RESEARCH ARTICLE

Influence of Black Soldier Fly (*Hermetia illucens L.*) Larvae Meal on Growth, Meat Quality and Sensory Attributes of Domesticated Japanese Quails

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Abstract

The purpose of the study was to evaluate the effects of varying concentrations of black soldier fly larvae on domesticated Japanese quail growth performance, carcass parameters, meat quality, and sensory qualities. A total of 120-day-old unsexed quail chicks were distributed into three equal groups at random: CON (basic diet without larvae), BSF1 (50 g black soldier fly larvae/kg feed), and BSF2 (100 g black soldier fly larvae/kg feed). Each group included five replicates of eight chicks. On day 0, 7, 14, 21, 28, and 35, measurements were taken of body weight, feed intake, and feed conversion ratio. Meat quality, sensory characteristics, and carcass features were assessed at the conclusion of the trial. According to the findings, the BSF2 group performed better in terms of average daily gain, final body weight, and feed conversion ratio than the BSF1 and CON groups. The BSF2 group outperformed the CON group in terms of slaughter body weight, eviscerated body weight, dressing %, heart weight, and breast weight. Addition of black soldier fly larvae meal to quail meat did not influence the meat's quality or sensory assessment. According to the study, feeding Japanese quails with black soldier fly larvae at a rate of 100 g/kg of feed would improve their performance.

Key words: Black soldier fly larvae, Carcass traits, Growth performance, Japanese quails, Unconventional feed ingredient.

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Introduction

The domesticated Japanese quail is gaining importance in India mainly for its eggs and meat production and biomedical research. Quail meat and eggs are an important source of protein and quail meat can satisfy the growing demand for white meat worldwide (Abdullah *et al*., 2011). To enhance productivity and lower feed costs, farmers should consider alternative protein sources in poultry feed to offset the increasing prices of traditional ingredients (Elahi *et al*., 2022). Insect larvae meal is a promising option as it facilitates nutrient recycling without competing for land or food resources (Sánchez-Muros *et al*., 2014). Insects are rich in lipids, amino acids, carbohydrates, trace minerals, and vitamins (Skotnicka *et al*., 2021). Because of its amino acid content and fatty acid profile, the meal of black soldier fly (BSF) larvae (*Hermetia illucens L.*) is being investigated as a protein and fat source for birds (Cullere *et al*., 2016). This feed ingredient aligns with quails' natural feeding habits and offers a sustainable solution for bird nutrition (Ewald *et al*., 2020). Black soldier fly larvae are high in lipids and protein (Barragan-Fonseca *et al*., 2017) and contain essential amino acids like threonine, lysine, and methionine (Elahi *et al*., 2022). Chitin, a component of the insect's exoskeleton, is also present in BSF larvae (Xiong *et al*., 2023). It has also been reported that black soldier flies are a good source of lipids for bird diets due to their high lauric acid content (Kierończyk *et al*., 2023). For commercial application, it is crucial to comprehend the ideal dietary inclusion rates of

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black soldier fly meal and how they affect development performance (Vilela *et al*., 2021). The purpose of this study was to assess how black soldier fly larvae meal affected quail growth performance, carcass characteristics, meat quality, and sensory attributes to enhance the utilization of insect-based diets in quail nutrition.

Materials and Methods

Experimental Design

A 5-week feeding trial was conducted on 120 day-old unsexed domesticated Japanese quail (*Coturnix coturnix japonica*) chicks. The chicks were randomly assigned to three equal treatment groups with five replicates of eight birds per cage measuring 100 cm x 50 cm x 17 cm. They were fed an iso-caloric and iso-nitrogenous basal experimental diet (Table 1) formulated for both the starter phase (1 to 14 days) and the grower phase (15 to 35 days). A control group (CON) was fed a basal diet, while other two treatment groups were fed experimental diet supplemented with 50 g (BSF1) and 100 g (BSF2) of black soldier fly larvae meal per kg of basal diet. Water and feed were provided *ad libitum*, and standard managemental practices were followed.

