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Broiler growth performance and carcass production as affected by feeding larvae of the black soldier fly (Hermetia illucens)

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Abstract

Black soldier fly larvae meal (BSFLM) may substitute soy bean meal in chicken diets at cheap cost. The feed intake, growth performance, and carcass characteristics of broilers given a diet with different BSFLM levels were studied. In a totally randomised design, 60 day-old ROSS 308 broiler chicks fed a beginning commercial diet for three weeks were assigned to one of the three broiler grower dietary treatments. The control broiler grower diet (T1) had no BSFLM, T2 had 5%, and T3 had 10% replacing soybean meal. With a substantial difference ($p < 0.05$) in feed intake, the control had the greatest intake followed by 5% BSFLM inclusion. A substantial difference ($p < 0.05$) in ultimate live weight was observed, with the 5% BSFLM treatment having the greatest and the control the lowest. The addition of BSFLM significantly ($p < 0.05$) affected carcass and thigh weight, with the greatest mean for 5% BSFLM inclusion and the lowest for the control treatment. The slaughter weight, wings, drumstick, and breast muscles did not alter between treatments ($p > 0.05$). The research found that 5% BSFLM improved broiler chicken development, carcass production, and characteristics.

Keywords: broiler, carcass, feeding, growth, black soldier fly

Introduction

The worldwide population growth, lifestyle changes, and dietary choices have raised demand for animal protein (Boland et al., 2013). Sánchez-Muros et al. (2014) found that animal protein has a good mix of necessary amino acids and vitamins, making it preferred over plant protein. According to Kralik et al. (2017), chicken meat provides several health advantages including a lot of high-quality, readily digested protein, low saturated fat, and high polyunsaturated fatty acids (PUFA). Awareness of chicken meat's advantages and chicken farming expertise have made grill meat popular (Vernooij et al., 2018). consumption for animal protein has increased livestock feed consumption, putting strain on limited natural resources (Van Huis, 2013). This raised feedstuff prices because to strong demand and shortage. Feed expenses make up over 70% of chicken production costs (Raza et al., 2019), lowering farmer profitability. Protein component supplies like soybean meal and fishmeal are expensive and projected to become scarce (Makkar et al., 2014). Global warming and climate change may disrupt major chicken feed components and raise feed and energy prices, compromising food security (Nkukwana, 2012).

Recently, insect-based feed has become a popular protein source globally (Van Huis, 2013). The black soldier fly (Hermetia illucens) larvae (BSFL) are potential poultry feed ingredients (Khan, 2018; Barragan-Fonseca et al., 2017; Dörper, 2021). The BSFL can convert low-quality organic waste into high-quality protein (37–49%) and fat (7–39%) (Dörper et al., 2021), but higher crude protein (CP) and fat levels have been reported at 37% to 63% (Barragan-Fonseca et al., 2017) and 15% to 49% (Dabbou et al., 2018). BSFL provides nutritional and health advantages to chicken, including vital amino acids, CP content (≤ 53%), crude fat (≤ 58%), and calcium (≤ 7%) (De Souza Vilela et al., 2021). Rearing black soldier larvae on decaying organic waste reduces environmental waste and improves sustainable farming (Van Huis, 2013; Diener et al., 2011; Spranghers, 2017). However, BSFL larvae contain chitin (54 g/kg to 106 g/kg DM), the main component of insects' exoskeletons, which is indigestible and can reduce nutrient utilisation and protein digestibility by chitin-protein matrixes (Dörper et al., 2021).

Insects may replace protein-rich feedstuffs or ingredients in poultry diets and improve the sustainability of the poultry supply chain, according to recent studies. BSFLM in chicken diets has had mixed outcomes in numerous tests. The effects of BSFLM addition in Namibian broilers are unknown. It is generally recognised that the organic substrate predominantly affects the nutritional content of BSFL (Gobbi et al., 2013; Liland, 2017). Thus, this research examined how adding black soldier fly larvae meal (BSFLM) as a protein source affected broiler feed intake, growth performance, and carcass output.

