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Research Article
Live Black Soldier Fly Larvae Ingestion In Broiler Chickens Growth Performance and Carcass Quality Characteristics

[1]Brah, Nouri, [2]Moussa, Hassan Ousseini, [1]Zounon, Felix, [1]Abdoulaye, Ousseina and [1]Amadou, Laouali

[1]National Institute of Agricultural Research of Niger (INRAN), BP: 429, Niamey, Niger
[2]Department of Animal Production, Faculty of Agronomy and Environmental Sciences, Dan Dicko Dankoulodo University of Maradi, P.O. Box 465, Maradi, Niger

Abstract

Objective: This study aimed to evaluate the effects of the gradual ingestion of live Black Soldier Fly Larvae (LBSFL) prior to feed distribution on the growth performance and carcass quality characteristics of broiler chickens. **Materials and Methods:** A total of 80 unsexed COBB 500 broiler chickens, 21 days of age, were used in a 4-week feeding trial. Birds were randomly assigned to 20 batches (4 birds per batch) housed in a 50 m^2 (10 m×5 m) poultry facility. Four dietary treatments were formulated: a control group without LBSFL supplementation (LBSFL0) and three experimental groups receiving 3 g (LBSFL3), 6 g (LBSFL6), or 9 g (LBSFL9) of live larvae per bird per day, administered prior to the distribution of the commercial feed. Each treatment was randomly allocated to five replicate batches. Growth performance parameters included feed intake, live body weight, Average Daily Gain (ADG) and Feed Conversion Ratio (FCR). Carcass characteristics measured were carcass weight and yield, viscera weight, full intestine weight, empty gizzard weight and liver yield. Orthogonal polynomial contrasts were applied to evaluate linear and quadratic effects of increasing LBSFL ingestion levels on growth and carcass parameters. **Results:** Feed intake and FCR were not significantly influenced by LBSFL supplementation ($p>0.05$). However, live body weight and ADG significantly increased ($p<0.05$) with higher levels of LBSFL ingestion. Among carcass characteristics, only the empty gizzard weight was significantly affected ($p<0.05$), while other organ and carcass yields remained unchanged ($p>0.05$). **Conclusion:** The inclusion of live Black Soldier Fly Larvae at levels up to 9 g per bird per day can be safely incorporated into broiler diets without adverse effects on growth performance or carcass quality. Further economic evaluation is recommended to determine the most cost-effective inclusion rate for commercial production.

Key words: Broiler chickens, carcass quality, growth performance, live BSF larvae

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Corresponding Author: Nouri, Brah, Department of Animal Production, National Institute of Agricultural Research of Niger (INRAN), BP: 429, Niamey Niger Tel: (+227) 96126256/90999066

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

To meet the growing human demand for animal-derived protein, poultry production represents one of the most efficient and sustainable sectors, particularly in terms of environmental impact and feed resource utilization[1]. However, the continuous expansion of poultry production inevitably increases the demand for feed ingredients, thereby exerting additional environmental pressure. This challenge has encouraged researchers to explore and develop alternative protein sources, including the incorporation of insects into poultry feed[2].

Due to their potential for large-scale production and their contribution to circular economy systems-where food and feed waste are reduced through bioconversion-insects such as Black Soldier Fly larvae, grasshoppers, mealworms, housefly larvae and crickets have been successfully evaluated as protein sources in non-ruminant and aquaculture feeds[3].

Among these, the Black Soldier Fly larvae (BSFL) have received particular attention for their role in enhancing circularity and sustainability within the feed value chain . BSFL can efficiently bioconvert organic waste materials, including cattle, chicken, or pig manure, into nutrient-rich larvae containing approximately 40% crude protein and 35% fat on a dry matter basis, while the residual frass retains valuable nutrients such as nitrogen and phosphorus[4-6]. Furthermore, the amino acid profile of BSFL typically includes 0.7-0.9% methionine, 2.3-2.6% lysine, 2.3-2.8% valine and 1.8-2.0% arginine[7-9] .

These nutritional and functional characteristics make BSFL an attractive and sustainable alternative to conventional protein ingredients, which are often expensive and compete directly or indirectly with human food resources[10].

Used BSFL Meal (BSFLM) as fishmeal substitute in broiler chicken diets improved broiler growth performance, crude protein digestibility and specific amino acid digestibility[11]. As replacement of 12% soybean meal in broiler chicken diets, BSFLM increased significantly growth performance, hematological and intestinal morphology characteristics as well as improved meat quality[12]. Fruci *et al.*[13] observed that during broiler starter phase, incorporation of BSFLM can enhance broiler growth, thus minimizing the need of antibiotics in poultry diets.

