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The effect of two different defatted insect meals in Japanese quail diets on the performance, ileal morphometry, apparent ileal digestibility and blood parameters

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ABSTRACT

There is a pressure to replace soybean meal in poultry diets with alternative protein sources, in order to ensure the sustainability of animal nutrition. The aim of this study was to evaluate the effect of two insect meals on performance, ileal morphometry, organs weight and blood biochemical parameters in Japanese quail. A total of 600 seven-day-old unsexed Japanese quail were equally divided into three groups (with four replicates each). The first group was the Control group (C) without insect meals (0 g/kg). The two experimental groups received diets containing 100 g/kg of defatted mealworm meal (TM) or defatted black soldier fly larvae meal (HI). The trial lasted from 7th to 47th days of birds age. Defatted black soldier fly larvae meal positively affected body weight gain in starter phase and provided comparable results in other parameters to the C group. Whereas defatted mealworm meal showed some negative effects on growth, ileal morphology and ileal digestibility of crude protein. Several blood parameters were changed significantly over time ($P < 0.05$), indicating that dietary treatments influenced quail physiology. Overall, these results indicate that defatted black soldier fly larvae meal is a promising alternative protein source for Japanese quail, providing comparable or superior results compared to conventional feed.

Introduction

In poultry nutrition, soybean meal is currently the most widely used plant protein source worldwide (Šťastník et al., 2021a). However, the European Union (EU) shows a very low level of self-sufficiency in soybean meal production, with only approximately 4 % produced within the EU and about 96 % being imported (European Commission, Joint Research Centre, 2024). This strong dependence on imports, together with the continuously increasing demand for animal products, highlights the need to identify alternative and sustainable protein sources for animal nutrition (Makkar et al., 2014; Sajid et al., 2023).

In this context, insects have attracted considerable attention as a promising alternative feed source. Insects are rich in crude protein, essential amino acids, fat, vitamins, and minerals (Rumpold and Schlüter, 2013; Makkar et al., 2014; Fu et al., 2025). Commonly used insect species include yellow mealworms (*Tenebrio molitor*) and black soldier flies (*Hermetia illucens*), which contain approximately 27–54 % and 35–61 % crude protein, and 4–34 % and 7–42 % crude fat, respectively (Elahi et al., 2022). In addition to these nutrients, insects also contain chitin as a component of crude fiber, which may be less digestible for non-ruminant animals (Sánchez-Muros et al., 2014; Abenaim and Conti, 2025).

Reflecting their nutritional potential and sustainability benefits, the European Union has authorized the use of insect meals derived from several insect species for poultry and pig feeding under Commission Regulations (EU) No 2017/893 and No 2021/1372. Consequently, insect meals are increasingly being evaluated as partial or complete replacements for conventional protein sources such as soybean meal, fish meal, or meat and bone meal in poultry diets.

Several studies have investigated the dietary inclusion of insect meals in quail nutrition; however, the reported results remain inconsistent. Insect meals derived from mealworms (*Tenebrio molitor*), black soldier flies (*Hermetia illucens*), silkworms (*Bombyx mori*), mopane worms (*Imbrasia belina*), cotton leafworms (*Spodoptera littoralis*), and

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peach fruit flies (*Bactrocera zonata*) have been evaluated at various inclusion levels. These studies reported effects on body weight, body weight gain, feed intake, feed conversion ratio (**FCR**), carcass traits, selected blood biochemical parameters, and gastrointestinal tract morphometry in quail (Sabirli and Cufadar, 2019; Sayed et al., 2019; Zadeh et al., 2019; Hatab et al., 2020; Secci et al., 2022; Silva et al., 2024; Al-Khalaifah et al., 2025a,b), whereas other studies found no significant effects on growth performance, carcass characteristics, internal organ weights, or blood biochemical parameters (Cullere et al., 2016; Mbhele et al., 2019). Japanese quail (*Coturnix japonica*) are considered a suitable experimental model for such nutritional studies due to their rapid reproduction rate (three to four generations per year), low production costs, good adaptability to diverse environmental conditions, and high resistance to diseases (Vali, 2008; Al-Sofee et al., 2025). Despite their relatively low body weight (approximately 80–300 g), they are efficiently bred for meat and egg production and are increasingly used in poultry production systems to help meet the growing global demand for animal products (Zadeh et al., 2020; Al-Sofee et al., 2025). Moreover, Japanese quail are widely employed in scientific research, including studies on developmental biology, genetics, behavior, diseases, nutrition, and even space flight experiments (Morris et al., 2020; Afshinnekoo et al., 2020). Importantly, insects naturally form part of the quail diet alongside grains, seeds, and fruits, further supporting the suitability of Japanese quail as a model species for evaluating insect-based feed ingredients (Al-Sofee et al., 2025).

In order to improve the sustainability of poultry nutrition in Europe, alternative protein sources capable of partially replacing soybean meal are required. While previous studies have primarily focused on the inclusion of a single insect species at varying dietary levels, comparative information on different insect meals included at the same level remains limited. Therefore, the present study aimed to evaluate the effects of incorporating two different types of insect meals at the same inclusion level in the diets of Japanese quail on growth performance, ileal morphometry, ileal apparent digestibility, carcass characteristics, internal organ weights, and selected blood biochemical parameters.

The hypothesis of the present study is that the replacement of conventional protein sources with insect meals in quail diets will maintain or improve growth performance, carcass traits, nutrient digestibility, and selected physiological parameters.

Materials and methods

The experiment was conducted in accredited experimental facilities of the Faculty of AgriSciences at Mendel University in Brno. The animal procedures were reviewed and approved by the Animal Care Committee of Mendel University in Brno and by the Ministry of Education, Youth, and Sports (MSMT-6859/2024-3) of the Czech Republic.

Birds and husbandry

A total of 600 unsexed seven-day-old broiler-type Japanese quail (*Coturnix japonica*) were weighed and divided by body weight into three experimental groups with four replicates, in each group were 200 quail without vaccination. The hatching eggs originated from our institutional breeding facility. The experimental quail were hatched and reared within the same controlled environment and were not transported or moved outside the facility at any life stage. The number of birds in the experiment was determined with the aim of ensuring a sufficient amount of biological material for planned analysis, particular ileal digesta for the determination of ileal apparent digestibility. Due to the small size of the digestive tract of Japanese quail, a single individual provides only a limited amount of ileal content, which is not sufficient for laboratory analysis. For this reason, it was necessary to use a higher number of birds and was required to obtain a representative and analytically adequate sample of ileal digesta. At the same time, the number of birds was designed to allow for reliable statistical evaluation of the results and minimize experimental variability. The conventional system with wood shavings was used. During first week of the experiment, the lighting regime was set to 23 h of darkness and 1 h of light. From day 15 of age onward, the lighting regime was adjusted to 18 h of darkness and 6 h of light. Ambient temperature was maintained at 30°C during first week of the experiment using heat lamps. Thereafter, the temperature was gradually reduced according to the age of the birds, reaching 23 °C by the end of the experiment. Relative humidity ranged from 40 % to 65 % throughout the experiment (Cheng et al., 2010). The trial lasted for 40 days. Throughout the experiment, the quail had *ad libitum* access to feed and water.

Diets

Before the start of the experimental period (up to 6 days of age), the quail were fed a commercial starter diet. Non-pelleted experimental starter diets containing standard anticoccidials (from the 7th to the 20th day of age) and experimental grower diets (from the 21st day to the 47th day of age) were used in the feeding trial. For the last three days of the trial, the quail were fed experimental grower diets containing chromium oxide Cr_2O_3 p.a. (3 g/kg of feed).

