RESEARCH ARTICLE

Effect of Dietary Inclusion of Black Soldier Fly Larvae (*Hermetia Illucens*) on Nutrient Utilisation and Carcass Characteristics in Broiler Chicken

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Abstract

The current research was carried to evaluate the effect of dietary inclusion of black soldier fly larvae (BSFL) at different levels on nutrient utilization and carcass characteristics of broiler chicken. In a 42-days trial, a total of 120 day-old Cobb-430Y chicks were randomly allotted to four treatments T_1 (0% BSFL), T_2 (5%), T_3 (10%), and T_4 (15%) - each with three replicates of 10 birds, in a completely randomized design. A metabolizability study was conducted during the last 3 days of finisher phase to evaluate nutrient utilization and 2 birds per replicate were slaughtered on completion of 42 days to evaluate carcass characteristics. Results indicated increased metabolizability coefficients for dry matter ($p<0.05$), organic matter ($p<0.01$), crude protein ($p<0.05$) and ether extract ($p<0.01$) in broilers fed diets included with BSFL compared to control. CF and NFE digestibility was not ($p>0.05$) affected by BSFL inclusion. Significant increase in calcium ($p<0.05$) and phosphorus ($p<0.01$) retention (%) was noticed with increasing BSFL inclusion. Inclusion of BSFL up to 15% in the diet did not affect carcass characteristics like dressing per cent, ready to cook yield and per cent weights (%) of liver, heart, gizzard and giblet. Based on the results it is concluded that BSFL inclusion up to 15% level in the diet improved nutrient utilization without changing the carcass characteristics.

Key words: Broiler chicken, BSFL, Carcass characteristics, Nutrient utilization.

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Introduction

To meet the global food demand, broiler chicken production is crucial. In broiler production, feed contributes about 60-70% of the total cost of production. The availability of feeds for poultry nutrition is becoming more competitive. Efforts are being made to use alternative feedstuffs to substitute portions of soybean meal and yellow corn in poultry diets. In the recent years, there is a rising interest in the use of insect protein as a viable alternative to conventional protein sources particularly the black soldier fly *(Hermetia illucens)* larvae (BSFL), have emerged as a promising substitute.

Black soldier fly larvae contain approximately 31 to 45 % crude protein in dry matter, and are rich in minerals such as Ca and P, implying its importance as feed ingredient in the chicken diets (Maurer *et al.,* 2016). Hence, this study was aimed to evaluate the effect of dietary inclusion of black soldier fly larvae on the nutrient utilization in broiler chicken.

Materials and Methods

The trial was conducted at the poultry experimental unit, LFC, and the chemical analysis was performed at the Department of Animal Nutrition, NTR College of Veterinary Science, Gannavaram, Andhra Pradesh (India). A total of 120 day-old broiler chicks (Cobb-430 Y) were allotted to four treatment groups, with each group containing three replicates of 10 birds each, in a Completely Randomized Design. These groups were subjected to different dietary regimens with BSFL meal inclusion levels of 0% (T_1), 5% (T_2), 10% (T_3) and 15% (T_4) across pre-starter, starter and finisher phases as per BIS (2007). A metabolism trial was executed during the last three days of the experiment. Two birds from each replicate thus a total of 24 birds from four treatments were transferred to individual metabolic cages for fecal collection

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in order to evaluate nutrient utilization including calcium and phosphorus retention. Daily feed offered and refusals were recorded. Collected fecal matter from each replicate was frozen at -20ºC in a deep freezer, pooled for three days, dried at 60°C for 48 h, ground, and preserved for nutrient analysis. Crude protein and moisture were assessed in fresh samples, while further analyses were conducted on dried material. Apparent digestibility was calculated using the formula

Apparent digestibility coefficient

$$= \frac{\text{Nutrient in feed} - \text{Nutrient in feces}}{\text{Nutrient in feed}} \times 100$$

At the end of 6-week trial period, two birds per replicate (total six birds per treatment group) were randomly chosen, weighed and sacrificed. The study recorded several parameters including dressing percentage, ready-to-cook yield, and the individual giblet weights.

Proximate composition of BSFL, feed ingredients, final experimental diets and fecal samples were analyzed by following the protocols of AOAC (2007). Calcium and phosphorus contents were assessed using the methods of Talapatra *et al.* (1940).

Statistical Analysis

Data were subjected to one-way analysis of variance using SPSS version 23.0 (Snedecor and Cochran, 1994). Significant treatment differences were identified using Duncan's multiple range test at p<0.05.