Most literature focused on BSFLM in broiler chickens' diet, while information about live larvae is lacking. However, the use of live larvae is viable and could promote new feeding practice and feasible strategy in poultry production[14-15].

The objective of this study is to evaluate the gradual ingestion of live BSFL before diet distribution in broiler chickens' growth performance and carcass quality.

MATERIALS AND METHODS

Experiment poultry house and chickens: This study was conducted at the Regional Center for Agronomic Research in Maradi, Niger in August 2025. A 50 m^2 (10 m$\times$5 m) poultry house was used for experiment. It was subdivided into 20 lots/boxes. The dimension of each lot/box was 2 m^2 (2 m$\times$1m). The poultry house was cleaned, disinfected with a standard product recommended in Niger and quarantined for two weeks before the start of the experiment.

A total of 80 unsexed broilers of COBB 500 strain (21 day-old) weighing 802$\pm$66 g was used in this study. At the start of the experiment, the chickens were distributed into the 20 lots/boxes with 4 chickens per batch. The birds were reared on floor pens bedded with peanut shell litter for a 4-week experimental period. Prior to the commencement of the trial, all birds were vaccinated against Newcastle disease, prophylactically treated to prevent coccidiosis and managed for post-vaccination reactions and heat stress. During the experimental period, measures were also taken to prevent calcium deficiency.

Live larvae and feed procurement: Live Black Soldier Fly Larvae (LBSFL) were produced in the Entomology Laboratory of the Maradi Regional Center for Agricultural Research, where the colony has been maintained since 2022. To obtain young larvae, Black Soldier Fly eggs were incubated in broiler starter feed at a ratio of 1 g of eggs per 15 g of feed for 4 days. Subsequently, the newly hatched larvae were transferred to production trays and reared for 12 days using a substrate composed of squash, potato peels, cabbage and orange fruit in proportions of 10, 40, 10 and 40%, respectively. The larvae were stocked at a density of 4 g of young larvae per 3 kg of substrate.

After 12 days of development, the larvae were subjected to a purging process by placing them in wheat bran for 12 hrs, followed by rinsing with warm tap water prior to experimental use.

The basal diet consisted of a commercial broiler pellet feed obtained from the local market, formulated to provide 3050 kcal/kg of metabolizable energy, 20% crude protein, 4.5% fat, 5% crude fiber, 1.2% lysine, 0.53% methionine, 0.90% calcium and 0.45% available phosphorus.

Experimental design: Four experimental diets were formulated for this study. The control group (LBSFL0) received no live Black Soldier Fly Larvae (LBSFL), while the other three treatment groups were supplemented with 3 g (LBSFL3), 6 g

(LBSFL6) and 9 g (LBSFL9) of LBSFL per bird, administered prior to the distribution of the commercial feed. The four dietary treatments were randomly allocated to 20 batches, with five replicates per treatment.

The evaluated parameters included zootechnical performance and carcass quality characteristics. During the 4-week experimental period, live larvae were provided daily by placing them in the feeders before offering the commercial feed. Birds had ad libitum access to the commercial diet throughout the study.

Date collection: Growth performance parameters recorded in this study included feed intake, live weight, Average Daily Gain (ADG) and Feed Conversion Ratio (FCR). Feed intake (g/day) was determined daily for each box as the difference between the quantity of feed distributed and the refusals. The average feed intake per bird was obtained by dividing the total feed consumed by the number of chickens in the respective batch. The initial body weight of the broilers was recorded at the beginning of the experiment and the final body weight was measured at the end. All chickens were weighed individually. The average live body weight (g) for each batch was calculated as the ratio of the total weight (g) to the total number of birds within that batch.

The average daily gain (ADG, g/day) was calculated as the difference between the final and initial average body weights, divided by the duration of the experimental period, representing the growth rate of the chickens. The Feed Conversion Ratio (FCR) was calculated as the ratio of the average feed intake to the average weight gain over the corresponding period.

Carcass characteristics were assessed by slaughtering five chickens per dietary treatment. The parameters measured included carcass weight, carcass yield, viscera weight, full intestine weight, empty gizzard weight and liver weight. Carcass and organ yields were expressed as a percentage of the live body weight at slaughter.