The first group was Control (**C**; n = 200), which received 0 g/kg of insect meal in the diet. The second group received a diet containing 100 g/kg of defatted mealworm meal (*Tenebrio molitor*) (**TM**; n = 200). The third group received a diet containing 100 g/kg of defatted black soldier fly larvae meal (*Hermetia illucens*) (**HI**; n = 200). The rations were calculated according to the adapted nutrient requirements of Japanese quail (National Research Council (NRC), 1994) to be isonitrogenous and isoenergic. According to the Commission Regulation (EC) No 152/2009, the chemical composition of the insect meals and experimental diets were analyzed in the terms of dry matter, crude protein, ether extract, crude fiber and crude ash. Table 1 shows the composition and nutrient composition of experimental diets.

The insect meals used in our experiment were obtained from Underground Food s.r.o. (Brno, Czech Republic). The insect meals were used as a partial substitute for soybean extracted meal in the diets. The amino acid composition of insect meals was analyzed. The amino acids were determined using AAA400 (Ingos, Czech Republic). This involved medium-pressure liquid chromatography using an Ostion KS ion exchanger. Measurement was based on ninhydrin derivatization of amino acids in acetate buffers from hydrolyzed samples using a UV detector. Acid hydrolysis was used to determine the following amino acids: alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, phenylalanine, proline, serine, threonine, tyrosine and valine. To determine the levels of methionine and cysteine, they had to be oxidized to homocysteine and methionine sulphone before undergoing acid hydrolysis. The content of the detected amino acids is based on a comparison with a mixed standard of known amino acid concentrations. The amino acid contents were determined as previously described by Volek et al. (2020, 2023). Table 2 shows the proximate analysis and amino acid composition of the insect meals used.

Collection of samples and end of the experiment

During the trial, the feed intake of each group was recorded daily and the FCR was subsequently calculated. The body weight was noticed weekly during the trial, and the average body weight gain was calculated from the body weights. Health status was evaluated daily based on mortality, clinical symptoms, and subsequent blood biochemical parameters.

At the 20th day of age, the quail were weighed. After that, a first slaughter by decapitation was carried out, during which were the blood and ileum from selected quail (n = 8 from each group) collected for further analysis (blood biochemical analysis and ileum histomorphometry).

At 47 days of age, the quails were weighed, slaughtered by

Table 1
Composition and chemical analysis of used starter and grower diets in dry matter.

Items	Starter			Grower		
	C	TM	HI	C	TM	HI
Components (g/kg)						
Wheat	50.0	141.5	84.0	100.0	200.5	146.0
Maize	349.3	365.0	366.0	470.2	472.5	479.0
Rapeseed oil	40.0	16.9	25.0	31.8	10.6	12.0
Soybean meal	530.0	346.1	390.0	365.0	185.4	228.5
Mealworm meal	0	100.0	0	0	100.0	0
Black soldier fly larvae meal	0	0	100.0	0	0	100.0
Premix[1]	30.0	30.0	30.0	30.0	30.0	30.0
DL-Methione	0.7	0.5	3.0	2.0	1.0	2.5
L-Lysine	0	0	2.0	1.0	0	2.0
Nutrient composition						
ME_N (MJ/kg)[2]	11.79	11.74	11.83	12.35	12.31	12.25
Dry matter	1 000	1 000	1 000	1 000	1 000	1 000
Crude protein	299.9	295.6	288.9	237.7	236.1	235.0
Ether extract	66.5	50.5	52.9	54.3	41.8	45.4
Crude fiber	41.7	40.9	47.1	35.3	34.6	37.2
Crude ash	72.3	69.0	75.3	62.2	59.1	66.5

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; ME_N = apparent metabolize energy.

[1] Premix for starter contains: Lysine 2.01 g; Methionine 2.49 g; Threonine 0.9 g; calcium 6.3 g; phosphorus 1.05 g; natrium 1.26 g; copper 15 mg; iron 75 mg; zinc 99 mg; manganese 99 mg; iodine 1.03 mg; selenium 0.18 mg; retinol 8 400 IU (international unit); calciferol 5 001 IU; tocopherol 45 mg; phylloquinone 1.5 mg; thiamine 4.2 mg; riboflavin 8.4 mg; pyridoxin 6 mg; cobalamin 30 μg; biotin 0.21 mg; niacinamide 36 mg; folic acid 1.8 mg; calcium pantothenate 13.5 mg; choline chloride 180 mg. Premix for grower contains: Lysine 2.1 g; Methionine 2.25 g; Threonine 0.93 g; calcium 5.7 g; phosphorus 0.99 g; natrium 1.38 g; copper 15 mg; iron 75 mg; zinc 99 mg; manganese 99 mg; iodine 1.03 mg; selenium 0.36 mg; retinol 8 400 IU (international unit); calciferol 4 950 IU; tocopherol 45 mg; phylloquinone 1.32 mg; thiamine 4.05 mg; riboflavin 8.4 mg; pyridoxin 6 mg; cobalamin 28.8 μg; biotin 0.18 mg; niacinamide 36 mg; folic acid 1.65 mg; calcium pantothenate 13.35 mg; choline chloride 180 mg.

[2] Apparent metabolize energy (calculated value).

Table 2
Nutrients and amino acid composition of defatted mealworm meal and defatted black soldier fly larvae meal in dry matter.

Items	Defatted mealworm meal	Defatted black soldier fly larvae meal
Nutrient composition (g)		
Dry matter	1 000	1 000
Crude protein	694.5	512.4
Ether extract	42.7	71.8
Crude fiber	56.2	112.7
Crude ash	94.9	125.4
Amino acid composition (%)		
Alanine	2.4	2.6
Arginine	4.4	2.7
Aspartic acid	5.1	4.5
Cysteine	1.9	0.4
Glutamic acid	10.4	6.3
Glycine	3.8	3.0
Histidine	1.0	1.9
Isoleucine	2.2	2.5
Leucine	4.3	3.8
Lysine	4.3	3.0
Methionine	1.5	0.7
Phenylalanine	2.0	2.3
Proline	6.1	3.2
Serine	4.3	2.1
Threonine	2.8	2.1
Tyrosine	1.9	3.6
Valine	3.3	3.4

decapitation, and eviscerated. The blood, ileum, gizzard, heart, and liver of the average-weight birds were collected for further analysis, and the weights of the gizzard, heart, and liver were recorded.

Carcass characteristics and internal organs

For assess carcass characteristics, were selected the eight quail from each group (two quail from each replicate). The carcass (the body without the head, neck and organs), and carcass parts without skin (breast without bones and thigh with bones) and internal organs (liver, heart and empty gizzard with cuticle) were weighed. The carcass yield was calculated as a percentage of the final body weight.

$$\text{Carcass yield (\%)} = [\text{carcass weight (g)} \ / \ \text{final body weight (g)}] \times 100$$

The breast and thigh yields were calculated as a percentage of the body weight (**BW**) and carcass weight (**CW**).

$$\text{Breast or thigh yield (\% of BW)} = [\text{breast or thigh weight (g)} \ / \ \text{body weight (g)}] \times 100$$

$$\text{Breast or thigh yield (\% of CW)} = [\text{breast or thigh weight (g)} \ / \ \text{carcass weight (g)}] \times 100$$

The weight of the internal organs was recorded. Then the relative weight of internal organs was calculated to body weight as a percentage of the final body weight.

$$\text{Relative weight of organ (\% of BW)} = [\text{organ weight (g)} \ / \ \text{body weight (g)}] \times 100$$

Histomorphometry analysis of the ileum

At 20 and 47 days of age, the ileum of quail was collected for histomorphometry evaluation. Immediately after slaughter, a defined section of the ileum (distal part of ileum – 10 cm proximal to the ileocecal junction) was removed from eight quail in each group (two quail from each replicate) and fixed in formaldehyde. The samples were collected and evaluated according to the method described by Novotný et al. (2023). Five villus heights (**VH**) and five crypt depths (**CD**) were evaluated per quail. The villus height to crypt depth ratio (**VH/CD**) was then calculated by comparing the villus height and the crypt depth. This resulted in a total of 40 evaluations (n = 40 from each group).

