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EVALUATION OF THE USE OF BLACK SOLDIER FLY LARVAE AS A PROTEIN SOURCE IN FEEDING QUAIL BREEDERS ON PRODUCTIVE AND REPRODUCTIVE PERFORMANCE

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ABSTRACT

This study aimed to evaluate the use of black soldier fly larvae (BSFL) as a protein source in the diet of breeder quails and its effect on productive and reproductive performance. A total of 120 quails, aged 49 days (80 females and 40 males), were used in the study. The birds were randomly assigned to four treatments, with each treatment consisting of five replicates and six birds per replicate (four females and two males). The treatments were as follows: the first group served as the control (without BSFL), while the second, third, and fourth groups were supplemented with BSFL meal at levels of 5,10 and 15% respectively. The results obtained at the end of the experiment indicated no significant differences in the studied productive traits among all treatments compared to the control group. These qualities included the percentage of egg production, average weight, mass, feed consumption and conversion ratio as well as the amount of change in live body weight. In addition, the study showed no significant changes in the reproductive performance of breeder quails in all treatments, including the percentages of fertility and hatchability from total eggs and fertilized eggs as well as embryonic mortality; all were compared to the control group. The present results suggest that black soldier fly larvae can be utilized as a protein in the diet of breeder quails at inclusion levels of up to 15% of the total feed components without a negative role on production or reproductive performance.

INTRODUCTION

In the animal production field, innovations and study efforts are increasing to enhance the productivity and quality of animal protein, which is considered essential for human nutrition. Projected data indicate that the global population is anticipated to reach approximately 9.7 billion people by 2050 (FAO, 2018). Ensuring a year-round supply of high-quality feed is one of the main challenges facing the animal production sector, as feed is a cornerstone of any successful livestock production project. Feed costs account for approximately 70% of the total production expenses in poultry farming projects (Al-Sofee, 2018; Al-Hiyali and Altamee, 2023). Moreover, the cost of protein sources accounts for the largest share of feed formulation expenses, driven by rising costs of imported raw materials such as soybean meal, fishmeal, and meat meal. Soybean meal is considered one of the most important plant-based protein sources used in poultry nutrition due to its high protein content, which ranges from approximately 38% to 48%. Additionally, it contains most of the essential amino acids required by poultry in well-balanced proportions, except for methionine, which is considered the limiting amino acid. Soybean meal also has high digestibility and palatability (Dörper *et al*., 2021; Al-Sofee and Yonis, 2020). These factors resulted in a significant increase in the demand for soybean meal, leading to higher prices, particularly because it was cultivated in countries such as China, the United States, Argentina, Brazil, and others (Younis and Al-Sofee, 2021; Mustafa *et al*., 2025). This is due to the specific conditions required for growth, including the environment. These countries play a major role in controlling prices and meeting global demand. Furthermore, soybeans are widely used in human nutrition, including the production of soy milk, tofu, and soybean oil. Given the growing rivalry between the production of human food and the supply of animal feed, establishing a new, sustainable production chain is becoming more necessary. This aims to identify more environmentally friendly proteins for poultry feed, reducing reliance on traditional, costly protein sources and reallocating them for nutrition. Many sorts of sources used in animal feed could also be appropriate for human consumption (Mottet *et al*., 2017; Salem *et al*., 2023).

With the increasing world population, the amount of human-produced organic waste is expected to increase, causing environmental pollution, as more than 1.3 billion tons of organic waste are produced annually worldwide. The accumulation of this waste may cause the spread of diseases and epidemics and environmental pollution, and therefore requires appropriate treatment and handling for disposal (Makkar, 2017; Al-Khateeb and Al-Sufi, 2023). Accordingly, researchers have pointed out the possibility of using insects to play this effective role, as insects are raised and grown on this waste and used in the feed industry, in addition to their high ability to convert organic waste of low nutritional value and harmful to the environment into a high-quality feed material that can be produced locally and sustainably at a lower economic cost than imported feed sources from abroad. In recent years, there has been an increasing demand for insect production and its inclusion in animal feed, and this industry is expected to continue to flourish. Insects have been recognized as a major feed source for poultry feed by the European Union (IPIFF, 2018). This type of production relies on the circular economy (Dicke, 2018) by using low-value resources to produce high-value feed sources. In addition, its negative effects on the environment and its sustainability have decreased.