Results and Discussion

The chemical composition of Black Soldier Fly Larvae (BSFL) used in the present study is presented in Table 1. The per cent DM, OM, CP, EE, CF, NFE, TA, AIA, Ca and P of BSFL were 96.22, 86.11, 34.91, 32.93, 13.18, 5.08, 13.89, 1.65, 1.62 and 0.98, respectively, on dry matter basis. The CP content of BSFL recorded in the present study was lower than the values reported by Onsongo *et al.* (2018), Waithaka *et al.* (2022), Auza *et al.* (2023), and La Mantia *et al.* (2023), who observed CP values from 43.90 to 58.05 % in BSFL meal. The EE content of BSFL meal in the present study was higher than the values of 11.90 and 19.05 % reported by Auza *et al.* (2023) and La Mantia *et al.* (2023), respectively, indicating that the BSFL meal used in the present study was in an un-defatted form.

Table 1: Chemical composition* (%) of feed ingredients

Nutrient	BSFL	Maize	DORB	SBM
Dry matter (DM)	96.22	92.01	93.06	88.01
Organic matter	86.11	98.42	83.35	91.68
Crude protein	34.91	10.10	17.52	49.53
Ether extract	32.93	5.20	1.66	2.81
Crude fibre	13.18	2.04	21.81	9.24
Nitrogen free extract	5.08	81.08	42.36	30.10
Total Ash	13.89	1.58	16.65	8.32
Acid insoluble ash	1.65	0.36	6.21	1.52
Calcium (%)	1.62	0.14	1.04	0.59
Total phosphorus (%)	0.98	0.17	1.35	0.63

*On dry matter basis, except for DM. DORB-Deoiled rice bran, SMB-Soybean meal

Chemical composition of experimental diets is given in Table 2. The CP estimated and ME calculated in all the experimental diets (T_1, T_2, T_3 and T_4) during different phases of growth were within the range of specifications recommended by BIS (2007). The ether extract content of the experimental diets increased gradually with increasing levels of BSFL meal inclusion across all phases, ranging from 6.75 to 8.84, 7.79 to 9.24, and 9.11 to 10.45 % in the pre-starter, starter, and finisher diets for T_1 to T_4, respectively. This trend was an expected consequence of the high EE content of the BSFL meal used in the present study, and a comparable increase in dietary ether extract with increasing BSFL meal inclusion was reported by Heuel *et al.* (2022), who noted that insect-based diets had considerably higher fat content relative to soybean-based control diets.

Metabolizability of Nutrients

The apparent total tract digestibility coefficients of dry matter (DM), organic matter (OM), crude protein (CP), crude fibre (CF), ether extract (EE), and nitrogen-free extract (NFE) of diets with BSFL inclusion are presented in Table 3. BSFL inclusion increased digestibilities of dry matter (p<0.05), organic matter (p<0.01), crude protein (p<0.05) and ether extract (p<0.01) with highest digestibilities witnessed in T_4. Crude fibre and NFE digestibilities among experimental groups did not differ significantly. Auza *et al.* (2023) reported significant (p<0.01) increase in crude fat digestibility in line with the present study and in contrast, non-significant variation in digestibilities of crude fibre and crude protein in village chicken with level of BSF inclusion in which fish meal was replaced at 0, 25, 75 and 100 % in the diet. Similarly, Schiavone *et al.* (2017) also observed significant increase (p<0.01) in digestibility of ether extract and non-significant variation in digestibility of DM, OM and CP of broiler chicken fed basal diet substituted BSFp (partially defatted) at 250 g/kg compared to BSFh (highly defatted) The higher CP digestibility in BSFL-supplemented groups in the present study aligned with the findings of Kareem *et al.* (2018), who reported higher CP digestibility in broilers fed increasing levels of larvae meal and attributed this to the well-balanced essential amino acid profile and high biological value of insect protein, which facilitates more efficient proteolytic digestion in the gastrointestinal tract.

The significantly higher EE digestibility in T_4 compared to the other groups likely reflects the interaction between the higher dietary fat content in T_4 and the emulsification properties of medium-chain fatty acids present in BSFL, particularly lauric acid, which are known to be more readily absorbed in the small intestine than long-chain fatty acids (Seyedalmoosavi *et al.*, 2022). In contrast to our study, Bovera *et al*. (2016) reported that apparent ileal digestibility of DM, OM and CP was lower in broilers fed diet in complete replacement of SBM with *Tenebrio molitor* larvae meal, and attributed this to the higher chitin content of the insect meal which may have hindered digestive enzyme activity. The improvement in DM and OM digestibility at lower BSFL inclusion levels (5-15%) in the present study, as opposed to the depression observed at complete replacement in the study by Bovera *et al*. (2016), suggests that moderate BSFL supplementation does not compromise and may even enhance overall nutrient digestibility in broilers.