Apparent ileal digestibility

The indicator method of digestibility was used to determine apparent ileal digestibility. Three days before slaughter, the quail were fed the experimental grower diets containing chromium oxide (3 g/kg of the feed). After the quail were slaughtered, the digesta from the distal part of the ileum were collected, frozen and then subsequently lyophilized. The dried ileal digesta were ground to pass thought a 1-mm sieve. The samples of feed and ileal digesta were analyzed for dry matter and crude protein according to the Commission Regulation (EC) No 152/2009. The 1 g of sample of the feed and 0.5 g of sample of ileal digesta were subjected chromium oxide determination and chromium oxide content and digestibility were calculated according to method described by Šťastník et al. (2025). The amount of chromium oxide was calculated:

$$Cr_2O_3 = (cv \times F \times V0 \times 2.533) \ / \ (V1 \times w)$$

where Cr_2O_3 = chromium oxide; cv = consumption of a standard volumetric solution of thiosulphate; F = volumetric solution factor; V_0 = leachate volume (100 ml); V_1 = pipetted volume (50 ml) and w = weight of the sample in g.

The apparent ileal digestibility of the crude protein was calculated:

$$100 - [(\% Cr_2O_3 \text{ in the diet} \times \% \text{nutrient in the ileal digesta content}) / (\% Cr_2O_3 \text{ in the ileal digesta content} \times \% \text{nutrient in the diet}] \times 100$$

Biochemical blood analysis

At 20 and 47 days of quail age, blood was collected from the *vena jugularis* into heparinized tubes. After the collection, the samples were centrifuged within 2 h. The centrifugation was performed for 10 min at 3 000 rpm. The blood plasma was obtained after the centrifugation process. The samples of blood plasma were then frozen at –20°C until biochemical analysis. Selected parameters were determined in blood plasma samples (n = 8 from each group) using standardized biochemical methods and commercial sets from Erba Lachema (Czech Republic). According to Zálešáková et al. (2025) the following enzyme activities and markers of hepatic metabolism, fat and nitrogen metabolism were analyzed on an automatic biochemical analyzer Ellipse (AMS, Spa, Italy): AST – aspartate aminotransferase (AST/GOT 500); GGT – gamma-glutamyl transferase (GGT 250); ALT – alanine aminotransferase (ALT/GPT 500); ALP – alkaline phosphatase (ALP AMP 500); concentrations of the TG – triglycerides (TG 250); CHOL – cholesterol (CHOL 250); urea (Urea, no. UR 107; Randox, United Kingdom); UA – uric acid (UA – UA 500, no. 10010225 Erba Lachema, Czech Republic); GLU – glucose (GOD/POD, GLU 500, Erba Lachema, Czech Republic); CREA – creatinine (CREA – CREA 500, no. 1010227 Erba Lachema, Czech Republic); TP – total protein (TP 500) and Alb – albumin (Alb 500). The globulin was calculated as total protein (**TP**) minus albumin and then the albumin to globulin ratio (**Alb/Glob**) were calculated.

Statistical analysis

The obtained data were processed by Microsoft Excel (USA) and TIBCO Statistica version 14.0 (USA). One-way analysis of variance (ANOVA) was used to determine the differences between the groups. Scheffe's test was used to analyze the differences between the groups. A value of $P < 0.05$ was considered as statistically significant for determining differences between the experimental groups. Values between $P < 0.05$ to 0.07 were considered as statistic trend. The results are presented as means and standard error of the mean (SEM).

$$\mathbf{Y_{ij}} = \mu + \boldsymbol{\tau_i} + \boldsymbol{\varepsilon_{ij}}$$

where Y_{ij} = observation in the i-th group; μ = overall mean; τ_i = effect of the -th group (subject to the constraint $\Sigma\tau_i = 0$); $\varepsilon_{ij} \sim N(0, \sigma^2)$ = random error term

For the evaluation of blood dynamics, an independent t-test was used to compare the mean values of blood biochemical parameters at 20 and 47 days of age within each experimental group. The results are presented as the P-value parameter vs age. A value of $P < 0.05$ was considered as statistically significant for changes in the monitored individual blood parameter within each experimental group.

$$\mathbf{Y_{ij}} = \boldsymbol{\mu_i} + \boldsymbol{\varepsilon_{ij}}$$

where i = 1,2 (group); j = 1,…n_i (observation within the i-th group); μ_i = mean of the i-th group; $\varepsilon_{ij} \sim N(0, \sigma^2)$ = random error term

Results

Growth performance

Table 3 shows the average body weight of the Japanese quail throughout the trial. At 20 days of age, TM group had a lower body weight compared to HI group ($P < 0.05$). The TM group had a 2.4 % lower body weight, whereas the HI group had a 2.3 % higher body weight compared to the C group. At 28 and 35 days of age, the TM group had a 3.9 % and 3.0 % lower body weight compared to the C and HI groups ($P < 0.05$). Moreover, a certain trend of differences in body weight between groups were observed at 14 days and 47 days of age ($P = 0.055$ and $P = 0.058$, respectively). The TM group tended to have a 2.0 % and 1.4 % lower body weight than the other groups. At 42 days of age, no statistically significant difference in body weight was observed between groups ($P > 0.05$).

The results of feed intake, average body weight gain and FCR of the Japanese quail for each phase and for the whole trial are reported in Table 4. The first value is for the starter phase (7–20 days), the second for the grower phase (21–35 days), and the last for the whole trial. No

Table 4
The average feed intake, body weight gain and feed conversion ratio of Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) for each phase and whole trial (n = 4 from each group).

	Groups				
	C	TM	HI	SEM	P-value
Feed intake (g/bird/day)					
Starter	14.21	14.50	14.67	0.12	0.336
Grower	29.86	31.26	30.45	0.26	0.067
Overall	24.77	25.81	25.32	0.20	0.097
Average body weight gain (g)					
Starter	89.34[ab]	86.90[b]	91.97[a]	0.87	0.038
Grower	135.22	134.31	136.73	1.42	0.813
Overall	224.57	221.21	228.69	1.92	0.305
FCR					
Starter	2.07	2.17	2.07	0.02	0.091
Grower	5.97	6.29	6.02	0.07	0.169
Overall	4.42[b]	4.67[a]	4.43[b]	0.05	0.036

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; FCR = feed conversion ratio; n = number of cases.
[a,b] Values within a row with different superscripts differ significantly at $P < 0.05$.

Table 3
The average body weight of Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) during the trial.

	n [1]			Groups				
Days of age	C	TM	HI	C	TM	HI	SEM	P-value
7	200	200	200	27.83	27.41	27.94	0.26	0.680
14	191	194	198	58.41	57.22	59.78	0.44	0.055
20	189	193	198	117.16[ab]	114.32[b]	119.90[a]	0.64	0.002
28	172	176	182	170.55[a]	163.84[b]	171.85[a]	0.76	0.000
35	171	175	182	206.25[a]	199.98[b]	206.16[a]	0.77	0.001
42	170	175	182	238.82	235.51	239.66	1.13	0.284
47	170	175	181	252.31	248.69	256.67	1.38	0.058

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; n = number of cases.
[1] Number of cases change during trial for reasons such as mortality and first slaughter at 20th day of age.
[a,b] Values within a row with different superscripts differ significantly at $P < 0.05$.

differences in feed intake were observed between the groups during the starter phase or throughout the experiment ($P > 0.05$). A trend in feed intake can be seen in the grower phase ($P = 0.067$). The TM group exhibited a 4.7 % higher feed intake, whereas the HI group showed a 2.0 % higher feed intake compared to C group. The average body weight gain was affected by insect meal in the starter phase. The HI group had the highest average body weight gain in the starter phase ($P < 0.05$) (2.9 % higher). Whereas the TM group had a 2.7 % lower body weight gain compared to the C group. In the other phases, the average body weight gains were unaffected by the insect meals in the Japanese quail diets ($P > 0.05$). There was no effect of insect meals on the FCR of Japanese quail in the starter and grower phases ($P > 0.05$). The TM group had a 5.7 % higher overall FCR than the C and HI groups ($P < 0.05$).