One of the most prominent insects proposed is the larvae of the black soldier fly (BSFL) *Hermetia illucens*, as they are an effective choice in the field of poultry nutrition that can meet environmental and economic standards (Makkar *et al*., 2014; Surendra *et al.*, 2016), as the larvae of the black soldier fly are characterized by their high protein content, which may reach about 36-44% based on dry matter (Elwert *et al*., 2010) It is rich in essential amino acids that are important in poultry nutrition, such as methionine, tryptophan, lysine, and others (Surendra *et al*., 2016). The larvae contain a high percentage of fat, which may reach about 28-41% based on dry weight (Newton *et al.*, 2005; Mutafela, 2015), which contains essential fatty acids such as linoleic (C18:2) and linolenic (C18:3). It also includes omica-3 and amica-6, which have a good ability to enhance the health status of poultry. It also contains lauric acid (C12:0), which is known for its anti-bacterial properties (Barroso *et al.*, 2014). Furthermore, BSFL is rich in mineral elements such as P, Na, Ca, Fe, and Zn (Mustafa et al., 2025). Liu *et al.* (2017) indicated that it is rich in vitamin E. Gerez *et al*. (2019) reported that the larvae contain chitin and its derivatives, which can be used as antioxidants and to enhance immunity in poultry (Swiatkiewicz *et al*., 2015). BSF larvae are also a rich source of antimicrobial peptides (Moretta *et al*., 2020).

BSFL represents a sustainable source, as these insects feed on the organic waste. Thus, they decrease and recycle waste, enhance production capacity, and provide locally produced protein at low cost (Nguyen *et al*., 2015). Therefore, this type of production contributes to environmental sustainability and reduces the costs of feed production.

The present research was conducted to evaluate the potential role of BSFL as a protein source for quail mothers and to assess its effect on their reproductive performance.

MATERIALS AND METHODS

Ethical Approve

The study was conducted in accordance with the controls and instructions issued by the Scientific Ethics Committee: College of Veterinary Medicine, University of Mosul, Iraq. according to its document numbered UM.VET.2024.121 dated May 16, 2024.

Management and Distribution of Treatments

The present study was conducted in the Poultry house at the Department of Animal Production, College of Agriculture and Forestry, Mosul University, Iraq, from July 10/ 2024 to August 21/ 2024. A total of 120 quail birds, 49 days old, were used and housed in a closed room containing rectangular wooden cages, every 2 meters in length and 1.5 meters in height, with three tiers. Each tier consisted of four chambers, each measuring 50×50×50 cm in length, width, and height, respectively, and each chamber had an individual door. The room was equipped with an air puller fan to ensure proper ventilation and contained electric heaters and thermometers distributed throughout the room to monitor temperature. The daily lighting program followed in this study consisted of 16 hours of light and 8 hours of darkness.

The birds were distributed across four treatments, with five replicates per treatment and six birds per replicate (4 females and 2 males), to ensure as much weight uniformity as possible within each replicate. The experiment lasted for six weeks. The treatments were as follows:

T1: Control group, fed a diet free of BSFL powder.

T2: The diet contains BSFL powder at 5% of the total diet composition.

T3: The diet contains BSFL powder at 10% of the total diet composition.

T4: The diet contains BSFL powder at 15% of the total diet composition.

Feed Composition and Nutrition

The diets were formulated according to the recommendations of the National Research Council (NRC, 1994). BSFL powder was added to the other feed ingredients by mixing the prescribed ratios according to the nutritional treatments.