Growth Parameters

In this experiment, the body weight (BW) of birds was recorded on the first day and at weekly interval before feeding and watering. Feed intake (FI) was determined by subtracting the leftover feed from the total offered feed and dividing by the number of birds in each replicate. The feed conversion ratio (FCR) was calculated accordingly. Mortality was recorded daily.

Carcass Traits

At 35th day of age, five quail birds from each dietary group were selected based on cage weight averages ± 10% after a 6-h fasting period. To evaluate carcass characteristics and internal organ weight, these quails were slaughtered by following standard procedures. Relative organ weight was calculated in relation to the fasted live weight using a digital weighing balance to accurately weigh and record different body parts.

Meat Quality and Sensory Attributes

A sample of flesh from breast was taken from each replicate to analyze physical attributes of the meat, including water holding capacity (WHC), cooking loss, and muscle pH. A

Table 1: Ingredients and composition (%) of the experimental diets

Ingredients	Starter			Grower		
	CON	BSF1	BSF2	CON	BSF1	BSF2
Yellow Maize	52.00	52.00	51.20	59.00	59.00	56.00
Soyabean Meal (HP)	35.80	30.60	25.40	25.00	19.80	14.60
MDOC	5.00	5.00	5.00	5.00	5.00	5.00
BSF	0.00	5.00	10.00	0.00	5.00	10.00
Yellow Maize	1.30	3.16	6.20	5.87	8.20	12.30
Soyabean Meal (HP)	2.10	1.10	0.00	1.55	0.40	0.00
MDOC	1.50	1.40	1.20	1.30	1.15	1.00
BSF	1.25	1.00	0.60	1.10	0.55	0.20
DORB	0.30	0.30	0.30	0.30	0.30	0.30
Yellow Maize	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.06	0.04	0.00	0.13	0.10	0.10
Premixes[1]	0.15	0.00	0.00	0.15	0.00	0.00
Analysed values (%)						
ME (kcal/kg)*	2907	2904	2904	2905	2902	2909
Crude protein (CP)	24.04	24.09	24.07	20.04	20.05	20.06
Crude fibre (CF)	4.49	4.74	5.13	4.70	5.01	5.51
Ether extract (EE)	4.40	4.73	5.14	4.08	4.37	5.30
Calcium	1.00	1.01	1.03	0.81	0.81	0.82
Total Phosphorus*	0.45	0.45	0.45	0.40	0.40	0.40
Lysine*	1.30	1.30	1.30	1.10	1.10	1.10
Methionine*	0.51	0.59	0.84	0.46	0.55	0.80
Meth. + Cyst*	0.90	0.97	1.21	0.79	0.87	1.11

[1]Premix contains per kg of diet: Vitamin Premix: 0.04%, Trace minerals: 0.10%, Choline chloride 60%: 0.05%, Toxin binder: 0.10%, Liver tonic powder: 0.05%, Emulsifier: 0.05%. *Calculated Metabolizable energy values.

digital pH meter (Systronics pH System 362) was used to measure the pH of a suspension containing 10 g of quail breast tissue and 50 mL of distilled water. WHC was calculated using the filter paper press method recommended by Grau and Hamm (1953). Following the method described by Yang *et al.* (2006), the fresh meat sample was cooked in a water bath until the internal temperature reached 70°C. After 20 min, it was weighed to determine the cooking loss percentage.

Hedonic evaluations of color, flavour, and tenderness were conducted as part of organoleptic tests. Thirty semi-trained panelists assessed cooked meat using a questionnaire with a rating scale from 1 to 5 (Smith *et al.*, 2012).

Statistical Analysis

The data was analyzed using a random approach with SPSS's one-way analysis of variance (ANOVA) (SPSS Inc., 1997). A significance level of p<0.05 was set for all analyses. Duncan's multiple range test was used to detect variations among treatment means in case of a significant treatment effect.

