND METHODS

Experimental animals – Stage I

The materials used in this study included tofu waste, fresh blood, and Probio-FM. The tofu waste was obtained from a tofu processing factory located in Padang City, Indonesia. Fresh blood was collected from a cattle slaughterhouse in Padang City, Indonesia, while Probio-FM was sourced from Jambi University, Indonesia.

The BSF growth media were prepared in plastic containers measuring 30 cm × 20 cm × 12 cm, covered with mesh to prevent contamination. A rack cabinet was used as a rearing space for the black soldier fly (*Hermetia illucens*). Additional tools included a digital scale, spatula/spoon for mixing and handling the substrate during the experiment, and glass jars used as fermentation containers for the media.

Experimental animals – Stage II

The experimental animals used in the second stage of this study were 200 laying quails (*Coturnix coturnix japonica*) aged approximately 12 weeks (84 days), with an average egg production rate of 60% at the start of the trial. The quails were purchased from a local breeder in Payakumbuh City, West Sumatra Province, Indonesia.

Experimental diet

The experimental diets were formulated and mixed manually to contain 20% crude protein and 2,800 kcal/kg metabolizable energy. The feed ingredients and their nutritional composition are presented in Table 1, while the ingredient composition and percentage of each feed component used in the study are shown in Table 2.

Table 1: The feed ingredients and their nutritional composition.

Feed Ingredients	Nutrient composition							
	Crude protein	Crude fat	Crude fiber	Metabolizable energy	Calcium	Phosphorus	Methionine	Lysine
Corn	8.58	3.80	2.91	3340	0.06	0.01	0.20	0.20
Rice bran	10.60	4.09	10.84	1900	0.70	1.50	0.20	0.50
Soybean meal	40.07	1.71	2.73	2540	0.70	0.31	0.70	3.20
Meat and bone meal	43.81	0.96	3.96	2500	1.94	3.11	0.70	3.60
BSF maggot	32.35	33.04	9.23	4225	1.07	0.61	1.74	7.18
Corn gluten meal	51.67	2.85	0.39	3770	0.77	0.66	1.80	1.00
Premix	0.00	0.00	0.00	0.00	0.06	1.14	0.30	0.30
Limestone flour	0.00	0.00	0.00	0.00	38.0	0.17		
Top mineral supplement	0.00	0.00	0.00	0.00	32.5	1.00		

Note: Results of laboratory analysis.

Table 2: The ingredient composition and percentage of each feed component used in the study.

Feed Ingredients	Feed ingredient composition (%)				
	A	B	C	D	E
Corn	53.00	52.50	52.00	51.00	50.00
Rice bran	5.50	5.50	5.00	5.50	6.00
Soybean meal	14.00	14.00	14.00	14.00	14.00
Meat and bone meal	6.00	5.00	4.50	3.50	2.50
BSF maggot	14.00	14.00	14.00	14.00	14.00
Corn gluten meal	0.00	1.50	3.00	4.50	6.00
Premix	3.00	3.00	3.00	3.00	3.00
Limestone flour	4.00	4.00	4.00	4.00	4.00
Top mineral supplement	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100
Nutrient content					
Crude Protein (%)	20.00	19.90	20.00	20.00	19.90
Metabolizable energy (kcal/kg)	2806	2815	2833	2835	2837
Crude Fiber (%)	3.10	3.20	3.30	3.50	3.60
Crude Fat (%)	2.80	3.20	3.70	4.10	4.50
Calcium (%)	2.90	2.90	2.90	2.90	2.90
Phosphorus (%)	0.60	0.60	0.60	0.60	0.60
Methionine (%)	0.40	0.40	0.40	0.40	0.40
Lysine (%)	1.20	1.20	1.20	1.20	1.20

Experimental method – Stage I

The experimental method used in Stage I was a factorial experiment arranged in a Completely Randomized Design (CRD) with a 3 × 3 factorial pattern, consisting of three replications. The treatments were as follows:

Factor A: Ratio of fresh blood to tofu waste

A1 = Fresh blood: tofu waste (1:2)
A2= Fresh blood: tofu waste (1:3)
A3= Fresh blood: tofu waste (1:4)

Factor B: Level of Probio FM added to the growth medium

B1 = 25 ml/kg of growth medium
B2 = 50 ml/kg of growth medium
B3 = 75 ml/kg of growth medium

