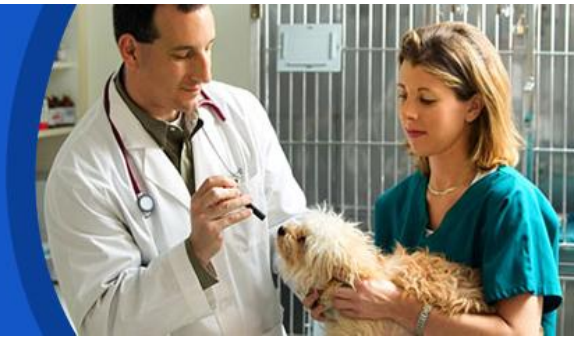
International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912
NAAS Rating (2025): 4.61
VET 2025; 10(12): 08-13

www.veterinarypaper.com
Received: 12-10-2025
Accepted: 15-11-2025

B Deepika
Assistant Professor, Department of Veterinary Physiology and Biochemistry, Veterinary College and Research Institute, Orathanadu, Tamil Nadu, India

V Leela
Professor and Head, Department of Veterinary Physiology, Madras Veterinary College, Chennai, Tamil Nadu, India

G Suganya
Professor, Department of Veterinary Physiology, Madras Veterinary College, Chennai, Tamil Nadu, India

S Ezhil Valavan
Professor and Head, Pharmacovigilance Laboratory for Animal Feed and Food Safety, Madhavaram Milk Colony, Chennai, Tamil Nadu, India

Corresponding Author:
B Deepika
Assistant Professor, Department of Veterinary Physiology and Biochemistry, Veterinary College and Research Institute, Orathanadu, Tamil Nadu, India

Influence of earthworm meal on growth performance of Japanese quails (*Coturnix coturnix* japonica)

B Deepika, V Leela, G Suganya and S Ezhil Valavan

DOI: https://www.doi.org/10.22271/veterinary.2025.v10.i12a.2781

Abstract
The rising cost and limited availability of high-quality protein sources such as fish meal have prompted the need for sustainable alternatives in poultry nutrition. Earthworm meal (*Eudrilus eugeniae*) is rich in protein, essential amino acids, and minerals, making it an attractive replacement. This study evaluated the influence of earthworm meal on growth performance and intestinal morphology in Japanese quails from hatch to six weeks of age. A total of 240 chicks were divided into four dietary treatments: 0% (control), 50%, 75%, and 100% replacement of fish meal with earthworm meal. Growth parameters such as body weight gain, feed consumption, and feed conversion ratio (FCR) were recorded weekly, and intestinal samples were collected at weeks 3 and 6. Results showed that 75% replacement significantly improved (p<0.01) body weight gain and FCR from the fourth week onwards, while 100% replacement increased feed consumption but did not enhance growth efficiency. Intestinal morphology indicated significant improvements in villus height, crypt length, and crypt width in earthworm-fed groups, with the best villus-crypt balance in the 75% group. All groups recorded 100% livability. The findings demonstrate that earthworm meal is a viable, eco-friendly protein supplement, with 75% replacement delivering optimal performance.

Keywords: Earthworm meal, Japanese quail, feed conversion ratio, intestinal morphology, alternative protein source

1. Introduction
Protein is the most expensive dietary component in poultry production, directly affecting growth, metabolism, and overall performance. Fish meal, traditionally valued for its superior amino acid balance and digestibility, has become increasingly scarce and costly due to ecological and economic constraints. This situation has driven the search for sustainable, economical, and nutritionally rich protein alternatives. Earthworms, often referred to as "nature's protein factories," have emerged as a promising option. Earthworm meal from *Eudrilus eugeniae* contains high-quality protein (Approximately 29-32%), essential amino acids such as lysine, methionine, valine, and threonine, and bioavailable minerals.
Japanese quails (*Coturnix coturnix* japonica) are fast-growing poultry with high feed efficiency and early maturity, making them ideal for evaluating alternative protein sources. Despite the proven nutritional value of earthworm meal in broilers and fish, limited research has focused on quail nutrition. The present study investigates the effect of replacing fish meal with earthworm meal on growth performance and intestinal morphology of Japanese quails, aiming to identify the optimal inclusion level for enhanced production efficiency.

2. Materials and Methods
2.1 Experimental Birds and Management
The experiment was carried out at the Poultry Research Station, Madhavaram. A total of 240 day-old Japanese quail chicks were randomly allocated into four dietary groups with three replicates of twenty chicks each. Birds were reared under uniform management with access to clean water and feed ad libitum. Temperature, ventilation, and hygiene were maintained according to standard quail rearing protocols.