Carcass characteristics and internal organs

The carcass characteristics and weight of the internal organs are shown in Table 5. The selected quail from the HI group had a 3.3 % higher body weight and a 10.4 % higher breast weight ($P < 0.05$). Whereas the selected quail from the TM group had a 1.8 % lower body weight. A trend toward a 5.4 % higher carcass weight can be seen in the HI group ($P = 0.053$). A 3.8 % higher carcass yield was observed in the TM group than in the C group ($P < 0.05$). The C group had a 7.6 % and 6.8 % lower breast yield as percentage of body weight compared to the TM and HI groups ($P < 0.05$). No differences were found out in other parameters of carcass characteristics between groups ($P > 0.05$). The weight of the liver, heart and gizzard of Japanese quail were similar in all groups ($P > 0.05$).

Histomorphometry of the ileum

Table 6 shows the average VH, CD and VH/CD ratio of the ileum of 20- and 47-day-old Japanese quail. In 20-day-old quail, ileal VH, CD and VH/CD ratio were not influenced by insect meals in the diets. In 47-days-old quail, the effect of insect meals on ileal VH was observed. The TM group had a 13.1 % lower ileal VH than the C and HI groups ($P < 0.05$).

Fig. 1 shows representative images of 20-day-old quail microscopic ileum sections from the C, TM and HI groups at a scale of 200 µm. From the histomorphological perspective, no surface epithelial injury was observed in any of the groups (C, TM, HI). Intraepithelial lymphocytes were observed in quantities of up to 10 per high-power field (**HPF**). The lacteals had a normal diameter, at less than 25 % of the villous width. Within the villous lamina propria lymphocytes and plasma cells occupied up to 25 % of the area of one HPF. Granulocytes were up to 2/HPF. Crypt dilation was up to 2 % crypts. A normal amount of mucosal fibrose tissue was found, with up to 2 fibrocyte separating the crypts. No *Coccidia* sp. was found in the samples (0/10 HPFs).

The representative images of microscopic sections of the ileum from the C, TM and HI groups of 47-day-old Japanese quail are shown in Fig. 2 (at a scale of 100 µm for the C group and at a scale of 200 µm for the TM and HI groups). In the C and HI groups were not found surface epithelial injuries. Intraepithelial lymphocytes were up to 10/HPF. The lacteals were observed a normal diameter, at less than 25 % of the villous width. Within the villous lamina propria the lymphocytes and plasma cells occupied up to 25 % of the area of one HPF. Granulocytes were observed in quantities up to 2/HPF. The dilation of crypt was up to 2 % crypts. There was found a normal amount of mucosal fibrose tissue (up to 2 fibrocyte separating the crypts). *Coccidia* sp. was not found (0/10 HPFs). In the TM group, the tips of the villi were multifocally autolytic. However, no surface epithelial injury was found in the preserved villi. The villi were shortened. The intraepithelial lymphocytes observed in the sample were found to be mildly increased (up to 20/HPF). The lacteals were a normal diameter, at less than 25 % of the villous width. Within the villous lamina propria the lymphocytes and plasma cells occupied up to 25 % of the area of one HPF. Granulocytes were found to be within normal limits of up to 2 fibrocyte separating the crypts. A normal amount of mucosal fibrose tissue was found, with up to 2 fibrocyte separating the crypts. *Coccidia* sp. was 0/10 HPFs.

Apparent ileal digestibility

Table 7 shows the apparent ileal digestibility of the crude protein. The TM group had a 10.9 % lower value for the apparent ileal digestibility of the crude protein than the C and HI groups ($P < 0.05$).

Blood biochemical parameters

Table 8 shows the selected blood biochemical parameters and blood dynamics of 20- and 47-day-old Japanese quail. The defatted insect meals influenced the concentrations of triglycerides and cholesterol at 20 days of age. The concentrations of triglycerides were 44.7 % and 64.1 % higher in the groups containing defatted insect meals (TM, HI) compared to the C group ($P < 0.05$). The concentration of cholesterol

Table 5
The carcass weight, yield, breast and thigh weight, yield and internal organs weight of Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) (n = 8 from each group).

	Groups				
	C	TM	HI	SEM	P-value
Carcass characteristics					
Body weight (g)	239.75[ab]	235.38[b]	247.75[a]	2.05	0.035
Carcass weight (g)	164.60	167.87	173.42	1.58	0.064
Carcass yield (% of BW)	68.68[b]	71.32[a]	70.00[ab]	0.41	0.023
Breast (g)	20.57[b]	21.71[ab]	22.70[a]	0.35	0.039
Breast yield (% of BW)	17.15[b]	18.46[a]	18.32[a]	0.24	0.047
Breast yield (% of CW)	24.99	25.89	26.17	0.33	0.316
Thigh (g)	17.17	17.61	18.42	0.26	0.144
Thigh yield (% of BW)	14.34	14.98	14.87	0.21	0.416
Thigh yield (% of CW)	20.90	21.01	21.24	0.29	0.897
Internal organs					
Liver (g)	4.78	4.57	4.77	0.19	0.890
Liver (% of BW)	1.99	1.94	1.92	0.07	0.931
Heart (g)	2.19	2.17	2.18	0.04	0.979
Heart (% of BW)	0.92	0.92	0.88	0.02	0.638
Gizzard (g)	4.47	4.38	4.12	0.12	0.467
Gizzard (% of BW)	1.86	1.86	1.66	0.05	0.113

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; BW = body weight; CW = carcass weight; n = number of cases.
[a,b] Values within a row with different superscripts differ significantly at $P < 0.05$.

Table 6
The average ileal villus height, crypt depth and villus height/crypt depth ratio of 20- and 47-day-old of Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) (n = 40 from each group).

	Groups				
	C	TM	HI	SEM	P-value
20 days of age					
VH (µm)	323.05	323.35	316.28	3.42	0.637
CD (µm)	60.50	61.70	61.35	0.84	0.839
VH/CD ratio (µm)	5.52	5.34	5.22	0.09	0.414
47 days of age					
VH (µm)	333.05[a]	289.53[b]	320.78[a]	4.64	0.000
CD (µm)	68.70	65.20	67.63	0.77	0.167
VH/CD ratio (µm)	4.91	4.53	4.78	0.08	0.154

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; VH = villus height; CD = crypt depth; VH/CD = villus height to crypt depth ratio; n = number of cases.
[a,b] Values within a row with different superscripts differ significantly at $P < 0.05$.