The feed was then manufactured into pellets. Table 1 shows the chemical composition of the BSFL powder used in this study (Zaki and Naji, 2022). The feed was provided manually using cylindrical plastic feeders suspended by metal wires from the cage ceiling, positioned at the level of the bird's back to minimize feed wastage. Additionally, inverted plastic drinkers with a capacity of 1.75 liters were raised above the cage floor to the level of the bird's back. Both feed and water were available to the birds ad libitum throughout the experiment. Four different diets were formulated based on the treatments of this study, with an approximate crude protein content of 20% and an energy value of approximately 2900 kcal/kg. Table 2 presents the composition of these diets.

Production Performance Criteria

The initial and final live body weight and the change in live body weight, egg production percentage (HD%), daily and total feed consumption, overall feed conversion ratio, feed conversion ratio per egg, egg weight, total egg mass, egg mass per day, and total mortality percentage were all calculated.

Hatching Criteria

In the last week of the experiment, eggs were collected separately for each replicate. After removing unfit eggs for incubation, 400 eggs were placed in the incubator, with 100 eggs per treatment, in an automatic incubator of Turkish origin (model Cimuka HB500C). The incubator machine was operated for 24 hours before placing the eggs to ensure proper functioning and preparation for egg hatching. The temperature of the incubator was set at 37.7°C ± 0.3°C for the first 14 days of incubation, with relative humidity maintained at 60-65%. The eggs were automatically turned 6 times per 24 hours at a 45° angle to the right and left. During the last three days of incubation, the incubator temperature was reduced to 37.2°C ± 0.2°C, the relative humidity was increased to 75%, turning was stopped, and the eggs were transferred to the hatching trays according to the treatments. On the 17th day, the eggs hatched. At the end of the incubation period (day 18), the remaining eggs were cracked open to calculate the fertilization percentage, and both fertilized and non-fertilized eggs were recorded, along with observations of embryonic mortality.

Data statistics

A completely randomized design (CRD) was used in the data analysis, and significance difference tests were conducted using the Duncan multiple range test (Duncan, 1955), with ready-made statistical analysis software (SAS, 2003).

Table 1: Chemical Analysis of BSFL Powder.

Ingredients	%	Ingredients	%
Humidity	4.32	Metabolic energy (kcal / kg)	4195
Crude Protein	40.80	Calcium	2.94
Fat	25.7	phosphorus	0.80
Ash	13.6	Methionine	0.69
Crude Fiber	7.8	Lysine	2.52

Table 2: Feed components used in the study.

feed materials	T1	T2	T3	T4
Maize	51	50	49	48
Soybean meal (44%)	34	29	24	19
BSFL (40.8%)	0	5	10	15
Wheat Bran	2	4	6	8
Oil	3.5	2.5	1.5	0.5
*Premix (25%)	2.5	2.5	2.5	2.5
Limestone	6.75	6.75	6.75	6.75
salt (NaCl)	0.25	0.25	0.25	0.25
Total	100	100	100	100
Calculated Chemical Analysis				
Crude Protein	20.2	20.3	20.4	20.4
Metabolic energy (kcal/kg)	2908	2908	2909	2909
Crude Fiber	3.72	3.67	3.62	3.57

*Premix ingredients: crude protein 25%, crude fat 2.10%, crude fiber 0.40%, crude ash 52.00%, lysine 8.03%, methionine 10.82%, methionine + cysteine 10.88%, represented energy 4000 (kcal/kg), vitamin A 2500 IU Vitamin D3 500 IU Vitamin E 1 mg Vitamin C 5 mg Dicalcium phosphate 80 mg Sodium chloride 70 mg Magnesium sulphate 20 mg Zinc sulphate 2 mg Iron sulphate 1.5 mg Sodium propionate 5 Sodium selenate 1000 µg Potassium iodide 15 µg Chloride Cobalt 10 micrograms, manganese sulphate 750 micrograms, calcium carbonate 1 gram.