Experimental method – Stage II

The experimental method used was an experimental study employing a CRD with five treatments and four replications. The treatments were as follows:
A= 0% BSF maggot meal (control)
B= 1.5% BSF maggot meal
C= 3% BSF maggot meal
D= 4.5% BSF maggot meal
E= 6% BSF maggot meal

Research procedure

Preparation of growth media

The growth media used in this study consisted of fresh blood and tofu waste. The fresh blood was obtained from a slaughterhouse (RPH) in Bandar Buat, Padang City, Indonesia, while the tofu waste was collected from a tofu processing factory in Padang City, Indonesia. The Probio FM probiotic was obtained from the Faculty of Animal Science, University of Jambi. After obtaining the fresh blood and tofu waste, the two ingredients were mixed according to the respective treatments and then fermented with different levels of Probio FM as specified in the experimental design.

Procurement of BSF eggs

BSF (*Hermetia illucens*) eggs were purchased from a BSF breeder located in South Solok, Indonesia. The eggs were placed in hatching trays containing a mixture of tofu waste and fine rice bran as the rearing medium. The eggs were allowed to hatch and develop for eight days until the larvae reached a uniform size. Afterward, the larvae were separated from the hatching medium.

Fermentation of BSF growth media

A total of 400 g of fresh blood and 1,600 g of tofu waste were weighed and mixed thoroughly. The mixture was then fermented by adding Probio FM at a dose of 25 ml/kg of substrate. The fermentation process lasted for three days, after which the fermented substrate was ready to be used as the BSF larval growth medium.

Rearing of BSF maggots

Newly hatched BSF larvae (approximately 2 g) were introduced into 2 kg of the prepared growth medium (a mixture of fermented tofu waste and fresh blood with Probio FM). The moisture level and nutrient availability of the medium were monitored regularly. Additional fermented growth medium was provided periodically depending on the remaining feed availability in the rearing container. The growth media were placed in a shaded area to protect them from direct sunlight and rain.

Harvesting of BSF maggots

BSF maggots were harvested 15 days after hatching. The maggots were separated from the growth medium using a sieve to ensure complete removal of the substrate residues. The harvested maggots were then washed thoroughly with running water. Subsequently, the maggots were killed by immersion in hot water and dried in an oven at 60 °C until reaching a maximum moisture content of 14% (storage level). The dried maggots were then ground into maggot meal, which was later used as a feed ingredient for laying quails.

Observed parameters

Stage I- Nutritional composition of BSF maggot meal

The parameters observed in this stage were the nutritional composition of the produced BSF maggot meal, including dry matter content, crude protein content, and crude fat content, which were analyzed according to the methods of AOAC (2016).

Stage II- production performance

Feed intake

Feed intake was calculated by subtracting the amount of feed remaining from the amount of feed offered each day and expressed in grams per bird per day (g/head/day).

Egg production

Egg production was calculated by dividing the number of eggs produced per day by the number of live quails and then multiplying by 100% to obtain the hen-day egg production percentage.

Egg weight

Egg weight was determined by weighing the eggs. The average egg weight was calculated using the following formula:

$$\text{Average Egg Weight (g)} = \frac{\text{Total Egg Weight (g)}}{\text{Number of eggs}}$$

Egg mass

Egg mass was calculated by multiplying the average daily egg production by the average egg weight.

$$\text{Egg Mass (g/hen/day)} = \text{Egg Production (\%)} \times \text{Average Egg Weight (g)}$$

Feed conversion ratio (FCR)

Feed conversion ratio was calculated by dividing the total feed intake by the total egg mass produced.

$$\text{FCR} = \frac{\text{Feed Intake (g/hen/day)}}{\text{Egg Mass (g/hen/day)}}$$

Data analysis

All data obtained were statistically analyzed by analysis of variance. Differences between treatments were determined using Duncan Multiple Range Test (DMRT) (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

The effect of varying ratios of fresh blood and fermented tofu waste, combined with different levels of Probio FM as a growth medium, on the nutrient composition of BSF maggots was investigated. The dry matter content of BSF maggots reared on growth media consisting of fresh blood and fermented tofu waste with different Probio FM levels is presented in Table 3.