Material and Methods

The research took place at the University of Namibia's Neudamm Campus, located at 22◦27′2″S, 17◦21′38″E, and 1856 m above sea level. Average day temperatures range from 30◦C in January to 20◦C in July, with nighttime temperatures ranging from 17◦C in January to 7◦C in June. Average yearly rainfall is 350–400 mm. Most rain falls from January to May (Mendelsohn, 2002).

A Completely Randomised Design (CRD) with three treatments duplicated five times assigned treatments to experimental units. The three experimental treatments were BSFLM 0% (T1), 5% (T2), and 10% (T3). 20 chicks were kept in 5 pens (experimental units), 4 per treatment, duplicated 5 times. A grower diet with yellow maize, wheat bran, soybean meal, and premix was the control. BSFLM meal was added to soybean meal at 5 and 10% to make treatments 2 and 3.

BSFL food was provided by Superfly Bio Converters, Northern Industry, Windhoek, Namibia. BSFL were fed wet brewer grain. Black soldier larvae were milled through a 3 mm sieve using a milling machine before feeding. Other experimental diet materials were from Animal Fedco Namibia, while the commercial diet beginning came from Agra, Namibia. The chicks were given a commercial starting feed for the first 3 weeks (0-21st days) and formulated diets from day 22 till the experiment ended. Tables 1 and 2 show the chemical makeup of BSFLM, SBM, and dietary therapies employed in this investigation.

Table 1: Chemical composition of black soldier fly larva meal and soybean meal used in the experiment.

Nutrient (% of DM)	BSFLM	SBM
Dry matter	92	93.4
Crude fat	28	2.3
Crude protein	49	49.9
Calcium	1.67	0.23
Phosphorus	1.25	0.65

BSFLM = Black soldier fly larva meal, SBM = Soybean meal

Table 2: Chemical composition (%DM) of the experimental diets.

Nutrient	T1 (0% BSFLM)	T2 (5% BSFLM)	T3 (10% BSFLM)
DM	92.59	90.95	93.06
Ash	3.10	3.07	3.96
CP	20.09	20.05	20.82
Crude fat	3.40	6.35	6.27
NDF	23.56	26.21	28.34
ADF	8.95	9.52	10.57
Ca	0.10	0.16	0.26
P	0.43	0.44	0.58

DM=dry matter, CP =Crude protein, NDF=Neutral detergent Fiber, ADF=acid detergent fiber, Ca=Calcium, P=Phosphorus.

Animal Fedco Namibia supplied 72 one-day-old chicks. At hatching, all birds were vaccinated against Newcastle disease, infectious bronchitis, fowl infectious laryngotracheitis, Marek's disease, and coccidiosis For the first three weeks, chicks were brooded in floor pens with infrared lights and fed commercial grill starter. Because chicks devour wood shavings, the floor was covered with paper cartons. Stress Pac (complex forte, vitamin and amino acid supplement) mixed in water was given to chicks for the first two weeks to reduce stress.

After three weeks, 60 birds were randomly allocated to experimental diets in 1.6 m × 1.5 m pens. There were 15 pens with 5 per treatment and 4 birds each pen. Wood shavings were used as bedding to absorb moisture, decrease bird-manure contact, and insulate the chilly floor. To avoid disease outbreaks and odours, wood shavings were replenished weekly. Daily cleaning of feeders and drinkers preceded feed and water adding. The experiment lasted 49 days, including a starting phase (0-21 days) and a combined grower and finisher period (22-49 days). Feed and water were provided ad libitum.

Subtracting surplus feed from daily feed given yielded feed intake. The birds were weighed at the start of the experiment and regularly to assess growth. BW = final weight - beginning weight. Divide the average feed mass by the grill mass to get feed conversion ratio (FCR). Daily avian mortality and health checks were done.

