Research Article

Effects of Cricket Extract and Protein Hydrolysate on Hematology and Egg Quality in Japanese Quails

Anna Lidiyawati[1,3], Suyadi Suyadi[1], Eko Widodo[1], Muhammad Halim Natsir[1*]

[1]Doctoral Program of Animal Science, Faculty of Animal Science, Brawijaya University, Malang 65145, Indonesia; [2]Faculty of Animal Science, Brawijaya University, Malang 65145, Indonesia; [3]Program Animal Science Faculty Exact Sciences Nahdlatul Ulama Blitar, St. Imam Bonjol 16, Sananwetan, Blitar, East Java, Indonesia.

Abstract | The increasing demand for sustainable animal protein sources necessitates novel feed additives to enhance poultry health and productivity. The present study was explored into insect-derived compounds, such as cricket extract (CE) and cricket hydrolysate protein (CPH) which have rich nutritional profiles and bioactive properties, and offer a promising avenue for novel feed additives. Four hundred Japanese quails were randomly allocated to four dietary treatments (five replicates per treatment, 20 birds per replicate), and egg quality was assessed using 300 eggs (15 eggs from each replicate unit treatment). Treatments consisted of basal feed (T0), basal feed plus zinc bacitracin (50 mg/kg; T1), basal feed plus CE (10 ml/kg; T2) and basal feed plus CPH (10 ml/kg; T3). Hematological parameters, including Red Blood Cell (RBC) count, hemoglobin (Hb) level, and White Blood Cell (WBC) count, were determined using an automated hematology analyzer. Internal egg quality was assessed based on albumen height, Haugh Unit, albumen weight, yolk weight and cholesterol level. Data were analyzed using one-way ANOVA by Duncan test. Statistical analysis, indicated that RBC counts were significantly higher ($p < 0.001$) in T2 (3.10×10^{12} cells/mm^3) and T3 (2.51×10^{12} cells/ mm^3) compared T0 and T1. Similarly, WBC values were significantly reduced ($p < 0.001$) in T3 (10.50×10^9 cells/ mm^3) compared to T0 (14.5×10^9 cells/ mm^3) and T1 (13.45×10^9 cells/ mm^3). Hb levels showed no significant differences across treatments. Regarding egg quality, albumen weight was significantly higher in T3 (6.22 g) compared to T0 (4.6 g; $p < 0.001$), while cholesterol content was significantly lower in T3 (183.00 mg per egg yolk) than in T0 (231.48 mg per egg yolk; $p < 0.001$). In conclusion the administration of CPH demonstrated a positive impact on physiological status and production performance, as evidenced by improvements in blood profile parameters and egg quality. Overall, these findings highlight the potential of CPH as a natural alternative to antibiotics in promoting animal health and sustaining productive performance.

Keywords | Cricket extract, Cricket hydrolysate, Insect protein, Hematology, Egg quality, Quails

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***Correspondence** | Muhammad Halim Natsir, Doctoral Program of Animal Science, Faculty of Animal Science, Brawijaya University, Malang 65145, Indonesia; **Email:** emhanatsir@ub.ac.id
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INTRODUCTION

Japanese quails (*Coturnix coturnix japonica*) are increasingly important in global poultry production, owing to their rapid growth rate, high egg-laying capacity, and efficient feed conversion. In layer production systems, maintaining optimal hematological status and internal egg quality is essential, as these parameters directly influence bird health, productivity, and economic sustainability. However, conventional strategies to improve quail performance often rely on synthetic feed additives or antibiotic growth promoters, raising concerns related to antimicrobial resistance, food safety, consumer perception, and environmental impact (Mnisi *et al*., 2021). In addition, poultry production systems in many countries remain highly dependent on imported conventional feed ingredients, which increases production costs and threatens long-term sustainability (Natsir *et al*., 2017; Muwakhid *et al*., 2025). Consequently, there has been a growing interest in identifying sustainable, natural, and biologically active feed additives that can support poultry health and product quality (Batool *et al*., 2021; El-Sabry *et al*., 2022).