Table 3: Dry matter content of BSF maggots reared on growth media consisting of fresh blood and tofu waste fermented with different Probio FM levels.

Factor B	Factor A			Average^{ns}
	A1	A2	A3	
B1	94.47	93.93	94.74	94.38
B2	93.98	95.08	94.56	94.54
B3	93.03	93.26	94.66	93.65
Average^{ns}	93.83	94.09	94.65	

Note: ^{ns}= not significant (P > 0.05). Factor A: Ratio of fresh blood to tofu waste; A1= Fresh blood: tofu waste (1:2); A2 = Fresh blood : tofu waste (1:3); A3= Fresh blood: tofu waste (1:4). Factor B: Level of Probio FM in the growth medium; B1= 25 ml/kg of growth medium; B2= 50 ml/kg of growth medium; B3 = 75 ml/kg of growth medium.

The dry matter content of BSF maggots in this study ranged from 93.03% to 95.08%. Based on statistical analysis, there was no interaction between the ratio of fresh blood to tofu waste (Factor A) and the Probio FM level (Factor B) used as BSF growth media on the dry matter content of BSF maggot meal. Each factor both the fresh blood and tofu waste ratio (Factor A) and the Probio FM level (Factor B) had no significant effect (P > 0.05) on the dry matter content of BSF maggot meal.

The absence of significant differences in dry matter content was likely due to the similar moisture content of the growth media. The growth media composed of different ratios of fresh blood and tofu waste with various Probio FM levels showed moisture contents ranging from 19.57% to 24.18%, which were relatively similar. Both fresh blood and tofu waste themselves also have comparable moisture levels, with fresh blood containing approximately 80% water (Ndelekwute *et al*., 2016) and tofu waste containing about 84.1% water (Mahmud *et al*., 2009).

Using the same types of materials as BSF growth media tends to produce maggot meal with similar dry matter contents. Thus, the variations in the ratios of fresh blood to tofu waste and different Probio FM levels in this study did not affect the dry matter content of BSF maggot meal. Differences in dry matter composition are generally caused by differences in the types of substrates used as growth media for BSF (Barragán-Fonseca *et al*., 2017).

Table 4: Crude protein content of BSF maggots reared on growth media composed of fresh blood and tofu waste fermented with different levels of Probio FM.

Factor B	Factor A			Average
	A1	A2	A3	
B1	46.85	46.84	48.85	47.51
B2	46.68	46.05	48.31	47.01
B3	46.55	47.43	50.35	48.11
Average	46.69^{b}	46.77^{b}	49.17^{a}	

Note: $^{a-b}$ = significantly different (P < 0.05). Factor A: Ratio of fresh blood to tofu waste; A1 = Fresh blood : tofu waste (1:2); A2 = Fresh blood : tofu waste (1:3); A3 = Fresh blood : tofu waste (1:4). Factor B: Level of Probio FM in the growth medium; B1 = 25 ml/kg of growth medium; B2 = 50 ml/kg of growth medium; B3 = 75 ml/kg of growth medium.

As shown in Table 4, the crude protein content of BSF maggots in this study ranged from 46.05% to 50.35%. Based on statistical analysis, there was no interaction between the ratio of fresh blood to tofu waste (Factor A) and the Probio FM level (Factor B) used as BSF growth media on the crude protein content of BSF maggots. Factor A showed a significant effect (P < 0.05), while Factor B had no significant effect (P > 0.05) on the crude protein content of BSF maggots.

In this study, the treatment A3 (fresh blood : tofu waste = 1:4) resulted in better BSF growth with a crude protein content of 49.17% (Table 4). Meanwhile, the use of different Probio FM levels (25 ml/kg, 50 ml/kg, and 75 ml/kg of growth medium) did not affect the texture of the substrate and served primarily as a fermentation agent, showing no significant effect (P > 0.05) on the crude protein content of BSF maggot meal.

The higher crude protein content of BSF maggots in treatment A3 (49.17%) was attributed to optimal larval growth supported by sufficient nutrient availability in the growth medium, resulting in higher protein deposition in the maggots. The body weight of the larvae reflects the amount of nitrogen absorbed and the energy stored for organ and tissue development during metamorphosis (Horie and Watanabe, 1983). Larger maggots tend to have higher nutrient content, which is essential for growth and metamorphic processes (Andika *et al*., 2023).