Results and Discussion

Body Weight Gain, Feed Intake and FCR

During the starter phase (days 1-14) and grower phase (days 15-28), the average daily gain (ADG) of the BSF2 group was significantly higher (p<0.05) than that of the BSF1 and CON groups (Table 2). The BSF1 group showed a significantly positive (p<0.05) effect compared to the CON group during the starter period (days 1-14), but did not differ significantly from the CON group during the growing phase (days 15-28). There were significantly higher values (p<0.05) in BSF2 group compared to BSF1 and CON group, and BSF1 was also significantly better (p<0.05) than CON group in overall 35-day experiment (day 1-35) period. Even though the BSF2 group had a quantitatively greater ADG than the BSF1 and CON groups, there were no significant differences (p<0.05) between the groups during the grower phase (days 29-35). Over the 35-day trial period, quails fed a diet containing 100 g/kg BSF larvae meal displayed the highest ADG, followed by those fed 50 g/kg BSF larvae meal and the control group with values of 5.60 g/d, 4.70 g/d, and 4.33 g/d, respectively. At the end of the trial, it was also evident that the BSF2 group had a significantly higher final body weight compared to the BSF1 group and outperformed the CON group when soybean meal was substituted with BSF larvae.

Findings showed that there were no significant differences (p>0.05) in average daily feed intake (ADFI) among the treatment groups during the starter and grower periods or over the entire 35-day experiment. However, increasing the percentage of BSF in the ration led to a reduction in ADFI. During the starter phase (days 1-14) and the initial phase of the grower period (days 15-28), the FCR in the BSF2 group was considerably better (p<0.05) than in the BSF1 and CON groups. Throughout the starter stage (days 1-14), the BSF1 group performed significantly better over the CON group (p<0.05), but in the initial growth period (days 15-28), there was no significant difference (p>0.05) with the CON group. There was a significant improvement (p<0.05) in FCR in the BSF2 group compared to the BSF1 and CON groups throughout the experiment (days 1-35), with the BSF1 group also showing a significant difference (p<0.05) compared to the CON group. However, during the grower phase (days 29-35), there was no significant impact (p>0.05) on FCR among the treatment groups.

The study revealed that incorporating BSF larvae meal had a positive impact on the quails' ADG, with the most notable enhancements observed at inclusion levels of 100 and 50 g/kg. These improvements were particularly evident in the overall 35-day experimental period. These findings were in line with Dabbou *et al*. (2018), who reported improved live weight (LW) and ADG in broilers fed BSF meal at various levels (15%, 10%, and 5%). Murawska *et al*. (2021) demonstrated that broiler diets supplemented with BSF in various forms, such as live or larvae, led to decreased feed consumption in the supplemented groups compared to the control group, consistent with the results of this study. Higher nutritional and energy content of BSF meal may have contributed to the increased ADG observed in quails fed BSF.

The findings of this study aligned with those of Widjastuti *et al*. (2014), who observed a reducing feed intake with higher proportion of BSF larvae. The high fiber content in the insect's exoskeleton contributes to the decrease in ADFI in diets containing BSF (Van Huis, 2015). Chitin, primarily composed of N-acetyl-D-glucosamine and small amounts of D-glucosamine linked by β-1, 4 glycosidic bonds, is the predominant fiber type present in insect exoskeletons. Due to its composition, chitin is insoluble and therefore not digestible by monogastric animals (Inaki *et al*., 2022).

Attivi *et al*. (2020) found that FCR decreased significantly when BSF larvae meal was included at 50% and 100% of the control diet for broiler birds. Additionally, De Souza Vilela *et al*. (2021) found that broilers fed a diet incorporating 20% BSF meal had a 10% lower FCR. Silva *et al.* (2024) suggested an inverse relationship between FCR and the level of BSF supplementation in quail diets, which is consistent with our trial results. Previous studies by Cockcroft (2018) and Mat *et al*. (2021) support the effectiveness of feeding dried pre-pupae over soybean-based feed in improving FCR in broiler diets. Additionally, Widjastuti *et al*. (2014) suggested that including up to 50% BSF maggot meal in quail diets led to the best FCR, which aligns with the current study's results.