Insects have emerged as promising alternative protein sources for animal feed due to their low land and water requirements, high feed conversion efficiency, and capacity to recycle organic waste (Sajjad *et al*., 2024). The exploration of locally available, non-conventional feed resources has been widely encouraged as a strategy to reduce dependence on commercial feeds while maintaining animal performance (Muwakhid *et al*., 2025). Among the edible insects crickets are particularly attractive because of their high protein content, balanced essential amino acid profile, beneficial fatty acids and diverse bioactive compounds. These nutritional and functional attributes make crickets a potential replacement for conventional protein sources while also contributing to more sustainable poultry production systems (Phesatcha *et al*., 2022).

Cricket proteins can be processed into crude extracts or further converted into protein hydrolysates through enzymatic hydrolysis. Protein hydrolysates are composed of short-chain peptides and free amino acids that are more digestible, bioavailable, and biologically active than intact proteins or crude extracts. Previous studies have demonstrated that insect-derived protein hydrolysates possess antioxidant, antimicrobial, and immunomodulatory properties, which may contribute to improved physiological stability and immune efficiency in animals (Chotphruethipong *et al*., 2024; Syamsuryadi *et al*., 2025a). In particular, brown crickets have been reported to contain all essential amino acids and numerous bioactive peptides, suggesting their potential role as functional feed ingredients capable of supporting erythropoiesis, mineral absorption, and inflammatory regulation (Hasnan *et al*., 2023). Despite the increasing scientific interest in insect-based feed ingredients, research on cricket- derived products in poultry nutrition remains limited. Most available studies have focused on growth performance or have evaluated whole insect meals, often using insect species other than crickets. Moreover, direct comparisons between cricket extract (CE) and cricket hydrolysate protein (CPH), particularly in relation to hematological parameters and internal egg quality in laying quails, are scarce. As a result, the functional superiority of protein hydrolysates over crude extracts in avian species has not been clearly established (Sedgh-Gooya *et al*., 2021; Sajjad *et al*., 2024). Therefore, the objective of the present study was to evaluate the effects of dietary supplementation with CE and CPH on hematological health and internal egg quality in Japanese quails. It was hypothesized that cricket-derived products, particularly protein hydrolysates, would improve hematological profiles and enhance internal egg quality characteristics compared to a conventional basal diet.

MATERIALS AND METHODS

Experimental design and treatments

A total of 400 Japanese quails aged five weeks were included in this study. The cages used during the study were 20 battery cages with dimensions (60 × 37 × 26 cm) for each cage. Each cage was filled 20 quails, ensuring uniform space allowance across all treatments. Birds were monitored daily for health status and mortality; any mortality was recorded and excluded from subsequent analyses, with an overall mortality rate of <1% and no differences among treatments. Quails were randomly assigned to treatment groups using a completely randomized design with equal numbers of birds per treatment.

CE were made using a cricket powder. The powder was soaked in 2000 mL of 96% ethanol, and maintained at 10:1 ratio. This method was chosen because it can extract many bioactive compounds, especially those are sensitive to heat (Solikin *et al*., 2024). The mixture was stirred to ensure that the powder was fully covered by the liquid. This was performed every day for five days until the liquid was almost clear. The extract was then filtered through Whatman No. 1 filter paper. The liquid was then concentrated using a rotary evaporator at 40°C.

CPH was prepared using a method described by Liceaga Gesualdo and Li-Chan (1999) with some modifications. For this, 90 g of dead brown crickets was mixed with 180 mL of distilled water (1:2 ratio) and blended. Then, CH3COOH and 1 M NaOH were then added until the pH reached 7. A meat tenderizer called "PAYA," which contains the enzyme papain, was added at 5.65 g (15 g/kg sample) to help the enzyme work well. Using papain to break down insect proteins is a sustainable method that can increase amino acid content (Batish *et al*., 2020). The cricket mixture was maintained at 50°C and a pH 7 for 6 h. Subsequently, the enzyme was stopped by heating at 90°C for 20 minutes. The mixture was then spun at 4000 rpm for 30 minutes to obtain CPH. Finally, the CPH was freeze-dried at -73°C.