Table 5: Crude fat content of BSF maggots reared on growth media consisting of fresh blood and tofu waste fermented with different levels of Probio FM.

Factor B	Factor A			Average^{ns}
	A1	A2	A3	
B1	13.69	12.39	11.82	12.63
B2	13.58	12.54	12.51	12.88
B3	13.86	13.12	13.02	13.33
Average^{ns}	13.71	12.69	12.45	

Note: ^{ns} = not significant (P > 0.05). Factor A: Ratio of fresh blood to tofu waste; A1 = Fresh blood : tofu waste (1:2); A2 = Fresh blood : tofu waste (1:3); A3 = Fresh blood : tofu waste (1:4). Factor B: Level of Probio FM in the growth medium; B1 = 25 ml/kg of growth medium; B2 = 50 ml/kg of growth medium; B3 = 75 ml/kg of growth medium.

As show in Table 5, the crude fat content of BSF maggots in this study ranged from 11.82% to 12.54%. Based on statistical analysis, there was no interaction between the ratio of fresh blood to tofu waste (Factor A) and the Probio FM level (Factor B) used as BSF growth media on crude fat content. Each factor individually also showed no significant effect (P > 0.05) on the crude fat content of BSF maggots.

The absence of interaction between the fresh blood-to-tofu waste ratio and the Probio FM level was likely due to the similar crude fat content of the growth media, which ranged from 4.22% to 5.73%. The nutrient composition of BSF maggot meal largely depends on the nutrient content of its growth substrate, including its fat content. The crude fat content of BSF maggots is strongly influenced by both the type of feed substrate and the developmental stage of the larvae (Stanley-Samuelson and Dadd, 1983).

In this study, the relatively low crude fat content of maggot meal was attributed to the high moisture content of the growth media. The water content of the media exceeded 80%, which may have limited fat synthesis and deposition in the maggots. Typically, the crude fat content of BSF maggot meal ranges between 29% and 32% (Bosch *et al.*, 2014). Moisture content is known to be closely related to both fat and protein levels (Suzuki, 1991).

The low fat content observed in this study may not be favorable for BSF development, as adult flies rely on stored fat reserves for survival. When these fat reserves are depleted, adult BSF tend to die earlier, reducing mating duration and consequently lowering egg production (Makkar *et al.*, 2014). Part of the fat reserves in BSF is utilized during oogenesis and for flight activity, indicating that lipids serve as an important energy source during the adult stage for maintenance, mating, and egg production (Chapman, 1998).

The combination of fresh blood waste (a high nitrogen source) and tofu waste (a source of carbon and fiber) has the potential to improve the balance of the carbon-to-nitrogen (C/N) ratio in the growth medium for BSF larvae. The C/N ratio is known as an important parameter that affects larval survival, bioconversion efficiency, and BSF growth performance because this ratio determines the availability of energy and nitrogen that can be utilized by larvae during the conversion of substrate into biomass (Lu *et al.*, 2021).

Substrates with a C/N ratio that is too low (excessively high nitrogen) can increase nitrogen loss through ammonification and NH_3 volatilization processes, thereby reducing the efficiency of nitrogen utilization for biomass formation. In contrast, a C/N ratio that is too high (carbon-dominant) can limit nitrogen availability for larval protein synthesis and reduce protein deposition, resulting in less optimal growth and nutritional quality of the larvae. This principle has been demonstrated in the processing of food waste by BSF, where C/N adjustment significantly affects larval performance and the efficiency of the bioconversion process (Lu *et al.*, 2021).

Mixing nitrogen-rich substrates (fresh blood) and carbon-rich substrates (tofu waste) provides an opportunity to produce a growth medium with a more balanced C/N ratio, thereby supporting more stable and efficient larval growth. Practically, the balance of carbon and nitrogen helps larvae optimize energy allocation for growth and maximize nitrogen retention in the form of body protein, which ultimately can improve the nutritional quality of maggot meal (Eriksen, 2024).

