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EFFECT OF SUBSTITUTING BLACK SOLDIER FLY LARVAE INSTEAD OF SOYBEAN MEAL ON PRODUCTIVE PERFORMANCE OF QUAIL AT GROWTH STAGE

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ABSTRACT

The research was conducted at the Research Center of the Department of Animal Production/ College of Agriculture and Forestry/ University of Mosul/ Iraq. A total of 120 unsexed quail birds of one day old, were used to study the effect of replacing different proportions of black soldier fly larvae (*Hermetia illucens*) instead of soybean meal, on the productive performance of quail during the growth stage. The birds were randomly distributed into four treatments as follows: the first is control (without replacement), second, third and fourth with replacement rates (20, 40 and 60) % respectively. Feed and water were provided ad libitum throughout the duration of the study, which extended until the birds reached 42 days of age. The productive performance evaluated to assess the efficiency of substituting black soldier fly larvae at varying replacement levels instead of soybean meal included final body weight, weight gain, feed intake, and feed conversion ratio, vitality rate, production index and Carcass characteristics. The findings revealed no significant differences in the variables examined productive traits among all treatments, indicating the possibility of replacing black soldier fly larvae powder up to 60% in place of soybean meal without negatively affecting the productive performance of the growing quail birds.

INTRODUCTION

The manufacture and production of domestic birds is one of the most important pillars necessary to provide protein sources in human nutrition, and an important factor in providing food security for peoples of the world, and this importance grows with the rising global population, which is projected to reach 9 billion people by the year 2050 (FAO, 2009; Makkar *et al.*, 2014). The challenge is to secure enough food to meet the needs of these growing numbers while preserving and sustaining natural resources.

The problem of providing fodder has become one of the most global problems addressed by researchers and poultry producers, as poultry feeding is the largest of the total costs involved in the poultry industry, which may reach 65-70% of total production costs (Younis & Al-Sofee, 2021a; Amen *et al.*, 2023). Poultry feed sources are primarily composed of soybean meal (SBM) as the main protein source and yellow corn as the primary source of metabolizable energy (Al-Khateeb & Al-Sufi, 2023; Altaleb & Batkowska, 2023a), as it is produced in specific countries of the world through which it controls the poultry production sector globally. Due to the increase in demand for the production of animal fodder, this has led to a rise in its price and thus an increase in the cost of production (Younis and Al-Sofee, 2021b; Ibrahim *et al*., 2023). In addition, the increase in the world's population is offset by an increase in organic waste and environmental pollution, as more than 1.3 billion tons of organic waste are produced annually in the world (Makkar, 2017), which causes harmful effects on humans and the environment, especially if not handled and disposed of properly (Sabiiti, 2011; Altaleb and Batkowska, 2023b).

Accordingly, researchers have striven to find new fodder sources that are an alternative to traditional fodder sources (Salem *et al.*,2023; Qui, 2023; Al-Ali *et al*., 2023). Insects are one of the most important of these options, as they are relied upon to be a successful alternative to sources of protein and energy in poultry diets instead of traditional sources (Smetana *et al.*, 2019; Heuel *et al.*, 2021). The black soldier fly larvae (BSFL) represent an efficient method for converting harmful and polluting organic waste into a valuable nutrient source, rich in proteins and fats (Caligiani *et al.*, 2018). The BSFL are used to recycle and dispose of organic waste such as food residues, crop residues, organic factory residues, and slaughterhouses, as well as animal and other organic waste, and convert them into high nutritional value biomass that can be used as sustainable animal feed (Erickson *et al.*, 2004; Zaki and Naji, 2022). Not only that, but residues from the process of breeding and producing BSFL are also utilized and used as an excellent soil fertilizer (Zaki and Naji, 2022).

The BSFL are abundant in amino acids, including arginine, histidine, lysine, methionine, valine, tryptophan, and others (Ruhnke *et al.*, 2018). They also possess a high concentration of essential fatty acids, such as linoleic and linolenic acids (Nijdam *et al.*, 2012). Additionally, these larvae are rich in essential minerals, including calcium, phosphorus, potassium, magnesium, iron, zinc, manganese, and sodium (Newton *et al.*, 2005). According to Liu *et al.* (2017), they are a significant source of vitamin E (Qosimah *et al*., 2023). Furthermore, Hu *et al.* (2018) and Gerez *et al.* (2019) highlighted the great benefits of chitin when used as feed additives in pig and poultry feed, acting as antioxidants and immune enhancers (Khambualai *et al*., 2009; Swiatkiewicz *et al.*, 2015). The BSFL are also a rich source of antimicrobial peptides (AMPs) that play an important role against bacteria, fungi and viruses (Moretta *et al*., 2020). Also, BSFL contain a wide range of medium-chain fatty acids (MCFA) especially lauric acid C12:0 (Gasco *et al*., 2018; Cullere *et al*., 2019) known for their antibacterial properties (Skrivanova *et al*., 2006). This makes it one of the best natural alternatives to reduce overuse of antibiotics used for poultry (Van Huis, 2013).