The birds were starved a day before killing to empty their crops, although water was accessible. For slaughter and carcass examination, one bird each pen was randomly picked. Slaughtered chickens were weighed before cervical dislocation. All birds were bled, scalded, plucked, and washed. The head, neck, and feet were removed. The carcasses were physically eviscerated, removing the neck, respiratory system, and oesophagus, then put in a chiller (4◦C) overnight for chilling and dripping. The vent and sternum were opened to remove the liver, spleen, heart, bursa, and gizzards by hand. The carcasses were weighed separately and given as live bodyweight percentages. Cut and weighed from carcass joints were drumsticks, thighs, wings, and breast muscles.

BSFLM, SBM, and experimental diets were sieved through 1 mm and kept in sealed plastic containers. Following the Association of Official Analytic Chemists' methods, samples were analysed for dry matter (#930.15), crude fat (#920.39), and crude protein (CP) (#954.01). Total nitrogen became crude protein by 6.25. The Van Soest et al. (1991) method was used to analyse feed samples for NDF and ADF using an ANKOM fibre analyzer. Calcium and phosphorus were measured using an ICP-OES (icap 6000 series).

The feed intake and live weight data were analysed using the general linear mixed effects model instead of repeated measures analysis of variance (ANOVA) to adjust for correlated errors from data taken from the same experimental units (pens). In SPSS version 27, significant differences were examined at 5%. The mathematical model for the Generalised linear model used is given in equation (1).

$$Y_{ijk} = \mu + \tau_i + W_j + (\tau \times W)_{ij} + cage(\tau)_{ki} + e_{ijk}, \quad (1)$$

where

Y_{ijk}	is the observation (weight or feed intake) taken from the k^{th} experimental unit of the i^{th} treatment in the j^{th} week
μ	is the overall mean for the experiment
τ_i	is the i^{th} treatment effect (i = 1, 2, 3 BSFLM inclusion levels)
W_i	is the effect of the j^{th} week (j = 1, 2, 3, 4 weeks)
$(\tau \times W)_{ij}$	is the i^{th} treatment and j^{th} week interaction
$cage(\tau)_{ki}$	is the effect of the k^{th} cage nested within the i^{th} treatment
e_{ijk}	random error term

The data on carcass components yield were analysed using the one-way ANOVA model equation (2)

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij} , \quad (2)$$

where

Y_{ij} is the observation (e.g. thigh, breast weight, of the j^{th} replicate of the i^{th} treatment (inclusion level)

μ is the overall mean for the experiment

τ_i is the effect treatment (i = 1, 2, 3 BSFLM inclusion level)

ε_{ij} is the random error of the j^{th} replicate of the i^{th} treatment Significant different means were detected using the Duncan Multiple Range test at 5% level of significance

Results

Table 3: Feed intake (g) per week of broilers fed the treatment diets.

TREATMENT	Week 4	Week 5	Week 6	Week 7	Week 8
T1 (0% BSFLM)	2134.20^{a}	1608.40	1933.80	1653.00	2524.60
T2 (5% BSFLM)	1401.00^{b}	1294.60	1572.40	1163.20	1882.00
T3 (10% BSFLM)	1740.00^{ab}	1505.40	1323.40	1492.60	1737.20
SEM	120.972	114.113	188.225	130.512	160.059
P-value	0.031	0.555	0.444	0.317	0.093

^{abcd}Means with different superscripts in a column differed significantly at $P < 0.05$

BSFLM 0% – control diet, BSFLM 5% – 5% inclusion of BSFLM, BSFLM 10% – 10% inclusion of BSFLM.

Table 4: The growth performance of broilers during the finisher phase (21- 49 d).

	Treatment diet				Sig.
Parameter	**T1(0%BSFLM)**	**T2(5%BSFLM)**	**T3(10%BSFLM)**	**SEM**	**Level**
Initial body weight (d21)/g	610.85	575.35	580.05	27.88	NS
Final Body Weight (d49)/g	1380.75^{b}	1745.35^{a}	1559.23^{a}	77.11	*
Feed Intake	2102.02^{a}	1462.64^{b}	1599.72^{b}	158.72	*
Ave. Daily Intake (g/day)	73.84^{a}	53.99^{b}	57.47^{b}	2.89	*
Ave. Daily Gain (g/day)	41.53	41.72	37.45	2.56	NS
Feed Conversion Ratio (g:g)	1.95	1.45	1.83	0.17	NS

[ab]Means in the same row with different superscripts differ significantly ($P < 0.05$); * = $P < 0.05$, NS = not significant ($P > 0.05$); SEM = Standard error of the mean.

