

Dietary inclusion of *Moringa oleifera* leaf meal enhances performance and cost of production of Broiler Japanese quails (*Coturnix coturnix japonica*)

A. Yadav^{1*}, A.K. Santra², A. Jain³, A. Dubey⁴ and A.K. Chaturvedani⁵

¹Department of Livestock Production and Management, College of Veterinary Science and Animal Husbandry, Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg-491001, India

²Department of Livestock Production and Management, College of Veterinary Science and Animal Husbandry, Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg-491 001, India

³Department of Animal Genetics and Breeding, College of Veterinary Science and Animal Husbandry, Nanaji Deshmukh Veterinary Science University, Jabalpur-482 001, India,

⁴Department of Livestock Production and Management, College of Agriculture and Research Station, Indira Gandhi Agriculture University, Raipur-492 012, India

⁵Department of Veterinary Extension, FVAS, Rajiv Gandhi South Campus, BHU, Mirzapur-231 001, India

Received: 24 March 2025

Revised: 19 August 2025

Accepted: 12 November 2025

*Corresponding Author Email: aayush.aayush091@gmail.com

*ORCID: <https://orcid.org/0009-0003-0876-534X>

Abstract

Aim: The present study aimed to assess the impact of replacing soybean meal with *Moringa oleifera* leaf meal on the growth performance and feed economics of broiler Japanese quails.

Methodology: A total of 300 day-old Japanese quail chicks were procured and reared from 1 to 6 weeks of age. The birds were randomly allocated into five dietary treatment groups (M₀, M_{0.5}, M₁, M_{1.5} and M₂) with three replicates per group, based on the graded inclusion levels (0, 0.5, 1.0, 1.5, and 2.0%) of *Moringa oleifera* leaf meal.

Results: The *M. oleifera* leaf meal was rich in crude protein and fibre. Significant improvements were observed on the growth traits, nutrient utilization, and serum biochemistry in quails fed on *M. oleifera* leaf meal based diets. The *M. oleifera* leaf meal based diets reduced feed cost per kilogram of live weight gain in quails by Rs. 9.80-45.84.

Interpretation: An inclusion level of 2% *Moringa oleifera* leaf meal was found to be optimal for all the parameters analyzed, and may therefore be recommended in the diets of broiler Japanese quails to enhance economic returns.

Key words: Broiler, Economics, Japanese quails, *Moringa oleifera* leaf meal

Effect of dietary inclusion of *Moringa oleifera* leaf meal on performance and cost of production of Broiler Japanese quails

300 day-old chicks divided in five groups based on five dietary inclusion levels (0, 0.5, 1, 1.5, 2%) of *M. oleifera* leaf meal for six weeks

Significant improvements in growth traits, nutrient utilization, and serum biochemistry in quails fed on *M. oleifera* leaf meal based diets

M. oleifera leaf meal based diets reduced feed cost per kilogram of live weight gain in quails. The best inclusion rate was 2%.

Introduction

Poultry production is a major contributor to global animal protein supply, but escalating feed costs particularly for conventional protein sources such as soybean meal pose significant challenges to profitability and sustainability. Identifying locally available, nutrient-rich, and cost-effective feed alternatives has therefore become essential. *Moringa oleifera*, widely known as the drumstick tree, offers considerable potential as a non-conventional feed ingredient due to its high crude protein content, balanced amino acid profile, and richness in vitamins, minerals, and bioactive compounds with antioxidant and antimicrobial properties (Gopalakrishnan et al., 2016; Sánchez-Machado et al., 2010). Recent studies in broiler chickens have demonstrated that *M. oleifera* leaf meal (MOLM) can enhance growth performance, carcass yield, and gut health (Akib et al., 2024; Egbu et al., 2024; Akinyemi et al., 2022). However, these effects vary with inclusion level, processing and species.

Over the past five years, limited controlled studies have investigated the graded substitution of soybean meal with MOLM in Japanese quails (*Coturnix coturnix japonica*), and few have integrated production performance with feed-cost and profitability analyses (Yadav et al., 2024). Given that quail digestive physiology, growth curve and amino-acid requirements differ from those of chickens, it cannot be assumed that *Moringa* responses will translate directly from broiler studies. In addition, quails are particularly sensitive to dietary fibre and anti-nutritional factors, making precise formulation critical (Makkar and Becker, 1996). Thus, rigorous research is required to determine whether small-scale inclusion of MOLM (e.g., 0.5–2.0%) can partially replace soybean meal without impairing nutrient utilization or growth metrics. Further, studies show optimal performance of Japanese quails below 3% (Nkukwana et al., 2014; Olugbemi et al., 2010). Higher levels may impair digestibility and palatability, reducing feed efficiency (Foidl et al., 2001).