2.2 Diet Formulation

Earthworm meal was prepared from *Eudrilus eugeniae* collected and dried at 60°C for 24 hours and ground into a fine powder (Figure 1 &2). Proximate analysis revealed 29.49% crude protein and 2649 kcal/kg gross energy. Four dietary treatments were formulated:

- **G1 (Control):** Basal diet with 7% fish meal
- **G2:** 50% fish meal replaced by earthworm meal
- **G3:** 75% fish meal replaced by earthworm meal
- **G4:** 100% fish meal replaced by earthworm meal

Starter diets were fed from 0-3 weeks, and finisher diets from 4-6 weeks. All diets were ISO-Caloric and ISO-Nitrogenous.

Experimental Design

Groups	Experimental feeding	No of replicates	No of Birds / replicate	Total no of birds / treatment
Group1 (Control group)	Japanese quail basal diet (with 7 % fish meal)	3	20	60
Group 2	Japanese quail basal diet replacing 50 % fish meal with earthworm meal.	3	20	60
Group 3	Japanese quail basal diet replacing 75 % fish meal with earthworm meal	3	20	60
Group 4	Japanese quail basal diet replacing 100 % fish meal with earthworm meal	3	20	60
	Total			240

Fig 1a: Earthworm PIT

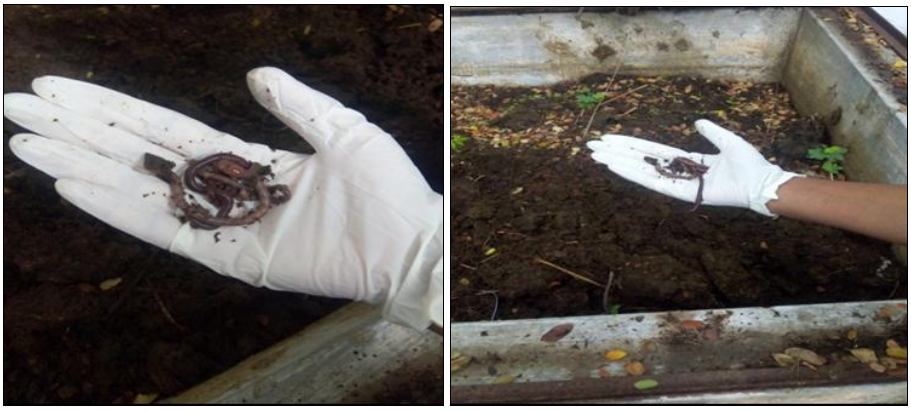


Fig 1b: Earthworm Culture

Fig 2a: Earthworm collection

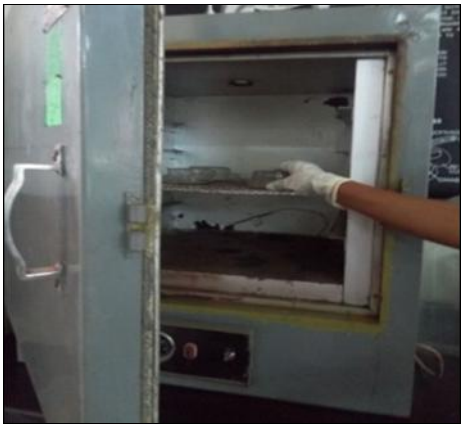


Fig 2b: Earthworms dried in hot airoven

Fig 2c: Powdering of dried earthworms

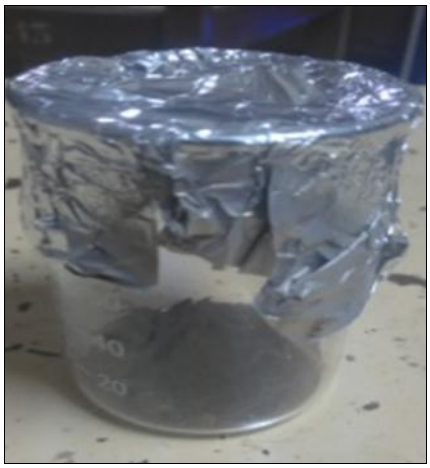


Fig 2d: Earthworm meal

Fig 2: Preparation of earthworm meal

2.3 Growth Performance Measurements

Weekly body weights were recorded individually using a digital scale. Feed consumption was calculated by measuring weekly feed offered and refusals. Body weight gain was computed as the difference between weekly measurements. Feed Conversion Ratio (FCR) was calculated as:

FCR = Total feed intake / Total weight gain

Livability was recorded daily.