Based on the above, this study came to use BSFL powder as unconventional and sustainable local feed alternatives and include them in quail relations as a protein source to replace SBM and study their influence on productive performance.

MATERIALS AND METHODS

Ethical Approve

This study was conducted in accordance with the guidelines issued by the Scientific Ethics Committee/ College of Veterinary Medicine/ University of Mosul/ Iraq**.** as per their document No. UM.VET.2024.071 dated January 15, 2024.

Distribution of Experimental Treatments

The research was conducted at the Research Center of the Department of Animal Production/ College of Agriculture and Forestry/ University of Mosul/ Iraq. A total of 120 non-sexed quail chicks, one day old, were utilized in this study. Birds were housed in cages measuring (40×40×40) cm, and were randomly allocated into four treatments, each consisting of three replicates with 10 birds per replicate, ensuring as much homogeneity as possible among the birds within each replicate. The treatments included the following:

T1- Control: birds were given a feed without substitution and free from the BSFL.

T2- birds were reared on a ration with substitution of the BSFL by 20% instead of SBM.

T3-birds were reared on a ration with substitution of the BSFL by 40% instead of SBM.

T4- birds were reared on a ration with substitution of the BSFL by 60% instead of SBM.

The BSFL powder was added to feed by mixing the prescribed substitution ratios according to nutritional treatments and homogeneously with rest of the feed components. Table (1), illustrates the chemical analysis of the BSFL powder utilized in the study. Then, the feed was manufactured in form of granules (Pellets) with sizes suitable for each age stage of bird. The feed and water were *ad libitum* throughout the duration of experiment. Table (2) illustrates the components of feeds used in the study to meet the growing quail requirements. The birds were weighed at the beginning and end of the study period to determine the average live body weight and total weight gain. The daily weight gain was calculated by dividing the total weight gain by the number of experimental days. The feed was weighed and total consumed feed quantity, feed conversion ratio, total vitality ratio, and production index (PI) were calculated, which is calculated by applying the following equation:

$$production\ index\ (PI) = Average\ body\ weight\ (g)\ \times\ vitality\ ratio / Number\ of\ farming\ days\ \times\ Feed\ Conversion\ ratio\ \times\ 10$$

Note that vitality ratio = 100 – Mortality ratio, (AL-Fayadh *et al.,* 2010)

Table (1): Chemical Analysis of BSFL Powder.

Ingredients	%
Humidity	4.32
Crude Protein	40.80
Fat	25.7
Ash	13.6
Crude Fiber	7.8
Metabolic energy (kcal / kg)	4195

(Zaki and Naji, 2022)

Experimental Sampling

At the end of the study at the age of 42 days, 6 birds were selected from each treatment, three males and three females were randomly selected, as the birds weighed while alive (before slaughter) and recorded their live weights, then weights of carcasses and edible internal organs (liver, heart and gizzard) were recorded to calculate the dressing percent using a sensitive scale (Sartorius) with a sensitivity of 0.1g.

Table (2): The components and calculated chemical analysis of the diets used in the study

feed materials	T1 control	T2 Substituting 20%	T3 Substituting 40%	T4 Substituting 60%
Maize	20.7	20	20	12
Wheat	29	29.5	31.5	39
Soybean meal	30	24	18	12
BSFL	-----	6	12	18
Wheat Bran	13.3	14.5	14.5	16
Oil	4	3	1	------
*Premix	2.5	2.5	2.5	2.5
salt	0.25	0.25	0.25	0.25
Limestone	0.25	0.25	0.25	0.25
Total	100	100	100	100
calculated chemical analysis				
C. Protein	21.0	21.0	21.0	21.3
Metabolic energy (kcal / kg)	2900	2936	2936	2949
C. Fiber	4.89	4.72	4.48	4.39
Lysine	1.09	1.09	1.08	1.08
Methionine	0.51	0.52	0.52	0.53.
Calcium	0.26	0.42	0.53.	0.75
Available Phosphorus	0.37	0.42	0.46	0.52

*Premix ingredients: protein 25%, fat 2.10%, fiber 0.40%, 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, Magnesium sulphate 20 mg, Sodium chloride 70 mg, Zinc sulphate 2 mg, Iron sulphate 1.5 mg, Sodium propionate 5 mg, Sodium selenate 1000 mg, Potassium iodide 15 mg, Chloride Cobalt 10 micrograms, manganese sulphate 750 micrograms, calcium carbonate 1 gram.