RESULTS AND DISCUSSION

Table (3) shows the effect of using BSFL powder in the diets of quail breeders on production performance. The results showed no significant differences among treatments in egg production percentage (H.D%). The overall egg production percentage was 86.43, 82.50, 88.93, and 85.60% for the treatments, respectively. Additionally, the results showed no significant differences in egg weight among all treatments. No significant difference was observed in total egg mass (g of eggs/female) or daily egg mass (g of eggs/female/day). The total egg mass was 415.74, 397.14, 437.23, and 423.97 g of eggs/female, respectively. These results are consistent with the study by Mawaddah *et al*. (2018), who showed no significant effect on egg production percentage, egg weight, and egg mass when feeding defatted BSFL meal as a replacement for meat and bone meal at levels of 0, 50, and 100% in the diets of laying quail. The results of this study also align with those of Amran *et al*. (2021), who observed no significant changes in egg production percentage, egg weight, and daily egg mass when BSFL replaced protein concentrate partially and totally. The findings also agree with Sadarman *et al*. (2022), who used BSF larvae in laying quail diets at 1.5, 2, and 2.5% of the diet composition and found no significant differences in egg production percentage and egg weight. However, our results differ from those of Suparman et al. (2020), who observed a significant decrease in egg production percentage when replacing BSFL powder with fish meal as the protein source at 6.37% and 9.56% in the diet. Additionally, the present results differed from those of Harlystiarini *et al*. (2020), who showed a significant improvement ($P \leq 0.05$) in the production of eggs when BSFL powder was replaced with fish meal as a source of protein in laying quail diets at 100%, in contrast with the control group.

Table 3: Effect of using BSFL on egg production percentage, average egg weight (g/egg), total egg mass (g/hen), and daily egg mass (g/hen/day).

Treatments		Studied traits			
		Egg production(%)	Average egg weight (g)	Total egg mass	daily egg mass
T1	Control	86.43±3.72 [a]	11.44±0.12 [a]	415.74±20.19 [a]	9.90±0.48 [a]
T2	BSFL 5%	82.50±3.75 [a]	11.46±0.06 [a]	397.14±18.83 [a]	9.46±0.45 [a]
T3	BSFL 10%	88.93±1.72 [a]	11.69±0.34 [a]	437.23±18.69 [a]	10.41±0.45 [a]
T4	BSFL 15%	85.60±3.73 [a]	11.79±0.20 [a]	423.97±21.20 [a]	10.09±0.50 [a]

* Averages with vertically different letters indicate a significant difference at $p \leq 0.05$.

** BSFL= Black soldier fly larvae.

Table (4) shows the effect of using BSFL powder in feeding quail breeders on the feed consumption rate. The results of the statistical analysis indicated no significant differences among treatments in daily feed consumption rate (g/bird/day) and total feed consumption rate (g/bird). The results also showed no significant difference in the total food conversion factor (g feed:g eggs) in all treatments compared to the BSFL-free control. Likewise, for the food conversion factor (g feed: egg), there was no significant difference among the factors. The results of this study were consistent with those of Harlystiarini *et al*. (2020), who found no significant differences in feed intake and feed conversion factor when BSFL powder replaced fishmeal as a protein source in 50-100% laying quail feed. Amran *et al*. (2021) confirmed that there was no significant change in the daily feed consumption and the nutritional conversion factor when BSFL was partially or completely replaced the protein center. Both Siregar and Warisman (2023), when they used BSFL powder as a substitute for fish powder in feeding laying quail, also explained that there was no significant difference in the nutritional conversion factor, while a highly significant decrease in the amount of feed consumed was observed for all replacement treatments compared to the control. The results of this study also differed from those of Widjastuti *et al.* (2014), who reported a significant increase in feed consumption and a significant improvement in the nutritional conversion factor when black soldier fly larval powder replaced fishmeal in Japanese quail diets by 25% and 50%. Mat *et al*. (2021) also showed a significant deterioration in the amount of feed consumed, matched by a significant improvement in the feed conversion factor when BSFL were used as 25% of the feed components in feeding laying quail.