To address this research gap, the present study evaluates graded inclusion levels (0–2.0%) of *M. oleifera* leaf meal as a partial replacement for soybean meal in broiler Japanese quail diets, assessing growth performance, feed conversion efficiency, and cost of production to establish species-specific, evidence-based recommendations for sustainable and economical quail feeding.

Materials and Methods

The proposed trial was conducted in 2021 at the Poultry Demonstration and Experimental Unit, College of Veterinary Science and Animal Husbandry, Anjora, Durg, Chhattisgarh, India. The trial was based on a completely randomized design and organized on 300-day-old unsexed Japanese quail chicks for 6 weeks. The chicks were randomly allocated into 5 groups of 3 replicates of 20 chicks each. The groups M_0 , $M_{0.5}$, M_1 , $M_{1.5}$ and M_2 corresponded to 0.0, 0.5, 1.0, 1.5, and 2% dietary inclusions of *M. oleifera* leaf meal, respectively. The chicks were maintained in a

deep litter system and given an iso-caloric and iso-nitrogenous diet twice daily as per ICAR (2013) (Table 1). *Ad libitum* water was provided to the birds around the clock. *M. oleifera* leaf meal was prepared as per the standard procedure (Yadav et al., 2022).

Parameters studied

Proximate composition of *M. oleifera* leaf meal and experimental diets: The proximate analysis of *M. oleifera* leaf meal and experimental diets was carried out as per the standard method (AOAC, 2012).

Growth Traits

Feed intake: The weekly feed intake per bird was calculated by dividing the weekly feed intake per group by the total number of birds in that group. Weekly feed intake per group was calculated by subtracting the feed left from the feed given during the week. The average cumulative feed intake per bird was also calculated.

Body weight: Body weights were recorded weekly using weighing balance. Before weighing, the birds were fasted overnight and weighed empty crops on the following morning. Weekly body weight gain was determined as the difference in the body weights at the end of the week to that of the start of the week. Total body weight gain was calculated by taking the difference of the body weight at the end of the 6th week from that of the 0th day.

Feed conversion ratio: The weekly FCR was determined as the ratio between weekly feed intake per bird and weekly body weight gain per bird.

Mortality rate: The mortality rate in the flock was determined as the ratio between the number of birds dead and the initial total number of birds in the flock multiplied by 100.

Nutrient utilization: A metabolic trial was conducted on 30 birds, 2 birds per replicate, for 4 days to study the utilization of nutrients using dry matter metabolizability, nitrogen retention, and protein efficiency ratio. Each bird was individually accommodated in a cage one day before the start of the trial for adaptation. The floor of the cages was underlined with fiber sheets to collect the faecal matter. Feed and water were provided *ad libitum* in accordance with the standard management practices for quail rearing (ICAR, 2013). The next day, the feed was withdrawn at 09:00 am and birds fasted for 2 hours, i.e., up to 11:00 am so that the feed consumed during the adaptation period gets voided out in faeces, keeping in mind the retention period of feed in the GIT of birds, i.e., 120 min. The faeces were removed from the fiber sheets by scrapping with a flat and blunt object during this time. Meanwhile, water was made available to the birds around the clock.

The birds become empty stomachs and ready for the trial. Hereafter, *ad libitum* feed was offered to the birds at 11:00 am and 05:00 pm in a measured quantity. The next morning, leftover feed from individual birds were collected separately to determine feed

intake. Besides, the faeces of each bird were scrapped and collected in pre-weighed faecal trays, weighed, and placed into the forced draft hot air oven for drying at 70 °C for continuous four days till a constant weight was achieved. The weight of dry faecal matter was then recorded. Thereafter, dry matter metabolizability (DMM) was calculated as:

$$DMM = \frac{\text{Dry matter intake} - \text{dry matter in excreta}}{\text{Dry matter intake}} \times 100$$

Nitrogen in faecal samples was estimated by the Kjeldahl method. Thereafter, nitrogen retention (NR) was calculated as:

$$NR = \frac{\text{Nitrogen intake} - \text{Nitrogen outgo through excreta}}{\text{Nitrogen intake}} \times 100$$

Protein efficiency ratio (PER) was calculated as:

$$PER = \frac{\text{Total body weight gain}}{\text{Crude protein fed in the group}}$$