Statistical Analysis

The data of this study were analyzed using the Completely Randomized Design (CRD), and the significance of differences between treatments were assessed using the Duncan's Multiple Range Test (Duncan, 1955). Statistical analysis was performed using the pre-built SAS program (SAS, 2003).

RESULTS AND DISCUSSION

Table (3) illustrates the impact of partially substituting BSFL with soybean meal (SBM) on average final live body weight, as well as average daily and total weight gain. The results of the statistical analysis indicated that there were no significant differences among all treatments in the studied traits. Noting that there was a slight, non-significant increase in favor of replacement treatments compared to control group. This result agreed with (Cullere *et al.*, 2016), who indicated that there were no significant differences in final live weight and daily weight gain when using the BSFL as a protein source in quail diets at percentages 10 and 15% of the diet components. It also agreed with Dalle Zotte *et al.* (2019) when they used defatted BSFL in feeding laying quail at a rate of 10 and 15% and showed that there was no significant effect on the final live weight. Also, Yusuf *et al.* (2020) did not find a significant differences in final live weight and weight gain when the fish powder was partially and completely replaced by the powder of the BSFL in quail female relations. While the result differed with El-Sayed *et al.* (2023), which indicated a highly significant improvement ($p \leq 0.001$) in final live weight of Japanese quail in favor of two treatments of replacing SBM with BSFL powder in proportions 50 and 100%.

Table (3): Effect of substituting BSFL instead of SBM on average final live body weight (g), average daily and total weight gain (g) of quail (Means ±SE).

Treatments		Average initial live weight (g/bird)	Average final live weight (g/bird)	Average daily weight gain (g/bird/day)	Average total weight gain (g/bird)
T1	Control	7.26±0.15 a	196.13±7.69 a	4.50±0.18 a	188.87±7.73 a
T2	Substituting 20%	7.82±0.46 a	199.87±8.47 a	4.57±0.21 a	192.05±8.68 a
T3	Substituting 40%	7.67±0.23 a	201.20±13.20 a	4.61±0.31 a	193.53±13.01 a
T4	Substituting 60%	7.46±0.13 a	208.13±12.66 a	4.78±0.30 a	200.6±12.74 a

* Averages marked with different letters vertically indicate significant differences ($p \leq 0.05$).

The results shown in Table (4) indicate demonstrate that partially replacing SBM with BSFL has no significant impact on feed intake, feed conversion ratio, or vitality ratio. It was also noted that there was an unnoticeable mathematical improvement in production index. In favor of alternative treatments compared to control group. This finding aligns with Cullere *et al.* (2016), who reported no significant differences in feed intake, feed conversion ratio, and mortality rate when BSFL were used as a protein source in quail diets at inclusion rates of 10% and 15%. Similarly, Mawaddah *et al.* (2018) found no significant differences in feed intake, feed conversion ratio, and mortality rate when defatted BSFL meal was used to replace meat and bone meal at levels of 50% and 100% in diets for laying quail, compared to the control group.

The results were also agreed with Woods *et al.* (2019) when they used BSFL in feeding broiler quails at a rate of 10% that made no significant deference on the consumption of daily feed, feed conversion ratio and mortality rate. Yusuf *et al.* (2020) noticed no significant effects on ratios of feed intake and feed conversion when BSFL meal was used partially or fully instead of fishmeal in the diet of female quail. Similarly, Harlystiarini *et al.* (2020) reported that replacing fishmeal with BSFL meal, at levels up to 100% in the diet of laying quail, resulted in no significant changes in feed consumption or feed conversion ratio.

The results of the statistical analysis in Table (5) indicate that there are no statistically significant differences in the percentages of dressing, heart, liver, gizzard and abdominal fat. The results obtained came identical with (Cullere *et al.,* 2016), who reported no significant variations in dressing percentage when BSFL were used as a protein source in quail diet at inclusion rates of 10% and 15%. While the result differed with El-Sayed *et al.* (2023), as they indicated that there was a highly significant improvement in carcass, heart, liver and gizzard percentages of Japanese quail in favor of two treatments of replacing SBM with BSFL powder in percentages (50 and 100) %. Also, Woods *et al.* (2019) noticed when they used BSFL in feeding broiler quails at a rate of (10%) that there was a significant improvement in dressing percent in the second treatment compared to the control.