The results of this study indicate that the crude protein content of BSF maggots in treatment A3 (fresh blood: tofu waste= 1:4) produced better maggot protein content compared to other ratios, indicating higher protein deposition in larval biomass. The superiority of A3 is presumed to be due to an energy–nitrogen balance that better supports nutrient utilization efficiency, where the more dominant tofu waste provides carbon and energy for anabolic processes, while fresh blood contributes nitrogen and minerals as precursors for protein synthesis. Sufficient energy availability helps larvae utilize nitrogen more effectively for tissue formation, thereby suppressing nitrogen loss and increasing protein accumulation; this condition is consistent with reports that improving the quality and availability of protein/energy in larval feed can accelerate growth while increasing the nutritional value of BSF biomass (Schneider *et al.*, 2025).

This interpretation is consistent with the estimated C/N ratio of maggot biomass in this study, namely A1= 5.90:1, A2= 5.91:1, and A3= 5.65:1; the lower C/N value in A3 indicates a relatively higher nitrogen fraction in larval biomass and aligns with the increased crude protein content in that treatment. The fresh blood:tofu waste ratio of 1:4 is presumed to provide nutritional conditions that better support nitrogen retention and protein deposition during the larval growth phase, although the C/N values presented are still estimates and require confirmation through total carbon analysis in both the biomass and the growth medium.

The effect of BSF maggot meal, produced from fresh blood and tofu waste (1:4) fermented with Probio FM (25 ml/kg), on the performance of laying quails was evaluated. The impact of feeding diets containing BSF maggot meal on feed intake, daily egg production, egg weight, egg mass, and feed conversion ratio (FCR) is presented in Table 6.

Table 6: Effect of feeding laying quails with BSF maggot meal–based diets on feed consumption, daily egg production, egg weight, egg mass, and feed conversion ratio.

Treatment	Feed consumption (g/head/day)	Quail day egg production (%)	Egg weight (g/grain)	Egg mass (g/grain)	Feed conversion ratio
A	23.06	66.78^{a}	10.20	6.80^{a}	3.42^{a}
B	23.01	75.85^{b}	10.14	7.69^{b}	3.00^{b}
C	23.10	72.68^{b}	10.33	7.50^{b}	3.09^{b}
D	22.27	73.23^{b}	10.03	7.34^{b}	3.06^{b}
E	22.90	72.53^{b}	10.13	7.35^{b}	3.15^{b}
SEM	0.33	3.02	0.11	0.27	0.12

Note: $^{a-b}$ = significantly different ($P < 0.05$). SEM: Standard error of the mean. A = 0% BSF maggot; B = 1.5% BSF maggot; C = 3% BSF maggot; D = 4.5% BSF maggot; E = 6% BSF maggot.

Feed consumption of laying quails during the experiment ranged from 22.27 to 23.10 g/bird/day. Statistical analysis showed that the inclusion of BSF maggot meal had no significant effect ($P > 0.05$) on feed consumption. BSF maggot meal could be included up to 6% in the diet of laying quails without affecting feed consumption. This was influenced by the palatability and nutrient composition of the diets, which were similar across treatments.

Palatability refers to the attractiveness of a feed ingredient that stimulates appetite and feed preference in animals (Pond *et al*., 1995). It is an important factor influencing feed consumption, determined by taste, smell, and color, which are affected by the physical and chemical properties of the feed (Asril *et al*., 2016).

Since the nutrient content and energy levels of the diets were similar among treatments, feed consumption remained consistent. When poultry energy requirements are met, birds tend to stop eating, whereas if energy intake is insufficient, they continue to eat until their energy needs are satisfied. In this study, all diets were formulated to be isoproteic and isoenergetic, and feed was provided ad libitum, resulting in similar feed consumption among treatments. Diets containing the same levels of protein and energy (isoprotein and isocaloric) and meeting the nutritional requirements of laying quails typically show no significant difference in feed consumption (Lima *et al*., 2020). Feed consumption reflects the total amount of nutrients consumed from the diet to meet the bird's nutritional requirements (Ensminger, 1992).

Egg production during the study ranged from 66.78% to 75.85%. Statistical analysis revealed that the inclusion of BSF maggot meal had a highly significant effect ($P < 0.01$) on egg production. Treatments B, C, D, and E produced significantly higher egg production ($P < 0.01$) compared with the control (A). This improvement was attributed to the high lipid content in BSF maggot meal, which serves as an excellent energy source for egg production. The good nutritional quality of BSF maggot meal at certain inclusion levels makes it a suitable feed ingredient for laying quails. The use of maggot meal has been reported to positively affect egg production (Sumiati *et al*., 2022). Similarly, defatted BSF meal (5%) as a substitute for meat and bone meal (5%) increased body weight and reduced FCR in chickens (Nahrowi *et al*., 2024).