The dietary treatments included: (1) T0: basal feed (control), (2) T1: basal feed supplemented with (50 mg/kg zinc-bacitracin), (3) T2: basal feed supplemented with 10 ml/kg CE, and (4) T3: basal feed supplemented with 10ml /kg CPH. CPH containing 20 amino acids and 41 peptides (70% of which are dipeptides, namely γ-glutamyl peptides) was administered for 60 days under a completely randomized design. The composition of cricket protein extract and hydrolysate is shown in Table 1. Prior to treatment initiation, quails underwent a 6-day adaptation period to standardize housing conditions and basal diet intake. The levels of cricket protein hydrolysate were determined based on previous research by Wen and He (2012). The quails were housed in a battery-cage system with free access to feed and water throughout the trial. The basal diet contained 20.06% crude protein, 2822.90 kcal/kg metabolizable energy, 0.80% calcium, and 0.45% non-phytate phosphorus, formulated according to nutritional standards for quail production. Environmental conditions, including temperature, humidity, and lighting schedule, were maintained according to the standard quail husbandry guidelines. All procedures were approved by the Animal Care and Research Ethics Committee, Institut Biosains, Universitas Brawijaya, Indonesia (Approval No. 004-KEP-UB-2024).

Table 1: Composition of cricket flour, extract and hydrolysate protein.

Sample	Ash	Moisture	Carbohydrates	Fat	Protein	DH
Cricket Flour	4.65	3.50	7.56	21.50	60.74	-
CE	4.75	3.60	8.56	20.50	60.84	-
CPH	7.03	4.50	17.19	0.85	86.5	26.50

Description: CE: cricket extract; CPH: cricket hydrolysate protein; DH: degree of hydrolysis.

Evaluation of blood parameters

Blood sampling was performed at the end of the experiment (60 days) to evaluate hematological characteristics. Three birds from each replicate were randomly selected, and approximately 200 µL of blood was obtained from the brachial (wing) vein using sterile 23–25G needles. Blood samples were immediately transferred to labelled tubes containing EDTA as an anticoagulant to preserve cellular integrity. Hematological parameters, including red RBC count, Hb concentration, and WBC count, were analyzed using a standard automated hematology analyzer following the procedures described by Abuoghaba *et al.* (2021). All samples were analyzed within two hours of collection to prevent hemolysis and ensure measurement accuracy.

Antioxidant activity

Malondialdehyde activity (MDA) of each sample was measured by reactive matrix test using thiobarbituric acid (TBA). Samples were vortexed, mixed with 8.1% sodium dodecyl, and left at room temperature for 10 minutes. Controls were treated in the same way. After incubation, 20% acetic acid and 0.6% TBA were added to the samples, which were then placed in a water bath for 1h at 90-95°C. Subsequently, butanol: pyridine (15:1) was added to the supernatant, and the mixture was stirred and centrifuged. MDA was expressed in nmol/ml.

Egg quality

At the 60 days, the eggs were collected in five consecutive days, then marked and analyzed for physicochemical quality. For physicochemical analysis, 300 eggs were collected in total, with 15 eggs sampled from each replicate unit treatment and were put in plastic clips that had been labelled according to the treatment. External egg quality, egg weight was measured using a digital balance with 0.01 g precision, while egg length and width were measured with a digital caliper to calculate the egg shape index. Eggshells were washed, air-dried, and weighed to determine shell proportion, Eggshell thickness was measured at the blunt end, equator, and sharp end using a micrometer, with the average value used for analysis. For internal egg quality, eggs were cracked onto a flat glass surface to measure albumen height, yolk height, and yolk diameter, which were then used to compute the albumen and yolk indices based on standard formulas. The Haugh Unit (HU) was calculated using albumen height and egg weight as the key indicators of albumen quality. The albumen and yolk were carefully separated and weighed to determine their absolute weights and relative percentages respectively. All egg quality analyses followed the procedures established by North and Bell (1990), Roberts (2004), and AOAC (2016).