The inconsistent results among these studies could be attributed to differences in the nutrient compositions of the insect meals utilized, which are influenced by the substrates used for larval development and directly impact their chemical composition (Tschirner and Simon, 2015). Factors such as insect processing techniques, inclusion rates, experimental procedures, and the specific bird species being studied also play a role. The study shows that BSF meal can be a sustainable protein source for quail feed, reducing composition variability and improving quail performance and feed efficiency.

Table 2: Effect of different levels BSF larvae meal on average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of quails

Parameter	Attribute	Treatment			SEM (n=5)	P-Value
		CON	BSF1	BSF2		
ADG (g/d)	D1-14	2.72^{c}	3.23^{b}	3.89^{a}	0.142	0.000
	D15-28	5.57^{b}	5.78^{b}	7.33^{a}	0.222	0.000
	D29-35	5.09	5.50	5.58	0.146	0.366
	D1-35	4.33^{c}	4.70^{b}	5.60^{a}	0.145	0.000
	Final BW	161.35^{c}	175.05^{b}	207.95^{a}	5.315	0.000
ADFI (g/d)	D1-14	8.10	8.09	8.02	0.116	0.963
	D15-28	16.82	16.47	16.83	0.123	0.429
	D29-35	16.53	17.18	16.96	0.125	0.082
	D1-35	13.27	13.27	13.23	0.057	0.887
FCR (g intake/g gain)	D1-14	2.99^{a}	2.52^{b}	2.07^{c}	0.120	0.001
	D15-28	3.03^{a}	2.86^{a}	2.30^{b}	0.090	0.000
	D29-35	3.26	3.15	3.09	0.084	0.708
	D1-35	3.06^{a}	2.82^{b}	2.38^{c}	0.077	0.000

Means bearing different superscripts in the same row differ significantly (p ≤ 0.05); CON- control diet/ basal diet; BSF1- Experimental diet containing 50g/kg BSF larvae; BSF2- Experimental diet containing 100g/kg BSF larvae

Table 3: Effect different levels BSF larvae meal on carcass characteristics of quails

Attributes	Treatment			SEM (n=5)	P-Value
	CON	BSF1	BSF2		
Slaughter BW (g)	159.31	171.28	201.71	8.304	0.075
Eviscerated BW (g)	108.89^{b}	114.52^{b}	141.12^{a}	6.261	0.050
Dressing percentage	68.46^{b}	66.79^{ab}	69.93^{a}	0.555	0.037
Liver (g)	5.05^{a}	5.59^{a}	2.43^{b}	0.524	0.002
Heart (g)	2.15^{b}	2.49^{a}	3.33^{a}	0.876	0.001
Gizzard (g)	4.51	4.75	5.05	0.128	0.245
Breast (g)	64.40^{b}	75.16^{a}	73.47^{a}	1.744	0.002
Thigh (g)	55.26	56.16	60.78	1.095	0.060

Means bearing different superscripts in the same row differ significantly (p ≤ 0.05); CON- control diet; BSF1- Experimental diet containing 50g/kg BSF larvae; BSF2- Experimental diet containing 100g/kg BSF larvae

Carcass Traits

Table 3 displays the eviscerated weight and dressing percentage of quail in the BSF2 group, which is significantly higher ($p<0.05$) compared to the CON group, while there were no significant variations ($p>0.05$) between the BSF1 and CON groups, although the BSF1 group had higher numeric values compared to the CON group. There was no significant difference in slaughter weight among the groups, although the BSF2 group showed numerically higher weight compared to the BSF1 and CON groups. Significant differences ($p<0.05$) were also observed in heart and breast weights of birds in the BSF2 and BSF1 groups against to the CON group. The liver weight in the BSF1 and CON groups was significantly heavier than in the BSF2 group, while the weight of the thigh and gizzard did not differ significantly among the groups. The BSF2 group had the highest gizzard and thigh weight compared to the BSF1 and CON groups.