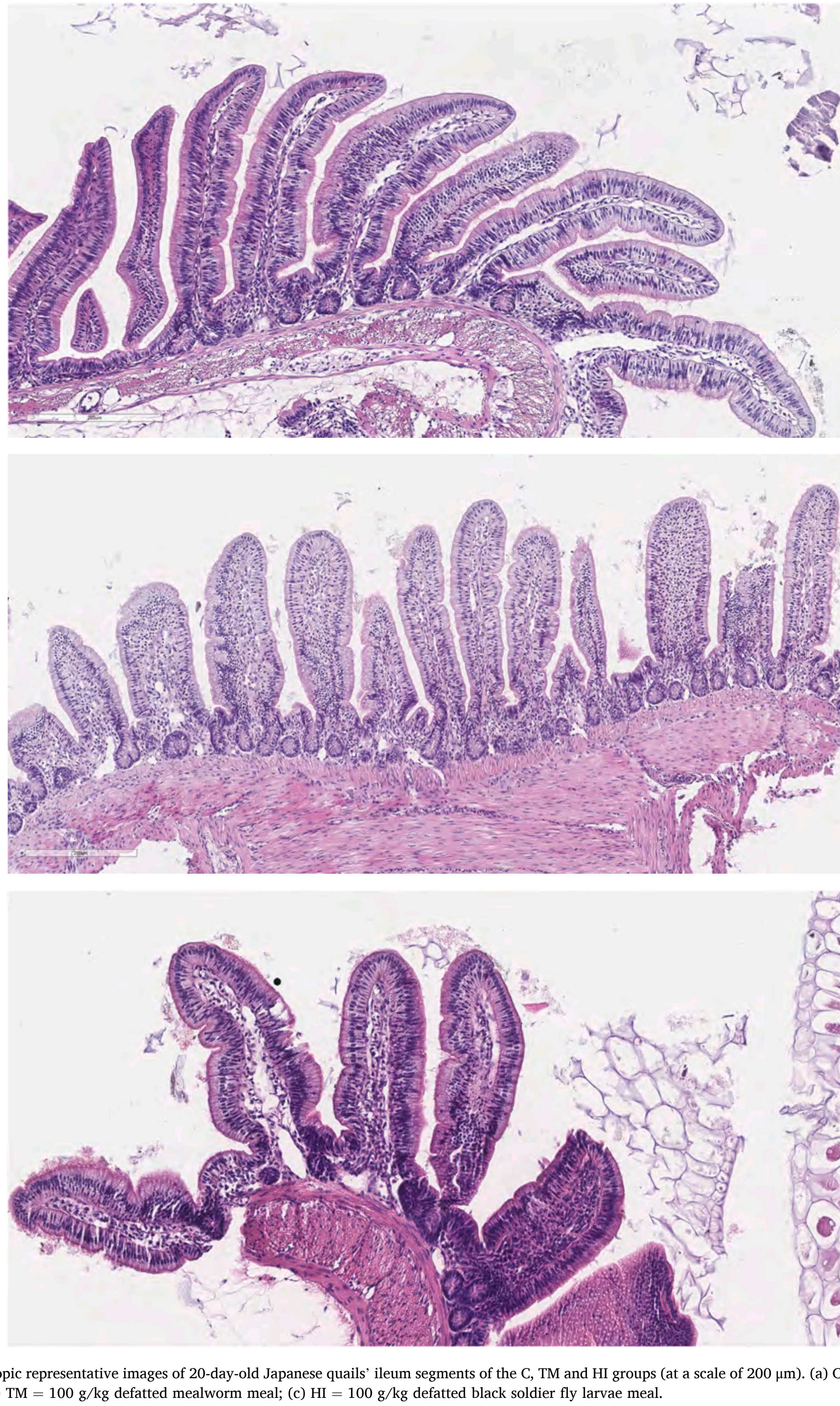

Fig. 1. Microscopic representative images of 20-day-old Japanese quails' ileum segments of the C, TM and HI groups (at a scale of 200 μm). (a) C = Control (0 g/kg insect meal); (b) TM = 100 g/kg defatted mealworm meal; (c) HI = 100 g/kg defatted black soldier fly larvae meal.

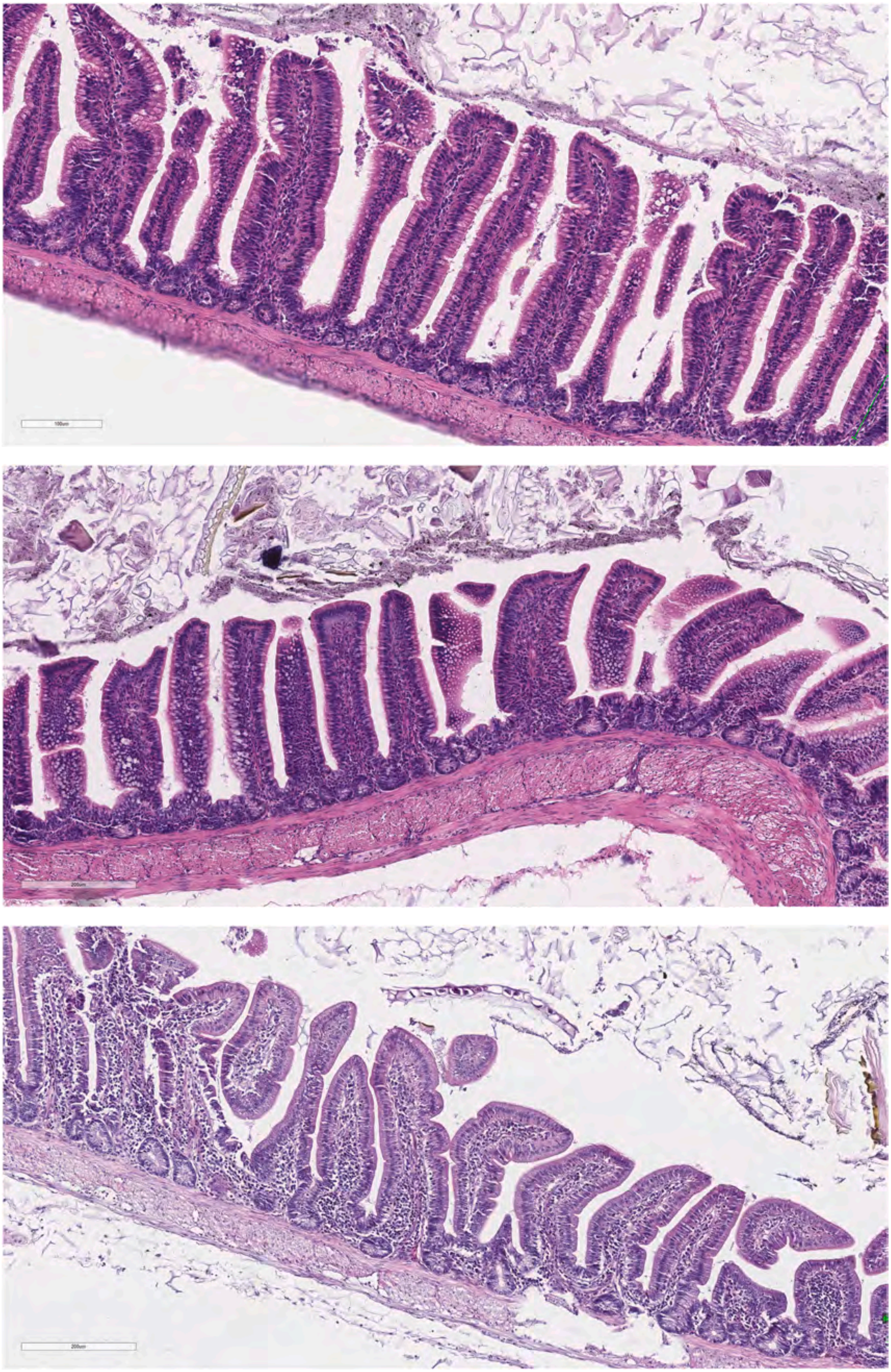

Fig. 2. Microscopic representative images of 47-day-old Japanese quails' ileum segments of the C, TM and HI groups (for the C group at a scale of 100 µm and for the TM and HI groups at a scale of 200 µm). (a) C = Control (0 g/kg insect meal); (b) TM = 100 g/kg defatted mealworm meal; (c) HI = 100 g/kg defatted black soldier fly larvae meal.