Table 3 shows the birds' average weekly feed consumption throughout the trial. During week 4, birds given a diet without BSFLM (control diet) had a significantly higher feed intake (2134.20 g) than those fed 5% BSFLM (1401.00 g) ($p < 0.05$). Week four feed consumption was not significantly different ($p > 0.05$) between birds given a control diet and 10% BSFLM inclusion level or 5% and 10% BSFLM inclusion levels. At weeks 5, 6, 7, and 8, feed consumption did not vary across treatments ($p > 0.05$). Total bird feed intake and growth performance are shown in Table 4. Birds on the control diet had higher feed consumption ($p < 0.05$) throughout the grower and finisher stages compared to those on the BSFLM diets. Between 5% and 10% BSFLM addition, feed intake was not different ($p > 0.05$). Higher daily consumption ($p < 0.05$) was seen in birds on the control diet compared to those on identical BSFLM diets ($p > 0.05$). Final life weight of pigeons on three diets was not significantly different ($p > 0.05$). Bird feed conversion rates did not change ($p > 0.05$) across treatments.

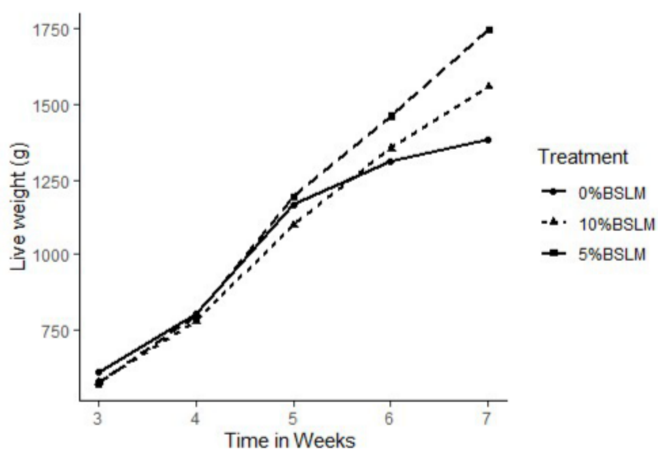

Figure 1: Live weight gain of the broiler birds fed the treatment finisher diets.

Figure 1 shows finisher growing birds' weekly live weights. Live weight at week 3, 4, and 5 was not significantly different between treatments ($p > 0.05$). 5% BSFLM inclusion treatment had a significantly greater live weight (1459.3 g) than control and 10% BSFLM inclusion (1310.1 and 1353.5 g, respectively) at week 6. The birds' live weight varied considerably ($p < 0.05$) across the three treatments at week 7. Birds on the 5% BSFLM inclusion diet weighed the most (1745.4 g), followed by those on 10% (1559.2 g) and the control (1380.8 g).

Table 5: Effects of diet on carcass characteristics and cuts yield.

	Treatment diet				Sig.
Yield	T1(0%BSFLM)	T2(5%BSFLM)	T3(10%BSFLM)	SEM	Level
Carcass characteristics					
Slaughter weight (g)	1453.6	1791	1553	117	NS
Carcass Weight (g)	972.40^{b}	1262.00^{a}	1076.80^{ab}	70.51	*
Dressing %	70.31	70.53	70.92	7.63	NS
Organ yield					
Wings (g)	125.2	147.4	131.8	14.45	NS
Drumstick (g)	161.6	196	166.8	14.45	NS
Thighs (g)	168.20^{b}	214.80^{a}	185.40^{a}	10.86	*
Breast muscles (g)	318.2	430	343.2	35.305	NS

^{ab}Means in the same row with different superscripts differ significantly ($P < 0.05$); * = $P < 0.05$, NS = not significant ($P > 0.05$); SEM = Standard error of the mean.