Statistical analysis

All data generated from the study were subjected to one-way ANOVA using the Statistical Analysis System (SAS Institute, 2002). When significant differences among the treatment means were detected at $p < 0.001$, Duncan's test was applied for mean separation. The results are expressed as the mean, standard error of the mean (SEM) to indicate variability within treatments.

RESULTS

Hematology

Dietary inclusion of hydrolysate protein influenced the blood hematological profile as presented in Table 2. This effect is reflected in changes in key parameters such as RBC, Hb concentration, hematocrit value, and WBC levels, which together indicate alterations in the birds' physiological and health status.

Table 2: Effects of dietary insect extract and protein hydrolysate on hematological parameters of Japanese quails.

Parameters	T0	T1	T2	T3	SEM	p-value
RBC ($x10^{12}/mm^3$)	2.01^a	2.0^a	3.10^b	2.51^b	0.10	<0.001
WBC ($x10^9/mm^3$)	14.5^d	13.45^c	11.5^b	10.50^a	0.36	<0.001
Hb (g/dl)	10.0	9.7	10.1	11.2	0.19	0.89
PLT ($x10^9/mm^3$)	9.0^a	10.5^b	8.5^a	11^b	0.30	<0.001
MCV (fL)	169.87^c	160.90^b	158.4^{bc}	157.4^a	0.97	<0.001
MCH (pg)	49.8	48.3	42.47	44.6	0.68	0.89
MCHC (g/dl)	27.7^b	23.4^a	27.5^b	28.4^b	0.47	<0.001
Lymphocyte (%)	56.1	56.7	51.5	51.2	0.60	0.99
Monocyte (%)	3.4	5.6	4.5	4.1	0.19	0.98
Hetrophil (%)	36.5^b	36.1^b	30.2^a	30.5^a	0.69	<0.001
Eosinophil (%)	2.5^c	1.8^{ab}	2.0^b	1.6^a	0.09	<0.001
H/L	0.65	0.63	0.61	0.59	0.05	0.5
Blood chemistry test						
MDA	9.59^b	5.39^a	5.06^a	4.90^a	0.48	<0.001

Description: ^{abcd} Different superscript letters within the same row indicate statistically significant differences ($p < 0.001$). If there is no notation in a row, it indicates that the result is not statistically significant ($p > 0.05$).
T0: Basal feed, T1: basal feed + 50 mg zinc-bacitracin, T2: basal feed + 10 ml/kg CE, T3: basal feed + 10 ml/kg CPH. RBC: red blood cell; WBC: white blood cell; Hb: hemoglobin; PLT: platelet count; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; MDA: malondialdehyde.

Table 2, demonstrated that, the highest RBC count was observed in T2 ($3.10 \times 10^{12}/mm^3$), followed by T3, while the lowest values were recorded in the control and antibiotic groups. WBC decreased markedly in T2 and T3 compared to T0 and T1, suggesting a reduced physiological stress response in birds receiving cricket extract or hydrolysates. Hb concentration did not differ among the treatments ($p > 0.001$). The platelet count increased in T1 and T3, whereas T2 showed the lowest value. Basal feed (T0) resulted in the highest MCV and the lowest MCH was T2, while CPH (T3) increased MCHC relative to other treatments. T2 increased RBC levels, while T3 appeared to improve overall hematological status, resulting in the most stable and healthy profile: RBC was sufficiently high, Hb was the highest, WBC was the lowest, and PLT remained high. Overall, the inclusion of cricket extract and hydrolysate produced notable improvements in RBC profile and immune-related parameters.