Serum biochemistry: At the end of the trial, around 2 ml whole blood sample was collected from the wing vein of 2 random birds per replicate into the pre-labeled sterile clot-activator vials for serum-biochemical analysis. The samples were centrifuged at 1000 rpm for 10 min and a clear supernatant serum was obtained and analyzed for glucose, total protein, albumin, globulin, albumin globulin ratio, total cholesterol, alkaline phosphatase, alanine aminotransferase, aspartate amino transferase, creatinine, and uric acid in semi-auto analyzer by using commercial diagnostic kits and

procedures recommended by the manufacturer (ARKRAY Healthcare Pvt. Ltd., Surat, Gujarat, India).

Carcass traits: Two random birds from each replicate were sacrificed by the humane method of slaughter at the end of the trial to study carcass traits. The birds were provided *ad libitum* drinking water but starved for 12 hr before slaughter. The body weight of birds was recorded individually before slaughter. The weight of organs such as breast, thigh, drumstick, liver, heart, gizzard, wing, neck, back, giblets (liver + gizzard + heart), total edible parts (dressed + giblets), and small intestine were weighed by using a digital weighing balance. The length of small intestine was measured with a measuring tape. Before taking observations, the intestines were excised and flushed with 0.9% saline to remove the contents. The dressed yield was calculated as the ratio of dressed weight with giblet to pre-slaughter live weight multiplied by 100.

Production cost: The cost of production was calculated as feed cost per kilogram of live weight gain in birds. Furthermore, to correctly reflect the economics of the study, the economic efficiency of the experimental diets was assessed through a feed-based Benefit–Cost Ratio (BCR). The BCR was estimated as:

$$BCR = \frac{\text{Price per kg live weight} \times \text{Total live weight gain (kg) per bird}}{\text{Total feed cost (Rs.) per bird}}$$

A BCR value greater than 1 indicates economic

Table 1: Feed composition (%) of broiler starter (1-3 weeks) and broiler finisher (4-6 weeks) Japanese quail diets

Ingredients	Broiler starter (1-3 weeks)					Broiler finisher (4-6 weeks)				
	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂
Maize	51.500	51.000	50.900	50.800	50.500	61.800	61.600	61.000	61.000	61.000
Soybean meal	42.600	42.500	42.200	41.800	41.600	33.400	33.100	32.900	32.600	32.200
Soybean oil	2.200	2.300	2.200	2.200	2.200	1.300	1.300	1.300	1.300	1.300
Limestone powder	0.850	0.850	0.850	0.850	0.850	1.200	1.200	1.200	1.200	1.200
Di-calcium phosphate	1.800	1.800	1.800	1.800	1.800	1.300	1.300	1.300	1.300	1.300
Methionine	0.150	0.150	0.150	0.150	0.150	0.140	0.140	0.140	0.140	0.140
Salt	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
TM. Premix	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Vitamin Premix	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Vitamin B complex	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Choline Chloride	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Toxin binder	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Vitamin C	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
<i>Moringa oleifera</i> leaf meal	0.000	0.500	1.000	1.500	2.000	0.000	0.500	1.000	1.500	2.000
Coccidiostat	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CP (%)	24.99	25.01	25.02	24.99	25.00	21.50	21.50	21.50	21.50	21.50
ME (Kcal/Kg)	2898	2900	2899	2899	2900	2950	2950	2950	2950	2950
Calcium (%)	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Phosphorus (%)	0.45	0.45	0.45	0.45	0.45	0.35	0.35	0.35	0.35	0.35
Lysine (%)	1.45	1.45	1.45	1.45	1.45	1.20	1.20	1.20	1.20	1.20
Methionine (%)	0.55	0.55	0.55	0.55	0.55	0.50	0.50	0.50	0.50	0.50

Table 2: Proximate composition (%) of *Moringa oleifera* leaf meal, and experimental diets under different dietary groups

Diets	Groups	DM	CP	CF	EE	TANFE	
MOLM	-	90.19	30.21	8.12	8.56	11.86	41.25
Broiler starter (1-3 weeks)	M ₀	90.52	25.20	2.90	1.42	5.94	64.54
	M _{0.5}	90.54	25.38	3.27	2.31	10.48	58.56
	M ₁	90.68	25.43	3.57	2.19	6.27	62.54
	M _{1.5}	90.79	25.10	3.68	2.89	7.93	60.40
	M ₂	91.56	25.12	5.42	5.64	8.54	55.28
Broiler finisher (4-6 weeks)	M ₀	91.04	21.67	3.99	2.50	7.02	64.82
	M _{0.5}	91.25	21.74	4.19	3.24	11.40	59.43
	M ₁	91.69	21.60	4.46	3.67	8.72	61.55
	M _{1.5}	92.27	21.65	4.50	3.11	7.20	63.54
	M ₂	92.30	21.54	6.05	6.27	9.18	56.96