2.4 Intestinal Morphology

At weeks 3 and 6, six birds per treatment were sacrificed. Jejunal samples were collected, fixed in buffered formalin, sectioned at 5 µm, and stained with hematoxylin and eosin. Villus height, villus width, crypt length, and crypt width were measured using a calibrated microscope.

2.5 Statistical Analysis

Data were analyzed using two-way ANOVA as per Snedecor and Cochran (1994). Duncan's Multiple Range Test identified significant differences among group means. Differences were considered significant at $p<0.05$.

3. Results

3.1 Body Weight Gain

Cumulative body weight gain is presented in Table 1 & 2. No significant differences ($p>0.05$) were observed among groups during the first three weeks. From the fourth week onwards, significant differences emerged. The 75% replacement group (G3) showed the highest gains at weeks 4, 5, and 6 (122.13 g, 170.43 g, and 206.43 g, respectively), significantly higher than G1, G2, and G4 ($p<0.01$). Although G4 showed better gains than G1 and G2, it did not outperform G3.

3.2 Feed Consumption

Feed consumption data (Table 3) revealed no significant differences during weeks 1-3. In week 4, G3 recorded significantly higher intake than all groups ($p<0.05$). At weeks 5 and 6, G4 exhibited the highest feed consumption, significantly exceeding all other groups ($p<0.01$). This suggests increased palatability and metabolic activity associated with higher earthworm meal inclusion.

3.3 Feed Conversion Ratio (FCR)

Table 4 illustrates that no significant differences existed during the first three weeks. From the fourth week onward, birds in G3 consistently demonstrated the best feed conversion efficiency. In week 6, G3 had an FCR of 3.32, significantly lower (better) than G1 (3.47), G2 (3.46), and G4 (3.44), ($p<0.01$). Although G4 consumed more feed, it did not convert it into body mass as efficiently as G3.

4. Discussion

The findings clearly demonstrate that earthworm meal positively influences growth performance and intestinal morphology in Japanese quails. The absence of significant differences in early growth suggests that chicks adapt well to earthworm-supplemented diets. However, as nutritional demand increases during the rapid growth phase, the benefits of earthworm meal become more pronounced. The superior weight gain and FCR in the 75% group (G3) can be attributed to the high-quality protein, excellent amino acid profile, and digestibility of earthworm meal. Similar improvements in poultry performance due to earthworm supplementation were reported by Mahmoud *et al*. (2015) [30].

Higher feed consumption observed in G3 and G4 during later weeks may be due to increased palatability and digestive efficiency stimulated by bioactive compounds present in earthworms. However, the highest inclusion level (100%) did not translate into the best FCR, suggesting that over-replacement may disturb optimal nutrient balance.

Thus, earthworm meal especially at 75% inclusion supports better growth, efficient feed utilization, and enhanced intestinal development in quails.

5. Conclusion

Earthworm meal (*Eudrilus eugeniae*) is a sustainable, nutrient-rich alternative to fish meal in quail diets. The study demonstrates that 75% replacement of fish meal with earthworm meal delivers:

- Highest body weight gain
- Best feed conversion ratio
- Enhanced intestinal morphology
- 100% livability

Complete replacement (100%) increases feed intake but does not maximize growth efficiency. Therefore, 75% inclusion is recommended for optimal performance and economic efficiency in quail production.

Table 1: Effect of feeding earthworm meal on body weight of Japanese quails (g), (Mean ± SE)

Groups	Hatch weight (N=240)	First week (N=240)	Second week (N=240)	Third week (N=240)	Fourth week (N=216)	Fifth week (N=216)	Sixth week (N=216)
G1	9.04±0.09	19.16±0.39	51.81±1.29	94.51±196	125.40^{a} ±1.62	165.05^{a} ±1.58	206.84^{a} ±2.49
G2	9.12±0.83	19.22±0.37	51.97±1.30	94.14±1.46	126.28^{ab} ±1.59	168.28^{a}±1.96	206.21^{a} ±2.23
G3	9.08±0.09	19.67±0.40	51.52±1.34	94.64±1.45	131.21^{c}±1.50	179.51^{c}±1.27	215.51^{c} ±1.41
G4	9.13±0.73	19.44±0.34	51.33±1.22	94.24±1.21	127.06^{b} ±1.51	175.64^{b} ±1.67	208.63^{b} ±1.82
F-Value	0.747^{NS}	0.360^{NS}	0.396^{NS}	15.891^{NS}	17.793^{*}	3.297^{**}	13.940^{**}