There were no significant effects on lymphocytes and monocytes, but significant differences were observed in heterophils and eosinophils (Table 2). Treatments T3 and T2 markedly decreased the heterophil percentage compared to T0 and T1. In contrast, for eosinophils, T3 showed the lowest values compared with T1 and T2, while T0 remained higher. The heterophil-to-lymphocyte ratio did not differ among treatments, indicating that all treatments had a similar effect on stress levels.

Egg quality

Appearance of quail eggs in Figure 1 and quantitative data presented in Table 3 consistently indicate that dietary supplementation with CE and CPH improved the internal quality of quail eggs. Eggs from the T2 and T3 treatments had thicker, more compact albumen and rounder, and more centrally positioned yolks, reflecting better internal quality than the control and antibiotic groups. These visual differences corresponded with the measured albumen traits, where T3 exhibited the highest albumen height (10.22 mm) and albumen weight (6.22 g), followed by T2. The gradual increase in the Haugh Unit from T0 to T3 further supports the enhanced albumen quality, although the differences were not statistically significant, as it aligns with the visually observed improvement in albumen viscosity.

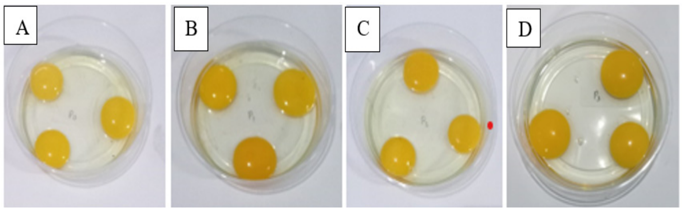

Figure 1: Appearance of quail eggs after dietary treatments of insect extract and protein hydrolysate.
A (T0: Basal feed), B (T1: basal feed + 50 mg zinc-bacitracin), C (T2: basal feed + 10 ml/kg CE), D (T3: basal feed + 10 ml/kg CPH).

In addition, cholesterol decreased significantly in T3 (183 mm/egg yolk), suggesting that the insect protein hydrolysate decreased cholesterol in the blood. Meanwhile, eggshell weight did not differ significantly across treatments, indicating that the improvements were primarily associated with internal rather than external egg characteristics.

Table 3: Quality of quail eggs after dietary treatments of insect extract and protein hydrolysate.

Parameters	Treatment				SEM	p-value
	T0	T1	T2	T3		
Yolk weight (g)	2.59	2.72	2.89	3.54	0.12	0.05
Albumen weight (g)	4.6^{a}	5.21^{ab}	5.48^{ab}	6.22^{b}	0.19	0.01
Albumen height (mm)	9.9	10.12	10.06	10.22	1.12	0.09
Haugh Unit	84.34	84.59	85.66	85.96	0.12	0.95
Egg shell weight (g)	1.34	1.42	1.42	1.43	0.08	0.16
Cholesterol (mg/egg yolk)	231.48^{c}	201.82^{b}	185.14^{a}	183.00^{a}	2.87	<0.001

Description: ^{abc} Different superscript letters within the same row indicate statistically significant differences (p < 0.05). T0: Basal feed, T1: basal feed + 50 mg zinc-bacitracin, T2: basal feed + 10 ml/kg CE, T3: basal feed + 10 ml/kg CPH.

Overall, both the visual assessment and quantitative measurements demonstrate that CPH (T3) consistently produced the best egg quality, followed by the CE (T2), whereas the control and antibiotic groups showed lower performance. These findings highlight the potential of bioactive compounds particularly peptides from insect hydrolysate to enhance albumen and yolk quality in laying quails.