The calcium and phosphorus utilization in broiler chickens fed diets containing graded levels of BSFL meal are presented in Table 4 and 5, respectively. Incorporation of BSFL in broiler diets increased (p<0.05) calcium retention (%) at 15% BSFL inclusion. Incorporation of BSFL in the diet increased phosphorous balance (p<0.05) and phosphorous % retention (p<0.01) with inclusion level. The improved phosphorus balance and retention at higher BSFL inclusion levels may be due to the higher phytate-free phosphorus fraction in insect-based diets compared to plant protein sources like SBM, in which a significant proportion of phosphorus is bound in the form of phytate and is thus less available for intestinal absorption (Bovera *et al.,* 2016; Seyedalmoosavi *et al.,* 2022).

Table 2: Ingredient and chemical composition (%) and diet cost of broiler finisher diets

	Pre-starter				Starter				Finisher			
Ingredient (%)	**T_1 (0%)**	**T_2 (5%)**	**T_3 (10%)**	**T_4 (15%)**	**T_1 (0%)**	**T_2 (5%)**	**T_3 (10%)**	**T_4 (15%)**	**T_1 (0%)**	**T_2 (5%)**	**T_3 (10%)**	**T_4 (15%)**
Maize	49.2	48.97	48.82	48.37	52.10	51.78	51.38	50.98	56.50	56.26	55.76	55.46
DORB	5.00	5.00	5.00	5.00	3.30	3.30	3.30	3.30	2.50	2.50	2.50	2.50
Soybean meal	38.42	34.9	31.25	27.7	36.13	32.55	29.05	25.55	31.20	27.60	24.10	20.50
BSFL	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00
Vegetable oil	4.10	2.90	1.70	0.70	5.30	4.20	3.10	2.00	6.66	5.50	4.50	3.40
Limestone	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Di Ca phosphate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Additives*	0.98	0.93	0.93	0.93	0.87	0.87	0.87	0.87	0.84	0.84	0.84	0.84
Total	100	100	100	100	100	100	100	100	100	100	100	100
Chemical composition**												
Crude protein	23.08	23.01	23.05	23.04	22.01	22.05	22.14	22.06	20.11	20.01	20.08	20.03
Ether extract	6.75	7.86	8.39	8.84	7.79	8.41	8.69	9.24	9.11	9.45	9.89	10.45
Crude fibre	5.62	5.64	5.73	6.02	5.35	5.63	5.99	6.26	5.16	5.33	5.57	6.01
NFE	53.81	52.80	51.89	50.93	55.33	53.96	52.57	51.78	56.42	55.61	54.88	53.12
Total Ash	8.09	8.12	8.53	8.84	7.23	7.74	8.51	8.71	7.06	7.51	7.59	8.46
AIA	1.81	1.84	1.92	1.96	1.80	1.82	1.89	1.94	1.65	1.72	1.81	1.93
ME kcal/kg***	3007.7	3008.5	3008.6	3015.7	3099.7	3103.1	3106.0	3108.9	3200.2	3201.5	3208.3	3211.9
Ca (%)	1.07	1.25	1.27	1.34	1.04	1.07	1.15	1.21	0.94	0.95	0.97	1.12
P (%)	0.57	0.58	0.67	0.70	0.57	0.60	0.62	0.65	0.63	0.65	0.66	0.67

*Additives: Lysine HCl, DL Methionine, Vitamin AB_2D_3 premix, choline chloride, coccidiostat, trace mineral mixture, and common salt.

** On dry matter basis except for DM and CP, *** ME calculated value

Table 3: Effect of BSFL on nutrient utilization (%) of proximate constituents in broiler chicken

Treatment (% BSFL)	DM	OM	CP	CF	EE	NFE
T_1 (0)	70.14^b±1.32	73.61^b±1.21	54.11^b±0.34	41.43±1.53	71.67^c±0.47	77.54±1.74
T_2 (5)	73.83^a±1.35	76.98^{ab}±1.15	57.74^a±0.94	42.77±2.69	75.90^b±0.05	77.68±1.44
T_3 (10)	74.10^a±1.02	77.70^a±1.09	57.76^a±0.38	42.91±2.45	76.37^b±0.40	78.08±1.59
T_4 (15)	76.38^a±0.67	79.34^a±0.64	59.21^a±1.70	43.34±1.52	78.65^a±0.56	79.23±1.38
n	3	3	3	3	3	3
P	0.03	0.01	0.04	0.37	0.00	0.03
SEM	0.83	0.85	0.71	1.08	0.47	1.15
SS	*	**	*	NS	**	NS

Values in column bearing different superscripts (abc) differ significantly *p<0.05, **p<0.01, NS: Non- significant.