Means bearing different superscripts in a column differ significantly between groups
**- Highly significant (p<0.01), *- Significant (p<0.05) and NS-Non-Significant

Table 2: Effect of feeding earthworm meal on cumulative body weight gain of Japanese quails (g), (Mean ± SE)

Groups	First week (N=240)	Second week (N=240)	Third week (N=240)	Fourth week (N=216)	Fifth week (N=216)	Sixth week (N=216)
G1	10.12±0.38	42.77±1.29	85.47±1.95	116. 36^{a}±1.49	156.01^{a}±1.95	197.80^{a}± 2.50^{a}
G2	10.10±0.38	42.85±1.29	85.02±1.59	117.16^{a}±1.63	159.16^{a}±1.60	197.09^{a}± 2.20^{a}
G3	10.59±0.41	42.44±1.36	85.56±1.86	122.13^{c}±1.62	170.43^{c}±1.84	206.43^{c}±1.84^{b}
G4	10. 31±0.35	42.20±1.22	85.11±1.72	117.93^{ab}± 1.60	166.51^{b}±1.82	199.50^{b}±1.82^{a}
F-Value	0.361^{NS}	0.424^{NS}	1.118^{NS}	2.595^{*}	4.056^{**}	4.115^{**}

Means bearing different superscripts in a column differ significantly between groups
**- Highly significant (p<0.01), *- Significant (p<0.05) and NS-Non-significant

Table 3: Effect of feeding earthworm meal on cumulative feed consumption of Japanese quails (g), (Mean ± SE)

Groups	First week (N=240)	Second week (N=240)	Third week (N=240)	Fourth week (N=216)	Fifth week (N=216)	Sixth week (N=216)
G1	44.58±1.24	90.50±0.75	220.97±0.51	362.24^{b}±3.02	513.59^{a}±0.67	685.47^{ab}±0.62
G2	44.80±0.26	90.86±0.42	220.73±0.81	360.95^{a}±0.71	516.69^{b}±1.99	681.90^{a}±0.82
G3	44.59±0.71	89.36±1.40	220.48±0.47	373.51^{c}±0.47	523.78^{c}±2.06	686.02^{b}±0.95
G4	44.60±0.95	90.10±0.10	220.16±0.52	360.96^{a}±1.96	535.46^{d}±1.90	688.50^{b}±1.87
F-Value	5.76^{NS}	5.07^{NS}	5.69^{NS}	0.591^{*}	19.88^{**}	11.68^{*}

Means bearing different superscripts in a column differ significantly between groups
**- Highly significant (p<0.01), *- Significant (p<0.05) and NS-Non-significant

Table 4: Effect of feeding earthworm meal on the feed conversion ratio of Japanese quails (Mean ± SE)

Groups	First week	Second week	Third week	Fourth week	Fifth week	Sixth week
G1	4.40^{b}±0.02	2.11±0.06	2.58±0.15	3.11^{b}±0.28	3.29^{c}±0.08	3.47^{b}±0.26
G2	4.43^{b}±0.08	2.12±0.06	2.59±0.08	3.08^{a}±0.01	3.24^{b}±0.12	3.46^{b}±0.26
G3	4.21^{a}±0.02	2.10±0.01	2.57±0.14	3.05^{a}±0.44	3.07^{a}±0.17	3.32^{a}±0.27
G4	4.32^{ab}±0.03	2.13±0.05	2.58±0.07	3.06^{a}±0.04	3.21^{b}±0.12	3.44^{b}±0.19
F-Value	1.033^{NS}	1.047^{NS}	1.236^{NS}	0.079^{*}	0.0001**	0.022^{*}

**- Highly significant (p<0.01), *- Significant (p<0.05) and NS-Non-significant
Means bearing different superscripts in a column differ significantly between groups

Conflict of Interest
Not available

Financial Support
Not available

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How to Cite This Article
Deepika B, Leela V, Suganya G, Valavan SE. Influence of earthworm meal on growth performance of Japanese quails (*Coturnix coturnix* japonica). International Journal of Veterinary Sciences and Animal Husbandry. 2025;10(12):08-13.