Table 4: Effect of using BSFL on daily feed intake (g/bird/day), total feed intake (g/bird), total feed conversion ratio (g feed: g egg), and feed conversion ratio per egg (g feed: g egg).

Treatments		Studied traits			
		Average daily feed consumption (g)	Average total feed consumption (g)	feed conversion ratio (g feed: g eggs)	feed conversion ratio (g feed: egg)
T1	Control	27.06±1.07 [a]	1136.54±45.14 [a]	2.75±0.15 [a]	31.48±1.61 [a]
T2	BSFL 5%	25.43±0.54 [a]	1068.20±22.70 [a]	2.72±0.19 [a]	31.20±2.06 [a]
T3	BSFL 10%	25.83±0.80 [a]	1084.74±33.68 [a]	2.49±0.09 [a]	29.06±0.78 [a]
T4	BSFL 15%	26.26±0.31 [a]	1102.94±13.15 [a]	2.63±0.14 [a]	30.96±1.57 [a]

* Averages with vertically different letters indicate a significant difference at $p \leq 0.05$.
** BSFL= Black soldier fly larvae.

Table (5) shows the effect of using BSFL powder in the diet of breeder quails on body weight change. The results of the statistical analysis indicated no differences in the final weight rate (g/bird) across all treatments. It was also noted that there were no significant differences in the rate of change in body weight for treatments containing larval powder compared to control, as it amounted to 34.80, 34.67, 30.00 and 39.93 g/bird, respectively. Results also showed that there was no significant effect of using BSFL in feeding quail breeders on the mortality rate among all treatments. The results of this study were consistent with the findings of Mawaddah *et al*. (2018), who showed that there was no significant effect on the mortality rate when fat-free BSFL were fed instead of meat and bone powder in white quail feed. It also agreed with Zotte Dalle *et al*. (2019), who confirmed that there was no difference in the final live weight and mortality rates when BSFL were used as a food source for white quail, with a ratio up to 15%. Both Kaplan and Göçmen (2023) also indicated that adding BSFL to the diets of Japanese quail breeders in proportions of 0, 4, and 8% of the feed components had no significant effect on the change in live weight. While Mat *et al.* (2021) reported a significant increase in live weight and daily and total weight gain in favor of the treatments of adding BSFL by 20 and 25% to the laying quail feed.

Table 5: Effect of using BSFL on initial body weight (g/bird), final body weight (g/bird), body weight change (g/bird) and total mortality (%).

Treatments		Studied traits			
		Initial body weight (g)	Final body weight (g)	body weight change (g)	mortality (%)
T1	Control	203.80±1.76 [a]	238.60±1.60 [a]	34.80±1.41 [a]	0.00±0.00 [a]
T2	BSFL 5%	208.07±1.68 [a]	242.73±4.81 [a]	34.67±4.68 [a]	0.00±0.00 [a]
T3	BSFL 10%	209.00±2.96 [a]	239.00±1.96 [a]	30.00±4.50 [a]	0.33±0.33 [a]
T4	BSFL 15%	206.80±1.25 [a]	246.73±2.66 [a]	39.93±3.32 [a]	0.00±0.00 [a]

* Averages with vertically different letters indicate a significant difference at $p \leq 0.05$.
** BSFL= Black soldier fly larvae.

Table (6) demonstrates the effect of using BSFL powder on fertility percentage. The statistical analysis showed no significant alterations in the fertilized eggs ratio among all treatments. Similarly, the results showed no differences in hatchability percentages for total eggs and fertilized eggs across all treatments. There was also no significant alteration in total mortality compared to the control group. In agreement with Aziz *et al*. (2022), the use of BSFL and anchovy fish waste as protein sources instead of soybean does not affect the fertility and hatchability of total eggs and fertilized eggs, as well as the mortality. Likewise, Kaplan and Göçmen (2023) found that adding BSFL to the diet of Japanese laying quails will not change fertility and hatchability.