Table 7
The apparent ileal digestibility of the crude protein of Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) (n = 8 from each group).

	Groups				
	C	TM	HI	SEM	P-value
Apparent digestibility (%)					
Crude protein	63.64[a]	52.78[b]	59.94[a]	1.41	0.002

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; n = number of cases.
[a,b] Values within a row with different superscripts differ significantly at P < 0.05.

was 39.1 % higher in the TM group than the C group (P < 0.05). There was some trend in the alanine aminotransferase activity (**ALT**) between groups (P = 0.068). The TM group exhibited a 36.4 % lower ALT activity, whereas the HI group showed a 27.3 % lower ALT activity compared to C group Statistically significant differences in aspartate aminotransferase activity (**AST**) were found at 47 days of age. The TM group exhibited a lower value of AST activity than the HI group (P < 0.05). The AST activity in the TM group was 12.3 % lower than in the C group. A trend toward a 33.7 % higher alkaline phosphatase activity (**ALP**) can be seen in the HI group (P = 0.053). At 20 and 47 days of age, the other blood biochemical parameters of Japanese quail were unaffected by defatted insect meals in the diets (P > 0.05).

In terms of blood dynamics, the results show that over time there have been statistically significant changes (P < 0.05) in groups in the following blood parameters: AST, ALP, gama-glutamyl transferase (**GGT**), uric acid, glucose, cholesterol, Alb/Glob ratio. The activity of AST in the C and HI groups and activity of uric acid in the HI group increased after 20th day of age. Conversely, the activity of ALP in all groups and activity of GGT in the C group decreased after the 20th day of age. In concentration of glucose and Alb/Glob ratio, the C and HI groups showed statistically decreasing level in the 47th day of age. Conversely, the concentration of cholesterol increased in the C and TM groups.

During the experiment, 13 (6.5 %) quail died in the C group, 9 (4.5 %) in the TM group, and 3 (1.5 %) in the HI group. Higher mortality was observed in the C group than in the HI group.

Discussion

Growth performance

According to our results, the lower body weight of the quail in the TM group may be due to a higher inclusion of mealworm meal in the diet, or a higher chitin content in the mealworm meal, and a lower apparent ileal digestibility of crude protein. Cheng et al. (2010) and Al-Sofee et al. (2025) mentioned that 5- to 6-week-old quail weighed around 160–250 g, which corresponds to the weight of the quail observed in our experiment. Similarly, Ait-Kaki et al. (2021) reported that 3- and 5-week-old quail fed a diet containing 3 % mealworm meal had a lower body weight. Sabirli and Cufadar (2019) also noticed a lower body weight in the groups of quail fed 4 % and 6 % mealworm meal compared to the group fed 2 % mealworm meal. The authors suggested that diets containing more than 2 % mealworm meal in the diet may negatively influence the quail growth performance. As well, Šťastník et al. (2021b) suggested that including mealworm meal can influence the chicken performance, because these groups had a lower body weight. Conversely, Secci et al. (2022) reported a quadratic effect of mealworm meal on body weight 42-day-old quail. No statistically significant differences between HI and C group could indicate that HI diet has good nutrient availability and growth potential. These results suggest that 100 g/kg of defatted black soldier fly larvae meal can effectively partially replace soybean meal without compromising the

Table 8
The blood biochemical parameters of 20- and 47-day-old Japanese quail fed diets containing defatted insect meals (mealworm meal – TM or black soldier fly larvae meal – HI) (n = 8 from each group) and blood dynamics of biochemical parameters.

	Groups	AST (µkat/l)	ALT (µkat/l)	ALP (µkat/l)	GGT (µkat/l)	Creat (µmol/l)	Urea (mmol/l)	UA (µmol/l)	Glu (mmol/l)	TG (mmol/l)	Chol (mmol/l)	TP (g/l)	Alb (g/l)	Glob (g/l)	Alb/Glob
20 days of age	C	2.36	0.11	25.58	0.05	20.66	0.28	560.52	14.91	1.03[b]	2.71[b]	24.75	16.95	7.80	2.25
	TM	2.44	0.07	25.75	0.04	19.64	0.25	417.84	14.18	1.49[a]	3.77[a]	29.39	19.96	9.43	2.14
	HI	2.53	0.08	23.84	0.04	20.67	0.20	493.74	15.40	1.69[a]	3.33[ab]	27.76	18.31	9.45	1.98
	SEM	0.09	0.01	0.75	0.00	0.59	0.04	26.22	0.27	0.08	0.13	1.02	0.65	0.41	0.06
	P-value	0.771	0.068	0.535	0.704	0.736	0.685	0.079	0.171	0.001	0.002	0.172	0.170	0.178	0.221
47 days of age	C	3.18[ab]	0.09	9.71	0.03	18.22	0.34	626.46	12.93	1.54	4.33	25.66	14.98	10.69	1.54
	TM	2.79[b]	0.08	8.18	0.04	19.76	0.32	650.34	13.58	1.15	4.69	28.26	17.58	10.69	1.79
	HI	3.65[a]	0.08	12.98	0.03	20.44	0.25	701.73	13.68	1.61	3.74	29.33	16.38	12.95	1.38
	SEM	0.14	0.01	0.85	0.00	0.71	0.05	54.98	0.26	0.15	0.26	1.35	0.67	0.90	0.10
	P-value	0.043	0.747	0.053	0.250	0.431	0.684	0.861	0.470	0.416	0.375	0.544	0.300	0.513	0.283
P-value parameter × age	C	0.022	0.330	0.000	0.005	0.111	0.609	0.611	0.005	0.098	0.012	0.772	0.295	0.104	0.019
	TM	0.138	0.788	0.000	0.600	0.944	0.526	0.056	0.440	0.202	0.006	0.678	0.131	0.445	0.079
	HI	0.001	0.753	0.000	0.053	0.896	0.516	0.019	0.008	0.167	0.114	0.612	0.193	0.083	0.002

Abbreviations: C = Control (0 g/kg insect meal); TM = 100 g/kg defatted mealworm meal; HI = 100 g/kg defatted black soldier fly larvae meal; AST = aspartate aminotransferase; ALT = alanine aminotransferase; ALP = alkaline phosphatase; GGT = gama-glutamyl transferase; Creat = creatinine; UA = uric acid; Glu = glucose; TG = triglycerides; Chol = cholesterol; TP = total protein; Alb = albumin; Glob = globulin; Alb/Glob = albumin/globulin ratio.
[a,b] Values within a column with different superscripts differ significantly at P < 0.05.

growth performance of Japanese quail. This is also confirmed by some studies which found that including black soldier fly larvae meal in quail diets had no effect on body weight (Cullere et al., 2016; Mbhele et al., 2019). Contrary, Al-Khalaifah et al. (2025a) noticed higher final body weight in Japanese quail.

The feed intake was unaffected by insect meals. Conversely, the authors (Sayed et al., 2019; Zadeh et al., 2019; Hatab et al., 2020; Sarica et al., 2020; Khan et al., 2022; Silva et al., 2024; Al-Khalaifah et al., 2025b) observed reduced feed intake in groups fed insect meals or mealworm scales in quail diets. These diets either replaced 25–100 % of conventional protein sources with insect meal, included insect meal at 3 g/kg or 25–100 g/kg, or were supplemented with 1–3 g/kg of mealworm scales. Zadeh et al. (2019) and Khan et al. (2022) suggested that the presence of chitin in the insect meal was responsible for this reduction. Contrary Al-Khalaifah et al. (2025a) reported higher feed intake in groups fed black soldier fly larvae meal. However, several studies (Cullere et al., 2016; Sabirli and Cufadar, 2019; Marareni and Mnisi, 2020; Secci et al., 2022) confirm our finding in feed intake that there was no difference in the feed intake between the groups fed diets with or without insect meal. Mbele et al. (2019) only observed a quadratic trend in the effect of insect meal on feed intake and body weight gain.