Egg weight of laying quails in this study ranged from 10.03 to 10.33 g/egg. Statistical analysis showed that the inclusion of BSF maggot meal had no significant effect ($P > 0.05$) on egg weight. The absence of significant differences among treatments was due to the similar feed quality and feed consumption across treatments. Egg weight is strongly influenced by the protein content of the diet; higher dietary protein levels are generally associated with heavier eggs (Agasi and Maulana, 2025). Factors that affect egg weight include feed type, feed quantity, housing environment, and feed quality (Rusfidra *et al*., 2025).

Egg mass in this study ranged from 6.80 to 7.69 g/egg. Statistical analysis indicated that BSF maggot meal inclusion had a highly significant effect ($P < 0.01$) on egg mass. Treatments B, C, D, and E showed significantly higher egg mass ($P < 0.01$) than treatment A (control). The lower egg mass in the control group was due to its lower egg production, as egg weight was similar across treatments. Egg mass is directly related to egg weight and egg production, since it is calculated as the product of these two parameters. Increases in either production rate or egg weight lead to a higher egg mass (Rusfidra *et al*., 2025). According to Leeson and Summers (2005), egg mass increases when egg production increases, and decreases when egg production declines.

Feed conversion ratio in this study ranged from 3.00 to 3.42. Statistical analysis showed that inclusion of BSF maggot meal containing omega-3 fatty acids had a highly significant effect ($P < 0.01$) on the FCR of laying quails. Treatments B, C, D, and E exhibited significantly lower FCR values ($P < 0.01$) compared with the control (A).

The lower FCR values in treatments B through E indicate better feed efficiency, as these groups achieved higher egg production with similar feed consumption. A lower FCR reflects higher feed utilization efficiency (Zhao *et al*., 2022). Feed conversion ratio is an important measure that reflects the efficiency of feed use in relation to productivity. Lower FCR values in quails indicate better conversion of feed nutrients into maintenance and egg production (Agasi and Maulana, 2025). FCR can be influenced by several factors, including nutrient content, egg production, egg weight, body weight, and feed palatability (Campbell *et al*., 2009).

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that the ratio of fresh blood to tofu waste at 1:4, combined with the use of Probio FM probiotic at 25 ml/kg of growth medium, produced BSF maggot meal with high dry matter, high crude protein, and optimal crude fat content. Furthermore, the inclusion of 6% BSF maggot meal in the diet was able to maintain the production performance of laying quails, with the following averages: feed consumption of 22.90 g/head/day, quail-day egg production of 72.53%, egg weight of 10.13 g/egg, egg mass of 7.35 g/egg, and a feed conversion ratio of 3.15.

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NOVELTY STATEMENT

1. This study presents a novel approach to optimizing growth media formulation using nutrient-rich waste materials (a mixture of fresh blood and tofu waste) fermented with Probio FM as a growth substrate for BSF. This approach integrates animal- and plant-based waste and has rarely been examined using a factorial experimental design.
2. The study provides new insights into the appropriate dosage of Probio FM for fermenting a mixture of fresh blood and tofu waste to be used as a growth medium for BSF maggots.
3. The research also investigates the use of BSF maggots reared on fermented fresh blood and tofu waste media as a feed ingredient for laying quails, focusing on their production performance.

AUTHOR'S CONTRIBUTION

MR contributed to conceptualization. FM and FF to data curation. SYA to validation. MKS and HSP to writing. M provided overall scientific supervision. H and PD to review and editing.

Ethical approval

This research complied with the ethical principles for the use of experimental animals as outlined in the Decree of the Minister of Agriculture of the Republic of Indonesia No. 306/KPTS/TN.330/4/1994 and in Law No. 18 of 2009 concerning Animal Husbandry and Animal Health, as amended by Law No. 41 of 2014.

Generative AI and AI-assisted technology statement

The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

Conflict of interest

All authors have declared no conflict of interest.

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