DISCUSSION

The present study demonstrates that dietary supplementation with cricket-derived products, particularly CPH, improved hematological stability and internal egg quality in Japanese quails. Birds receiving insect-based supplements exhibited higher RBC counts and improved erythrocyte indices, indicating enhanced erythropoiesis and oxygen-carrying capacity without disrupting nutrient metabolism, thereby supporting efficient physiological function. Consequently, nutrient utilization remained optimal, contributing to enhanced egg production and improved egg quality. These findings are consistent with the role of bioactive peptides and high-quality insect proteins in supporting hematopoietic function and mitigating metabolic stress (Belhadj Slimen et al., 2023; Elahi *et al.*, 2022).

Notably, quails supplemented with cricket protein hydrolysate showed more pronounced hematological responses than those receiving crude extracts, which may be attributed to the higher bioavailability and biological activity of short-chain peptides produced through enzymatic hydrolysis. Furthermore, the reduction in WBC counts observed in supplemented groups, while remaining within physiological ranges, suggests a lower inflammatory status rather than immune suppression. This response aligns with previous reports indicating that insect-derived peptides possess antioxidant and immunomodulatory properties capable of stabilizing immune homeostasis in poultry (Ma *et al.*, 2023; Sajjad *et al.*, 2024; Syamsuryadi *et al.*, 2025). Collectively, these findings indicate that cricket-derived bioactives function not only as nutrient sources but also as functional immunonutrients that support systemic physiological stability and productive performance in laying quails.

These physiological improvements were closely reflected in enhanced internal egg quality, particularly in the group receiving cricket protein hydrolysate (T3). Significant increases in albumen height, albumen weight, and yolk weight indicate superior protein deposition and nutrient allocation during egg formation. Albumen height is highly sensitive to protein metabolism and overall physiological health, and improvements in this parameter are closely associated with dietary protein quality and the internal freshness of eggs (Silversides and Scott, 2001). The upward trend in the Haugh Unit, although not statistically different, was consistent with the visual evidence of denser and more viscous albumen in T2 and T3, suggesting meaningful biological improvement. These results align with previous studies showing that hydrolyzed protein sources, owing to their superior digestibility and peptide availability, enhance albumen and yolk development more effectively than non-hydrolyzed protein sources (Clemente, 2000).

Mechanistically, the concurrent improvement in hematology and egg quality may be attributed to the presence of short-chain peptides, essential amino acids, and micronutrients in the insect hydrolysates. CPH produce bioactive peptides with proven antioxidant, immunomodulatory, and metabolic regulatory properties (Ma *et al.*, 2023; Slimen *et al.*, 2023). These peptides may enhance oxygen delivery by stimulating erythropoiesis and facilitating efficient protein synthesis for albumen formation. Minerals such as iron, zinc, and manganese in insects are known to support hemoglobin formation, antioxidant responses, and yolk precursor transport, which may explain the simultaneous improvements observed in the RBC profile and yolk deposition (Elahi *et al.*,2022). Thus, cricket hydrolysate functions as a dual-action feed ingredient, that improves both physiological stability and reproductive output.

This study provides a novel contribution to poultry nutrition by demonstrating for the first time that cricket protein hydrolysate can produce integrated improvements in hematological variables and egg quality parameters in quails. Much of the existing literature has focused on whole insect meal or crude insect protein as alternative protein sources, with limited emphasis on hydrolysates and almost no combination of hematological and egg quality outcomes. The superior efficacy of the hydrolysate observed here confirms that enzymatic hydrolysis yields peptides with higher bioavailability and stronger biological activity than traditional insect meals (Ma *et al*., 2023; Sajjad *et al*., 2024). This establishes a previously unreported mechanistic link between blood health and egg formation driven by insect-derived peptides, marking an important advancement in the field of functional poultry nutrition.