Table 6: Effect of using BSFL on fertility percentage, hatchability percentage from total eggs, hatchability percentage from fertilized eggs and total embryonic mortality percentage.

Treatments		Studied traits			
		Fertility percentage	Hatching percentage of total eggs	Hatching percentage of fertilized eggs	embryo mortality percentage
T1	Control	90.00±2.74 [a]	79.00±1.87 [a]	87.93±1.90 [a]	9.85±3.10 [a]
T2	BSFL 5%	86.00±3.67 [a]	80.00±3.54 [a]	93.09±1.99 [a]	6.91±1.99 [a]
T3	BSFL 10%	89.00±2.45 [a]	79.00±3.32 [a]	88.79±2.98 [a]	11.21±2.98 [a]
T4	BSFL 15%	90.00±1.58 [a]	80.00±2.24 [a]	88.99±2.84 [a]	11.01±2.84 [a]

* Averages with vertically different letters indicate a significant difference at $p \leq 0.05$.

** BSFL= Black soldier fly larvae.

CONCLUSIONS

The present research indicated the potential role of BSFL as a protein source in the diet of breeder quails, with up to 15% inclusion, without any negative effects on productive or reproductive performance. Moreover, incorporating BSFL into poultry feed contributes to the main role of sustainable agriculture by providing local production of low-cost protein, which can replace traditional proteins such as fish meal and soybean. Additionally, the BSFL process is environmentally friendly, as it involves the disposal and utilization of harmful organic waste, which, if left unchecked, could lead to the spread of diseases or epidemics. This waste is transformed into a high-nutrient product that can be used as animal feed thereby providing both economic and environmental benefits simultaneously.

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CONFLICT OF INTEREST

The researchers hereby confirm that there is no conflict of interest associated with the publication of this research.

تقييم استخدام يرقات ذبابة الجندي الاسود كمصدر بروتيني في تغذية امهات السمان في الاداء الانتاجي والتناسلي

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الخلاصة

هدفت هذه الدراسة الى تقييم استخدام يرقات ذبابة الجندي الاسود (*Hermetia illucens*) كمصدر بروتيني في تغذية امهات طائر السمان في الاداء الانتاجي والتناسلي، استخدم فيها 120 طائر سمان بعمر 49 يوم وبواقع (80 أنثى و40 ذكر) وزعت عشوائياً الى أربع معاملات، كل معاملة خمس مكررات وبواقع 6 طيور في كل مكرر (4 إناث و 2 ذكور) كانت المعاملات كالآتي: الأولى سيطرة (بدون يرقات) الثانية، الثالثة والرابعة: إضافة مسحوق يرقات ذبابة الجندي الأسود بالنسب (5 ، 10 و 15)% إلى العليقة على التوالي. بينت النتائج المتحصل عليها في نهاية التجربة عدم وجود فروقات معنوية في الصفات الإنتاجية المدروسة بين جميع المعاملات مقارنة بالسيطرة والتي شملت نسبة انتاج البيض، معدل وزن البيضة، كتلة البيض، استهلاك العلف، معامل التحويل الغذائي ومقدار التغير في وزن الجسم الحي. كذلك اشارت النتائج الى عدم وجود فروقات معنوية الأداء التناسلي لأمهات السمان بين جميع المعاملات مقارنة بالسيطرة والتي شملت نسبة الخصوبة، نسبة الفقس من البيض الكلي، نسبة الفقس من البيض المخصب والهلاكات الجنينية. نتائج هذه الدراسة تدل على إمكانية استخدام يرقات ذبابة الجندي الأسود كمصدر بروتيني في تغذية امهات السمان بنسبة تصل لغاية 15% من مكونات العليقة دون التأثير سلباً على الأداء الإنتاجي والتناسلي.

الكلمات المفتاحية: السمان، ذبابة الجندي الاسود، الأداء الإنتاجي، الأداء التناسلي.

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