Table (4): Effect of substituting BSFL instead of SBM on total feed intake (g), feed conversion ratio, vitality percentage and production index of quail (Means ±SE).

Treatments		Total feed intake (g)	feed conversion ratio	Vitality %	production index
T1	Control	605.56±25.19 a	3.21±0.04 a	96.7±3.33 a	14.08±0.75 a
T2	Substituting 20%	596.94±28.00 a	3.11±0.03 a	96.7±3.33 a	14.76±0.10 a
T3	Substituting 40%	590.48±22.82 a	3.07±0.13 a	100±0.00 a	15.76±1.68 a
T4	Substituting 60%	659.19±29.49 a	3.29±0.08 a	100±0.00 a	15.10±1.23 a

* Averages marked with different letters vertically indicate significant differences ($p \leq 0.05$).

Table (5): Effect of substituting BSFL instead of SBM on dressing percent, heart, liver, gizzard and the Abdominal fat percent of quail (Means ±SE).

Treatments		Dressing %	Heart %	Liver %	Gizzard %	Abdominal fat %
T1	Control	62.91±1.86a	0.86±0.04a	1.90±0.20a	1.23± 0.10a	1.11±0.23 ab
T2	Substituting 20%	62.64±2.19a	0.72±0.07a	2.03±0.12a	1.28±0.06a	0.79±0.09 b
T3	Substituting 40%	64.29±2.73a	0.85±0.02a	1.85±0.07a	1.27±0.08a	1.01±0.14 b
T4	Substituting 60%	62.25±1.10a	0.87±0.06a	1.86±0.20a	1.19±0.02a	1.64±0.25 a

* Averages marked with different letters vertically indicate significant differences ($p \leq 0.05$).

CONCLUSIONS

The results of the present study showed the possibility of replacing soybean meal with black soldier fly larvae powder by up to 60% without negatively affecting the productive performance of quail. Therefore, the black soldier fly larvae can be used as sustainable feed alternatives that are produced locally and at low cost, and can be relied upon to reduce the increasing demand for traditional raw feed such as soybeans and yellow corn and thus reduce competition between their supply Such as human food and poultry feed.

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CONFLICT OF INTEREST

The researcher's affirmation is to that there were no conflicts of interest related to the publication of this study.

تأثير احلال يرقات ذبابة الجندي الاسود محل كسبة فول الصويا في الأداء الإنتاجي للسمان في مرحلة النمو

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الخلاصة

تم تنفيذ هذه الدراسة في مختبر الدواجن التابع لقسم الإنتاج الحيواني في كلية الزراعة والغابات بجامعة الموصل. استخدم فيها 120 طير سمان بعمر يوم واحد غير مجنسة لدراسة تأثير احلال يرقات ذبابة الجندي الاسود العملاقة وبنسب مختلفة محل كسبة فول الصويا في الأداء الإنتاجي للسمان في مرحلة النمو، وزعت الطيور عشوائياً الى أربع معاملات وهي كالآتي: الأولى سيطرة (بدون إحلال) الثانية والثالثة والرابعة بنسب إحلال (20، 40 و 60) % على التوالي، وكان العلف والماء متوفر بصورة حرة طيلة مدة الدراسة والتي استمرت لغاية عمر 42 يوم. اما الصفات الإنتاجية المدروسة كمؤشر على كفاءة إحلال يرقات ذبابة الجندي الاسود وبنسب مختلفة محل كسبة فول الصويا فشملت الوزن الحي النهائي والزيادة الوزنية، كمية العلف المستهلك، معامل التحويل الغذائي، نسبة الحيوية، الدليل الإنتاجي وصفات الذبيحة. بينت النتائج عدم وجود فروقات معنوية في الصفات الإنتاجية المدروسة بين جميع المعاملات، مما يدل على إمكانية إحلال مسحوق يرقات ذبابة الجندي الأسود بنسبة تصل لغاية 60% محل كسبة فول الصويا دون التأثير سلباً على إنتاجية طائر السمان النامي.

الكلمات المفتاحية: ذبابة الجندي الأسود ، سمان ، الأداء الإنتاجي ، كسبة فول الصويا.

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