CPH has hypolipidemic properties that lower blood cholesterol levels. Bioactive peptides in the insect *Gryllus bimaculatus* can reduce cholesterol synthesis in the liver by inhibiting the enzyme HMG-CoA reductase, which is a key enzyme in the cholesterol synthesis pathway (Kim *et al*., 2022). Oktavelia and Kusuma (2022) explained that HMG-CoA reductase is a key enzyme in the cholesterol biosynthesis pathway in the liver, which catalyzes the conversion of HMG-CoA into mevalonic acid as a cholesterol precursor. The inhibition of the enzyme 3-Hydroxy-Methyl Glutaryl-Coenzyme A (HMG-CoA) reductase enables the reduction of cholesterol in the body (Jang and Kim, 2021).

From a practical perspective, these findings highlight the potential of cricket hydrolysate as an efficient, low-dose feed additive capable of improving bird health and egg quality without relying on antibiotics. Enhanced RBC profiles, reduced physiological stress, and improved albumen and yolk characteristics translate directly into healthier birds and higher-value eggs. The adoption of insect-based feed ingredients also supports sustainable and environmentally responsible poultry production, offering locally available, renewable protein sources with low ecological impacts (Sajjad *et al*., 2024; Belhadj Slimen et al., 2023). Therefore, the integration of cricket hydrolysate into quail diets represents a practical and cost-effective strategy for improving farm productivity, animal welfare, and product quality in modern egg production systems.

Environmental stressors, such as oxidative stress and ammonia exposure, disrupt erythropoiesis and exacerbate these changes in MCV and MCH. High ammonia levels recorded in the poultry housing can contribute to respiratory irritation, oxidative stress, and tissue inflammation, which may impair oxygen exchange and lead to compensatory erythropoiesis. Oxidative stress damages cellular components, including lipids and proteins within erythrocytes, accelerating their destruction and triggering the need for increased erythropoiesis (Obeagu *et al*., 2024). Environmental stress through various mechanisms such as oxidative stress, metabolic dysfunction, and nutritional disturbances can result in mild macrocytosis detectable through hematological parameters, particularly MCV (Heidari and Lawrence, 2023).

Quail layers in this study showed moderate stress levels with an H/L ratio of 0.59 -0.65 (Gross and Sieigeil, 1983). Stress in laying hens is caused by prolonged confinement in cages (Shini, 2019). This is in line with the decreased in Malondialdehyde (MDA) values with the use of the protein hydrolysate. MDA is a well-recognized biomarker of oxidative stress, specifically lipid peroxidation, which indicates the extent of oxidative damage in biological samples (Cordiano *et al*., 2023). Protein hydrolysates derived from insects, such as those from *Hermetia illucens* (black soldier fly) or *Alphitobius diaperinus*, have been studied for their bioactive properties, including antioxidant potential, which can influence oxidative stress markers, such as MDA (Riolo *et al*., 2024).

CONCLUSION

The administration of CPH was shown to improve blood profile parameters and enhance egg quality. These improvements reflect a better physiological condition and increased productivity in the treated group. Based on these findings, cricket protein hydrolysate demonstrates strong potential as a natural feed additive and may serve as an alternative to antibiotic growth promoters. Therefore, it can be considered a promising substitute for antibiotics in supporting animal health and production performance. Future research should focus on evaluating the long-term effects of CPH supplementation under different management and environmental conditions, as well as determining optimal dosage levels for various production stages.

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NOVELTY STATEMENT

This study represents the first comprehensive assessment of the utilization of hydrolysate protein derived from insects as an immunonutrient for the hematological and egg quality parameters of Japanese quails. These findings indicate that the incorporation of 10 ml/kg of brown cricket

(*Grillus asimilis*) hydrolysate into the complete feed diet of quails resulted in enhanced egg quality and improved animal health. This study provides a scientific foundation for the broader application of cricket hydrolysate in poultry farming for egg production.

AUTHOR'S CONTRIBUTION

AL and MHN: conducted the study, data analysis, and statistical analysis and wrote the original manuscript. EW and SS: formulated the methodology, supervised, reviewed, and edited the manuscript

Generative AI or AI-assisted technology statement

The authors declare that no genuine AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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