Table 5 shows how diets affect slaughter weight, carcass weight, wings, drumstick, thigh, and breast muscles. The treatments had similar slaughter weights ($p > 0.05$). The 5% BSFLM resulted in a significantly increased carcass weight (1262.00 g) compared to the control (972.40 g) ($p < 0.05$). The 10% BSFLM carcass weight was similar to the control and 5% BSFLM treatments ($p > 0.05$). The three treatments did not significantly vary in wing, drumstick, and breast muscle weight ($p > 0.05$). A substantial difference ($p < 0.05$) in thigh weight was seen between treatments. The 5% and 10% BSFLM treatments had heavier thighs than the control treatment (214.80 g and 185.40 g versus 168.20 g).

Discussion of Results

Chemical composition of BSFLM

In this investigation, BSFLM had DM content (92.8%) equivalent to Spranghers et al. (2017) but lower than De Marco et al. (2015), which showed 95.7%. BSFLM's main nutrient is protein. The crude protein content from this research (49% CP) was greater than Makkar et al. (2014) (41.1–43.6%). However, the present study's CP content was lower than Nguyen et al. (2015)'s 57.9% for BSL raised on fish waste. From 7% to 39% DM, BSL fat content varies most (Barragan-Fonseca et al., 2017). This study's crude fat content (28%) matches literature expectations.

Phosphorus is essential for bone growth. The BSFLM utilised in the research has 1.25% phosphorus, more than Dierenfeld and Kin (2009) but lower than Barragan-Fonseca et al. (2017). Another essential component for bone formation is calcium. The study BSFLM has 1.67% calcium, compared to 5.36% (Dierenfeld and Kin, 2009). The BSL's chemical makeup varies depending on the substrates the BSF was raised on to create larvae and the age at which they were gathered. This research found that BSFLM contained more crude fat, calcium, and phosphorus than SBM, but equivalent CP content. The nutritive value of commercial SBM varies based on factors such as seed variety, environmental conditions, and oil extraction method, but the CP content ranges from 41 to 50% (Ibáñez et al., 2020).

Growth performance

Black soldier larvae meal reduced feed consumption. Attivi et al. (2020) found a reduction in feed consumption at 6% and 8% BSFLM incorporation. BSFLM's high fat content may explain this. Veldkamp et al. (2005) found that high-energy diets reduce feed intake linearly. T1, T3, and T2 had different feed intakes. BSFLM-fed birds (T2 and T3) took longer to adjust to their diets than T1-fed chickens, who did not need to adapt to a commercial grill grower diet.

BSFLM improved chicken live weight and average daily growth in the research. Dabbou et al. (2018) also found that BSFLM increased live weight. In contrast, Onsongo (2017) found no effect of BSFLM incorporation on body weight. BSFL exoskeletons include chitin, a fibre, which may impair diet efficiency at greater inclusion levels. High chitin concentration may limit nutritional utilisation and digestibility (Hossain and Blair, 2007; Schiavone et al., 2018; El-Hack et al., 2020), reducing ultimate live weight.

Carcass characteristic and cut yield

According to Fernandes et al. (2013), grill breed carcass traits have improved significantly in recent decades, resulting in genetic advantages. Since breast and legs are the most costly cuts and well-priced, their yield is crucial (Fernandes et al., 2013). Dressing percentage was greatest in 5% BSFLM carcasses and lowest in control. This suggests that BSFLM increased bird carcass output. Thus, broiler diets with BSFLM increase carcass yield. Supplementing broiler diets with high-protein alternatives like BSFLM may reduce rising feeding costs. Since breast is one of the most costly and valuable carcass components in the processing business, birds administered 5% and 10% BSFLM had a greater breast production, which may increase meat yield (Attivi et al., 2020). Thigh weights differed greatly. Schiavone et al. (2018) found increased thigh weight at 0, 5%, 10%, and 15% BSFLM in broiler diets.

Conclusion

BSFLM contains protein and other nutrients including lipids, according to the research. Broiler development, carcass traits, and meat output enhanced by BSFLM. Thus, BSFLM may replace soybean meal in broiler diets up to 5% without affecting growth performance or carcass characteristics.

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