Table 4: Effect of BSFL on calcium retention of broiler chicken

Treatment/% BSFL	Ca intake (g)	Ca outgo (g)	Ca balance (g)	Ca retention (%)
T_1 (0)	1.20±0.03	0.63±0.01	0.57±0.02	47.61^b±0.87
T_2 (5)	1.44±0.10	0.75±0.05	0.69±0.05	47.81^b±0.98
T_3 (10)	1.37±0.10	0.73±0.05	0.64±0.05	46.41^b±1.21
T_4 (15)	1.60±0.18	0.77±0.08	0.82±0.09	51.47^a±0.63
n	3	3	3	3
P	0.18	0.32	0.09	0.03
SEM	0.06	0.03	0.04	0.70
SS	NS	NS	NS	*

Values in column bearing different superscripts (ab) differ significantly *(p<0.05), NS: Non significant

Table 5: Effect of BSFL on phosphorus retention of broiler chicken

Treatment (% BSFL)	P intake (g)	P outgo (g)	P balance (g)	P retention (%)
T_1 (0)	0.80±0.02	0.58±0.02	0.22^b±0.01	27.24^d±0.30
T_2 (5)	0.98±0.07	0.67±0.04	0.32^{ab}±0.03	32.04^c±1.03
T_3 (10)	0.93±0.07	0.60±0.04	0.34^a±0.03	35.98^b±0.82
T_4 (15)	0.95±0.10	0.55±0.05	0.41^a±0.05	42.37^a±1.29
n	3	3	3	3
P	0.36	0.25	0.03	0.00
SEM	0.04	0.02	0.03	1.72
SS	NS	NS	*	**

Values in column bearing different superscripts (abc) differ significantly *p<0.05, **p<0.01, NS: Non significant

Carcass Characteristics

The effect of dietary inclusion of BSFL on dressing percentage, ready-to-cook yield (RCY), and relative weights of internal organs of broiler chicken is presented in Table 6.

Dressing percentage and RCY were not significantly affected (p>0.05) by dietary treatments. The non-significant effect of BSFL inclusion on dressing percentage in the present study was consistent with the findings of Onsongo *et al.* (2018), Oddon *et al.* (2021), Lalev *et al.* (2022) and Brah *et al.* (2024). In contrast, Murawska *et al.* (2021) and Nampijja *et al.* (2023) reported decreased dressing percentage in broilers fed diets containing BSFL compared to control, whereas, Auza *et al.* (2023) observed increased (p<0.05) carcass yield with inclusion of BSFL in broiler chicken diets.

The relative weights (%) of liver, heart, gizzard, and giblets were not influenced (p>0.05) by dietary treatments. The non-significant effect of BSFL inclusion on internal organ weights in the present study was in agreement with Lalev *et al.* (2022) and Brah *et al.* (2024), who reported no significant differences in the relative weights of liver, gizzard, and heart in broilers fed insect-based diets compared to conventional SBM-based control diets. The stable organ weights across all dietary treatments in the present study confirm that BSFL meal inclusion at up to 15 % did not cause any organomegaly or organ atrophy and therefore did not compromise the health or physiological integrity of the birds, supporting the safety of insect meal inclusion at moderate levels in broiler nutrition.

Conclusion

Based on the results it can be concluded that inclusion of black solider fly larvae (BSFL) up to 15% level in the diet of broilers improved nutrient utilization without any effect on carcass parameters.

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Table 6: Effect of BSFL on Carcass parameters of broiler chicken

Treatment	Dressing wt (%)	RCY (%)	Liver (%)	Heart (%)	Gizzard (%)	Gibblet (%)
T1(0)	66.84±0.74	71.18±0.80	1.91±0.10	0.62±0.05	1.82±0.04	4.34±0.14
T2(5)	68.03±0.53	72.22±0.51	1.92±0.09	0.54±0.02	1.73±0.08	4.19±0.12
T3(10)	67.96±0.37	72.21±0.39	1.93±0.05	0.56±0.01	1.76±0.08	4.25±0.09
T4(15)	68.39±0.41	72.38±0.40	1.89±0.07	0.56±0.02	1.62±0.12	3.99±0.05
n	6	6	6	6	6	6
p	0.22	0.42	0.99	0.26	0.43	0.14
SEM	0.28	0.28	0.04	0.01	0.04	0.06
SS	NS	NS	NS	NS	NS	NS

NS: Non significant

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