Data processing and statistical analysis: Data were entered and organized using Microsoft Excel® 2023. Statistical analyses were conducted using R software (version 4.4.3). Mean values and Standard Errors of the Mean (SEM) were calculated and one-way analysis of variance (ANOVA) was performed to evaluate the effect of dietary treatments. Orthogonal polynomial contrasts were applied to assess linear and quadratic trends associated with the gradual ingestion of Live Black Soldier Fly Larvae (LBSFL) on broiler feed intake, body weight, average daily gain, feed conversion ratio and carcass quality traits. When significant differences were detected, mean comparisons were performed using the Student-Newman-Keuls (SNK) test at a 5% significance level ($p<0.05$).

RESULTS

Growth performances: The ingestion of Live Black Soldier Fly Larvae (LBSFL) prior to feed distribution did not significantly influence feed intake in broiler chickens (Table 1), either linearly ($p = 0.075$) or quadratically ($p = 0.179$). Nevertheless, birds that did not receive live larvae consumed slightly more feed overall. Among the groups receiving live larvae (LBSFL3, LBSFL6 and LBSFL9), feed intake exhibited a gradual increase with the rising inclusion level of LBSFL (Table 1).

At the beginning of the trial, the difference in live weight among treatments was 43 g, with the LBSFL6 group showing the highest initial live weight and the LBSFL3 group the lowest (Table 1). This difference was not statistically significant ($p>0.05$). By the end of the experimental period, broilers in the control group (LBSFL0) achieved a higher final live weight (2807 g), differing significantly ($p = 0.007$) by 346 g from the LBSFL3 group, which recorded the lowest weight. However, differences among the LBSFL0, LBSFL6 and LBSFL9 groups were not statistically significant (Table 1).

Average Daily Gain (ADG) followed a similar pattern to final live weight, with LBSFL0 broilers exhibiting the highest growth rate (77.5 g/day) and LBSFL3 the lowest (65.2 g/day), showing a significant linear effect ($p = 0.027$). Although, the

Table 1: Effect of live black soldier fly larvae ingestion on broiler zootechnical performances

	Live black soldier fly larvae (g/chicken/day)					Contrast[7]	
Parameters	0	3	6	9	SEM[6]	Linear	Quadratic
FI[1] (g/day)	162	146	155	159	2.3	0.075	0.179
ILW[2] (g)	805.4	781.3	824.3	796.4	7.5	0.227	0.887
FLW[3] (g)	2807^{a}	2461^{b}	2658^{ab}	2576^{ab}	36.9	0.007	0.139
ADG[4] (g/day)	77.5^{a}	65.2^{b}	70.6^{ab}	68.6^{ab}	1.6	0.027	0.127
FCR[5]	2.1	2.3	2.2	2.3	0.1	0.175	0.162

[1]Feed Intake in gram per day, [2] Initial live weight at the start of experimentation in gram per check, [3]Final live weight at the end of experimentation in gram per check, [4]Average daily gain in gram per day, [5]Feed conversion ratio in kilogram of feed to produce 1 kilogram of weight gain, [6]Standard Error Mean, [7]Linear or quadratic response estimated using orthogonal polygonal contrast, [a,b]Means in the same row not sharing a same subscription is significantly different at $p<0.05$

Table 2: Effect of live black soldier fly larvae ingestion on broiler carcass quality characteristics

	Live black soldier fly larvae (g/chicken/day)					Contrast[2]	
Parameters	0	3	6	9	SEM[1]	Linear	Quadratic
Live weight (g)	3019[a]	2615[b]	2626[b]	2581[b]	63.3	0.030	0.021
Carcass weight (g)	2350[a]	2014[b]	2007[b]	1979[b]	52.7	0.023	0.015
Carcass yield (%)	77.77	77.01	76.51	76.60	0.4	0.608	0.389
Viscera yield (%)	9.70	9.59	9.79	10.99	0.3	0.169	0.075
Full Intestine yield (%)	3.96	4.03	4.05	4.74	0.1	0.194	0.096
Liver yield (%)	2.03	1.94	2.08	2.20	0.1	0.432	0.296
Empty gizzard yield (%)	2.01[b]	1.90[b]	2.19[ab]	2.40[a]	0.1	0.012	0.009

[1]Standard error of mean, [2]Linear or quadratic response estimated using orthogonal polygonal contrast, [a,b]Means in the same row not sharing a same subscription is significantly different at $p<0.05$

LBSFL0 group surpassed the LBSFL6 and LBSFL9 groups by 6.9 and 8.9 g/day, respectively, these differences were not significant at the 5% level (Table 1).