Mealworm meal was probably less digestible and provided quail with fewer available nutrients needed for growth compared to black soldier fly larvae meal. This could explain why the HI group had higher body weight gain during the starter phase and why the overall FCR in the TM group was higher. Similarly, Silva et al. (2024) noticed increased body weight gain, but reduced FCR in groups fed black soldier fly larvae meal compared to the control group. In our experiment, a similar FCR was observed between the HI and C groups. Some studies confirmed our findings of decreased body weight gain and increased FCR in groups fed mealworm meal (Sabirli and Cufadar, 2019; Secci et al., 2022). Furthermore, Sarica et al. (2020) reported that replacing 75 % and 100 % of dietary fish meal with mealworm meal decreased body weight gain, but FCR in these groups were similar with the control group. FCR was reduced when 25 % and 50 % of dietary fish meal was replaced with mealworm meal (Sarica et al., 2020). Conversely, in some studies were observed that insect products in diets increased body weight gain and reduced FCR (Zadeh et al., 2019; Hatab et al., 2020; Khan et al., 2022; Al-Khalaifah et al., 2025a,b). Respectively, Zadeh et al. (2019) noticed the highest body weight gain in groups fed diets containing 22.5 or 30 g/kg of mealworm meal. Sayed et al. (2019) observed a reduced FCR, but similar body weight gains between the groups. On the other hand, Cullere et al. (2016) and Marareni and Mnisi (2020) did not notice effect of the insect meal on body weight gain or FCR.

Carcass characteristics and internal organs

The insect meals influenced carcass characteristics. The difference in body weight and breast muscle weight could be related to the selection of quail for evaluation of the proportion of the main meat part. However, a trend towards differences in the final body weight of the quail was observed. Breast yield as percentage of BW was affected by insect meals. It possible that insect meals promoted the development of breast muscle tissue. Several studies (Cullere et al., 2016; Mbhele et al., 2019; Sabirli and Cufadar, 2019; Marareni and Mnisi, 2020; Ait-Kaki et al., 2021) have found out that the insect meal does not affect the carcass characteristics. However, Sarica et al. (2020) and Secci et al. (2022) noted a negative effect of insect meal on some carcass characteristics. Sarica et al. (2020) reported that replacing fish meal with defatted mealworm meal by 50 %, 75 % and 100 % reduced the hot and cold carcass yields. Furthermore, Secci et al. (2022) found out that the carcass weight decreased linearly as the level of mealworm meal increased. Conversely, Zadeh et al. (2019) noted that 30 g/kg of mealworm meal in quail diets resulted in higher carcass, legs and breast yields than other groups fed insect meal, however, yields were similar with those of the control group fed fish meal. Contrary, Al-Khalaifah et al. (2025b) reported that group fed a diet containing combination mealworm and super worm meals had the highest carcass yield. Khan et al. (2022) reported an increase in carcass and breast yields with higher inclusion levels of mealworm scales in the diets. They also observed an increase in carcass weight, while mealworm scales had no effect on leg yield. Al-Khalaifah et al. (2025a) observed that quail fed a diet of 15 % black soldier fly larvae meal exhibited higher values in terms of carcass characteristics. Sayed et al. (2019) ranked insect meal from peach fruit flies or cotton leafworms and Hatab et al. (2020) both ranked cotton leafworms in quail diets, finding that groups fed insect meals had higher carcass yields. Hatab et al. (2020) attributed this to the higher nutrition composition of insect meal compared to meat and bone meal. This may be the same reason for the higher carcass yield observed in the TM group in our study.

The unaffected weight of the internal organs suggests that insect meals do not influence their weight, which corresponds with the findings of several studies (Mbhele et al., 2019; Zadeh et al., 2019; Marareni and Mnisi, 2020; Sarica et al., 2020; Ait-Kaki et al., 2021 Silva et al., 2024). Additionally, Khan et al. (2022) did not observe that the mealworm scale influenced the weight of the heart and liver. However, in contrast to the results in our study and of previous studies by other authors. Sayed et al. (2019) noticed that insect meals affected the relative weight of the liver, heart, spleen and bursa, which were higher in groups fed insect meals (peach fruit flies or cotton leafworms). Also, Hatab et al. (2020) observed that the groups fed cotton leafworm meal had a higher relative weight of liver, spleen and bursa, however the relative weight of the heart, proventriculus and gizzard were unaffected by the insect meal. These authors (Sayed et al., 2019; Hatab et al., 2020) attributed these findings to an increased immune system function. Furthermore, Hatab et al. (2020) suggest that the higher weight of the internal organs may be due to the higher nutritional composition of insect meal, including protein, essential amino acid, fat and energy, compared to the meat and bone meal.

Histomorphometry of the ileum

At 20 days of age, the insect meals had no effect on the histomorphometry of ileum. The decreased ileal VH in the TM group at 47 days of age may have been caused by the higher chitin content in the mealworm meal. Sudwischer et al. (2025) reported that analyzed mealworm meal contained 9.3 g/kg of chitin on a dry matter, whereas black soldier larvae meal contained between 8.6 and 13.6 g/kg of chitin on a dry matter. In our case, it is possible that black soldier fly larvae meal had lower chitin content than mealworm meal. Due to the lower ileal VH in the TM group, there was also less area for nutrient absorption. Novotný et al. (2023) suggested that the area of the villi height and crypt depth are important for nutrient absorption from feed. Similarly, Biasato et al. (2018) observed a negative effect of mealworm meal on morphometry of the intestines of male broiler chickens as the level of mealworm meal increased. However, Biasato et al. (2017) did not find out effect of the inclusion of mealworm meal on the intestinal morphometry of female broiler chickens. Additionally, the inclusion of 2 % or 5 % of mealworm meal in laying hens diets unaffected the ileal villus height (Šťastník et al., 2021a). Khan et al. (2022) and Addeo et al. (2022) observed the effect of mealworm scales or mealworm meal on the morphometry of the ileum of quail. A group of quail fed a diet containing 3 g/kg of mealworm scales had a higher VH and CD, however, the VH/CD ratio was not affected (Khan et al., 2022). Addeo et al. (2022) also noticed that a group fed 5.6 % mealworm meal had a higher VH and CD and a lower VH/CD ratio in the ileum. While the group fed 2.8 % mealworm meal had a higher VH and VH/CD ratio and a lower CD. Addeo et al. (2022) suggested that the higher VH and CD in ileum could indicate that absorption and utilization of nutrient was inefficient in duodenum and jejunum, because the morphometry of these parts of the small intestine were also affected by the insect meal. Zadeh et al. (2019) observed in morphometry of the jejunum that groups of quail fed 22.5

and 30 g/kg of mealworm meal had a higher VH and that the group fed 30 g/kg also had a higher CD than the other groups. Groups of quail fed diets containing insect meals had higher VH and VH/CD and lower CD in the jejunum (Al-Khalaifah et al., 2025b). The authors suggest that these findings indicate better nutrient utilization.