Among the different groups, the BSF2 group exhibited the highest dressing percentage at 69.93% and the highest slaughter and eviscerated weights of 201.71 g and 141.12 g, respectively. This may be due to the higher protein efficiency of BSF larvae meal, resulting in increased protein deposition, muscle mass, and ultimately a higher dressing percentage (Cockroft, 2018). In contrast with this study, Mbhele *et al.* (2019) found that weight of the gizzard increased linearly when BSF larvae were added to the diet, but there was no significant impact on the weight of the liver or heart. Cockcroft (2018) also experimented that the incorporation of BSF larvae did not remarkably affect gizzard or liver weight, but did have a significant impact on heart weight, which perfectly aligns with the findings of our study.

Meat Quality

There were no significant changes in muscle pH, water holding capacity (WHC), and cooking loss of quail meat when different levels of BSF were included in the diet, as shown in Table 4. The muscle pH remained stable across all diets, indicating that the isoprotein and isoenergy rations did not affect pH levels. This is in line with previous research

Table 4: Effect of different levels BSF larvae meal on meat quality and sensory evaluation of quails

Parameter	Attribute	Treatment			SEM (n=5)	P-Value
		CON	BSF1	BSF2		
Meat quality	Muscle pH	5.77	5.99	6.05	0.155	0.796
	Water holding capacity (%)	6.37	6.29	6.77	0.117	0.201
	Cooking loss (%)	18.10	21.66	24.95	1.429	0.141
Sensory evaluation	Appearance/ Colour	3.04	3.66	4.17	0.281	0.289
	Flavour	3.94	4.28	4.72	0.345	0.712
	Tenderness	3.52	3.61	3.76	0.112	0.732

CON- control/basal diet; BSF1- Experimental diet containing 50g/kg BSF larvae; BSF2- Experimental diet containing 100g/kg BSF larvae

by Secci *et al*. (2018), who also found no impact of nutrition on the pH of Barbary partridge meat. Muscle glycogen levels can influence meat pH (Kim *et al*., 2014). The pH values in this study (6.05 in BSF2, 5.99 in BSF1, and 5.77 in CON) fell within the normal range for meat, typically reported as 5.7-6.1 (Nkukwana *et al*., 2016). There was no remarkable difference in WHC across the treatment groups in our study. WHC and muscle connective tissue composition, which are related to free water content, can be influenced by age (Beuchat, 2002). Since the birds in the study were of the same age and breed, there was no noticeable difference in cooking loss among the groups. Cooking loss values typically range from 18.10% to 24.95% for different types of meat, with a normal range of 15% to 40%, as suggested by Soeparno (2005), which aligns with the results of this study.

Sensory Evaluation

Organoleptic testing, including hedonic quality evaluation of cooked quail meat, showed no significant differences (p>0.05) in taste, aroma, texture, and color among the treatment groups (Table 4). Quail meat fed with BSF larvae meal did not differ significantly from the control feed in terms of sensory attributes. However, panelists noted that quail meat from birds fed with BSF maggot meal had a reddish color compared to those fed a basal diet without BSF supplementation. The brighter color of the meat may be due to the higher iron concentration in BSF larvae. Myoglobin, which contains iron, is known to influence the color of meat (Suman and Joseph, 2013). Meat with higher iron content tends to have a redder pigment. Furthermore, it was suggested that adding carotenoids (~2.15 mg/kg) to the feed with BSF could enhance the yellowness of the meat (Secci *et al*., 2018). BSF larvae supplemented Japanese quail meat did not taste fishier in comparison to quail meat from the control group, according to the panelists' evaluation of the meat's flavour. Panelists preferred it for its savory flavour. The tenderness of quail breast meat fed with varying concentrations of BSF larvae did not differ significantly. Various factors such as species, age, gender, and management practices can affect meat tenderness. According to Warner *et al*. (2022), meat tenderness values can range from 3.3 to 5.0 kg cm². The meat tenderness values for the BSF2, BSF1, and CON groups were 3.76, 3.61, and 3.52, respectively (Table 4).

Conclusion

According to the results of this study, incorporating 100g of black soldier fly larvae meal per kg of basal feed in Japanese quail diet enhances growth performance and carcass yield without affecting feed intake. Nevertheless, no notable impact on meat quality or sensory evaluation was noted with the use of BSF larvae meal.

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