Feed Conversion Ratio (FCR) was not significantly affected by live BSFL consumption, either linearly ($p = 0.175$) or quadratically ($p = 0.162$). Broilers in the control group (LBSFL0) demonstrated a slightly better FCR (2.1) compared with those in the LBSFL3, LBSFL6 and LBSFL9 groups, exceeding them by 0.2, 0.1 and 0.2 points, respectively.

Carcass quality characteristics: The live weight of broiler chickens sampled for carcass characteristic evaluation differed statistically among treatments ($p>0.05$). Birds in the control group exhibited the highest live weight (3019 g), whereas those fed Live Black Soldier Fly Larvae (LBSFL) showed statistically similar live weights (Table 2).

Following slaughter, plucking, heading and evisceration, carcass weight was significantly higher ($p<0.05$) in broilers fed the control diet (2350 g) compared with the LBSFL-fed groups. However, carcass weights among the LBSFL3, LBSFL6 and LBSFL9 groups were not significantly different (Table 2).

The inclusion of live BSFL prior to feed distribution did not significantly affect ($p>0.05$) carcass yield, viscera yield, full intestine yield, or liver yield (Table 2). Nonetheless, carcass yield exhibited a decreasing trend with increasing levels of live larvae consumption. Conversely, among the groups receiving live larvae (LBSFL3, LBSFL6 and LBSFL9), viscera, full intestine and liver yields tended to increase as the quantity of live larvae consumed increased.

Feed treatment had a significant effect on empty gizzard yield (Table 2). Broilers in the LBSFL9 group presented a significantly higher ($p<0.05$) empty gizzard yield (2.40%), exceeding those of the LBSFL6, LBSFL3 and LBSFL0 groups by 0.21, 0.50 and 0.39%, respectively.

DISCUSSION

Growth performances: Live Black Soldier Fly Larvae (BSFL) did not adversely affect feed intake in broiler chickens; however, dry matter intake was lower in birds fed the control diet, resulting in reduced energy consumption that could not be compensated by the higher fat intake associated with live BSFL ingestion[16]. Elevated dietary fat levels are known to alter hypothalamic appetite-regulating mechanisms[16]. While Seyedalmoosavi *et al.*[16] reported no significant adverse effects on voluntary feed intake up to a 30% inclusion of whole BSFL, Tognoli *et al.*[15] observed a significant decrease in feed intake beginning at 20%. The chemical composition of BSFL can vary depending on the rearing substrate and in response to dietary factors such as energy level, leading broiler chickens to adjust their feed intake accordingly[17-19].

Final Live Weight (LW) and Average Daily Gain (ADG) were negatively influenced by the ingestion of live BSFL compared to the control diet. However, some researchers have observed a tendency toward increased LW and ADG in broilers and cockerels supplemented with BSFL compared with control groups[20,21]. In fact, when provided with a balanced diet, the inclusion of live BSFL-particularly at higher levels-may cause trade-offs in nutrient and energy intake, ultimately resulting in imbalances, reduced nutrient efficiency and impaired growth performance[16]. Moreover, protein digestibility has been reported to decrease with increasing chitin content in BSFL[22], with specific reductions in methionine and lysine utilization leading to diminished growth performance[23]. Feed Conversion Ratio (FCR) was not affected, as broiler chickens with greater final live weight also exhibited proportionally higher feed intake.

Carcass quality characteristics: Ingestion of live black soldier fly larvae before feed distribution did not exert any effect on most of the evaluated carcass quality characteristic. Fiorilla *et al.*[14], also reported no significant differences in the overall slaughter performance among birds in relation to different dietary treatments. The significant difference observed in live weight and carcass weight were due to random effects[15]. Sex and genotypes were the main factors that influence carcass characteristics, but the low-nutrient diet reduced the carcass weight[24]. However, when expressed as a percentage of the total carcass, no significant interactions were observed between nutrient density and the carcass component proportions[25]. Dietary regimen had no effect on visceral yield because heavier chickens also have greater viscera mass[24]. The significant increase in empty gizzard yield indicate the digestive effort associated with live BSFL compared with the control diet.

CONCLUSION

The ingestion of live black soldier fly larvae prior to feed distribution had no detrimental effect on broiler chickens' feed intake, feed conversion ratio, or major carcass quality traits. However, it influenced final live weight and average daily gain. Based on feed conversion ratio, live black soldier fly larvae can be provided up to 9 g per day per bird without compromising performance. Nevertheless, further studies focusing on the economic implications and larval digestibility are required to determine the optimal inclusion level of live larvae in broiler diets.

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