Apparent ileal digestibility

Black soldier fly larvae meal unaffected the apparent ileal digestibility. However, apparent ileal digestibility of crude protein was reduced by mealworm meal, which may be related to its higher chitin content and lower VH in the ileum. Similar results were found out by Dalle Zotte et al. (2021), who evaluated the full-fat and defatted silkworm pupae meal. Their results showed that the group of Japanese quail fed defatted silkworm pupae meal had a lower apparent digestibility of all nutrients. Secci et al. (2021) investigated the effect of varying levels of mealworm meal (0 %, 1.4 %, 2.8 % and 5.6 %) in the diets of laying hens of Japanese quail and reported that the apparent ileal digestibility of the dry matter, organic matter and crude protein decreased linearly as the level of mealworm meal increased, expect for ether extract. It is possible that the level of mealworm meal inclusion in our study was too high. Cullere et al. (2016) found out that the including 10 % or 15 % black soldier fly larvae meal in Japanese quail diets had no effect on the apparent nutrient digestibility other than ether extract. Our results regarding the digestibility of crude protein are consistent with those of these authors. Contrary, Al-Khalaifah et al. (2025a) observed that quail fed a diet containing 15 % black soldier fly larvae meal exhibited higher digestibility of dry matter, organic matter and crude protein. In contrast, this study found out that the digestibility of the ether extract was higher in the group fed a diet of 10 % black soldier fly larvae meal.

Blood biochemical parameters

Higher concentrations of triglycerides and cholesterol may be due to the higher concentration of ether extract in insect meals compared to the soybean meal. The concentration of triglycerides in our study falls within the range of values reported by Scholtz et al. (2009). However, lower value was observed for the concentration of cholesterol than the range of values found out by Scholz et al. (2009). Conversely, the observed concentration of cholesterol is within the range of values reported by Agina et al. (2017). Lower value of AST activity could be due to a lower weight of liver (Jones, 1999). However, AST is not a specific enzyme to the liver, it is also present in skeletal muscle, the heart, the brain and the kidneys (Tennant and Center, 2008). Similar results for the parameters cholesterol and triglycerides were observed by Sayed et al. (2019) and Hatab et al. (2020), who found out that groups fed insect meals had higher values for these parameters. Sayed et al. (2019) suggested that an increased triglycerides concentration may be due to a higher concentration of ether extract in diets that include insect meals. Furthermore, Sayed et al. (2019) reported that the groups fed insect meals had lower values for albumin, globulin and the Alb/Glob ratio, and a lower ALT activity was observed in the group fed cotton leafworms meal. Hatab et al. (2020) observed that the group whose meat and bone meal was fully replaced by insect meal had significantly higher levels of total protein and globulin. Both groups fed insect meal had higher level of albumin (Hatab et al., 2020). Sarica et al. (2020) found out that replacing 50 %, 75 % and 100 % of the fish meal with defatted mealworm meal decreased total protein and uric acid levels than a diet containing fish meal or replacing 25 % of the fish meal with mealworm meal. Furthermore, the groups fed defatted mealworm meal had lower globulin, the Alb/Glob ratio, cholesterol and triglycerides levels compared to the group fed fish meal (Sarica et al., 2020). In our experiment, at 20 days of age Japanese quail, the opposite effect was observed: the groups fed insect meals had increased triglycerides and cholesterol concentration compared to the C group. However, at 47 days of age, there were no statistically significant differences between groups in these parameters. Mbhele et al. (2019), Marareni and Mnisi (2020) and Ait-Kaki et al. (2021) did not observe any effect of insect meal on blood biochemical parameters in quail. Al-Khalaifah et al. (2025a) also found out that the black soldier fly larvae meal did not affect most of blood biochemical parameters, only triglyceride levels. Mbhele et al. (2019) only observed quadratic trend for the Alb/Glob ratio.

There are few available studies dealing with the effect of age on blood biochemical parameters in Japanese quail. Ali et al. (2012) and Abou-Kasem et al. (2019) examined differences in selected hematological and biochemical blood parameters in Japanese quail at 5, 6 and 7 weeks of age. A recent study by Zálešáková et al. (2025) examined intervals and dynamics of blood biochemical parameters in broiler chickens. In our study, the following parameters changed with age: AST, ALP, GGT, uric acid, glucose, cholesterol and the Alb/Glob ratio. These changes could be due to sex, male and female sexual maturity, ovulatory activity associated with egg laying, or diets. Zálešáková et al. (2025) found out a correlation between age and activity of GGT, level of uric acid, protein, albumin and urea. Overall, the authors concluded that changes in enzyme activity in the blood are influenced by housing, movement, stress and handling before collecting of blood. In our study blood parameters of Japanese quail were evaluated, therefore the results obtained may differ from those reported by Zálešáková et al. (2025), as their study focused on broiler chickens. Japanese quail and broiler chickens are different species of poultry. In addition to the above-mentioned reasons, the difference could be influenced by hybrid lines and sex, as well (Farahat et al., 2018; Abou-Kasem et al., 2019).

Level of uric acid increased in the HI group at the end of the fattening period. In general, uric acid is the primary end metabolic product of nitrogen metabolism in poultry (Donsbough et al., 2010). Our finding is supported by Ali et al. (2012), who noted increasing level of uric acid with age of Japanese quail. In contrast, Abou-Kasem et al. (2019), did not notice change in the levels of uric acid with age. Conversely, Zálešáková et al. (2025) observed decreasing level of uric acid from 1st day of broilers chicken life. Level of glucose decreased in the C and HI groups at 47 days of age, similar finding observed in study by Ali et al. (2012). Our results do not correspond with results, which were observed in studies by Abou-Kasem et al. (2019) and Zálešáková et al. (2025). Abou-Kasem et al. (2019) did not notice change in the level of glucose. On the other hand, in study by Zálešáková et al. (2025) the level of glucose increased from the 1st day and after its level was stable. Moreover, level of cholesterol decreased from 1st day and then the level was stable until the 35th day of age in the broiler chickens (Zálešáková et al., 2025). However, this is not observed in our study. In the C and TM groups were increased levels of cholesterol at 47th day of age and Ali et al. (2012) and Abou-Kasem et al. (2019) noticed increasing level of cholesterol with age, as well. Abou-Kasem et al. (2019) suggested that laying may influence changes in cholesterol level. In our study, it is possible that ovulatory activity in female Japanese quail could also influence the changes in cholesterol level. The Alb/Glob ratio with age decreased in the C and HI groups. In this parameter Ali et al. (2012) did not observed difference with age of Japanese quail. A decrease in the Alb/Glob ratio in birds' blood may indicate better immune system function (Biasato et al., 2017). Sabater and Forbes (2015) suggested that decreasing Alb/Glob ratio may indicate insufficient albumin production or be caused by losses though the digestive tract or kidneys, which may be related to infection.

Conclusions

The study evaluated effect of two defatted insect meals in the Japanese quail diets at one level of inclusion, which did not allow determination of the optimal inclusion level. Even though diets were formulated according to current recommendations, differences in nutrient composition between the insect meals may have influenced nutrient availability. The lower number of replicates for certain parameters, as well as the selection of birds, may have affected statistical power.

Deffated black soldier fly larvae meal positively affected growth performance during the starter phase and showed results comparable to the control diet in most evaluated parameters. In contrast, defatted mealworm meal negatively affected some performance traits, although it resulted in a higher carcass yield. Overall, defatted black soldier fly larvae meal appears to be a more suitable alternative protein source for Japanese quail nutrition than mealworm meal, providing comparable or superior results to soybean meal–based diets. Despite these limitations, the study contributes to the understanding of potential of insect meals as alternative protein sources in Japanese quail diets.

Data and model availability statement

The authors declare that data are not deposited in an official repository. The data that support the study findings are available upon request.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not use any artificial intelligence assisted technologies in the writing process.

CRediT authorship contribution statement

Lenka Kudlová: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jakub Novotný:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Lukáš Čumplík:** Writing – review & editing, Investigation, Formal analysis. **Nikola Dvořáčková:** Writing – review & editing, Investigation, Formal analysis. **Michal Řiháček:** Investigation, Formal analysis. **Dana Zálešáková:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Lucie Horáková:** Investigation, Formal analysis. **Leoš Pavlata:** Writing – review & editing, Resources. **Ondřej Šťastník:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Disclosures

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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