DM: Dry matter, CP: Crude protein, CF: Crude fiber, EE: Ether extract, TA: Total ash, NFE: Nitrogen free extract, MOLM: *Moringa oleifera* leaf meal

Table 3: Effect of different inclusion levels of *Moringa oleifera* leaf meal on growth traits, nutrient utilization, and serum biochemistry (Mean ± SE) of broiler Japanese quails

Traits	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂
Overall weekly feed intake (g) per Japanese quail	166.49±14.66	162.54±14.08	158.44±13.65	152.23±13.37	148.38±13.39
Average cumulative feed intake (g) per Japanese quail	998.94 ^a ±0.17	975.24 ^d ±0.26	950.68 ^e ±0.19	913.42 ^b ±0.15	890.32 ^a ±0.22
Overall weekly body weight (g)	125.63 ^a ±3.85	131.26 ^{ab} ±4.05	141.53 ^{bc} ±4.44	150.73 ^{cd} ±4.69	157.27 ^d ±4.86
Overall weekly body weight gain (g)	35.42 ^a ±1.03	37.45 ^b ±0.98	41.01 ^b ±0.99	43.72 ^{bc} ±0.99	46.05 ^c ±0.98
Average total body weight gain (g)	212.53 ^a ±0.82	224.70 ^b ±0.33	246.10 ^c ±0.63	262.33 ^d ±0.59	276.33 ^e ±1.21
Overall weekly feed conversion ratio	6.40±1.26	5.62±1.02	4.93±0.91	4.35±0.75	3.80±0.58
Average mortality rate	11.66 ^b ±1.67	6.66 ^{ab} ±1.66	5.00 ^a ±2.88	3.33 ^a ±1.66	3.33 ^a ±1.66
Dry matter metabolizability	71.43±1.32	71.81±1.76	71.39±1.29	73.07±1.71	74.50±1.83
Nitrogen retention	61.49 ^a ±0.19	63.50 ^{ab} ±0.44	65.22 ^{bc} ±0.50	66.26 ^c ±1.31	68.67 ^d ±1.01
Protein efficiency ratio 1-3 week	5.50 ^a ±0.04	5.59 ^a ±0.03	5.85 ^b ±0.03	6.27 ^c ±0.02	6.58 ^d ±0.03
4-6 week	2.01 ^a ±0.04	2.11 ^a ±0.02	2.37 ^b ±0.03	2.40 ^b ±0.03	2.80 ^c ±0.06
1-6 week	3.76 ^a ±0.16	3.85 ^a ±0.16	4.11 ^{ab} ±0.16	4.33 ^{bc} ±0.17	4.69 ^c ±0.17
Serum glucose (mg/dl)	97.83 ^a ±0.79	99.11 ^a ±0.65	102.43 ^b ±0.99	103.70 ^{bc} ±1.02	105.63 ^c ±1.17
Serum total protein (g/dl)	4.81±0.34	4.73±0.21	4.65±0.41	4.56±0.32	4.50±0.38
Serum albumin (g/dl)	1.54 ^a ±0.07	1.48 ^{cd} ±0.05	1.33 ^{bc} ±0.04	1.16 ^{ab} ±0.06	1.08 ^a ±0.07
Serum globulin (g/dl)	3.27±0.29	3.25±0.20	3.32±0.43	3.40±0.36	3.42±0.39
Serum albumin: globulin	0.48±0.03	0.46±0.03	0.44±0.06	0.36±0.05	0.34±0.05
Serum total cholesterol (mg/dl)	198.70 ^a ±3.80	182.58 ^b ±5.69	171.83 ^{bc} ±4.92	164.16 ^{cd} ±2.85	153.11 ^d ±3.20
Serum alkaline phosphatase (U/L)	394.50 ^b ±6.91	384.50 ^{ab} ±3.76	380.33 ^{ab} ±5.47	377.16 ^a ±4.38	376.33 ^a ±3.77
Serum ALT (U/L)	16.80 ^c ±0.58	16.18 ^b ±0.48	14.40 ^b ±0.47	13.25 ^b ±0.28	11.16 ^a ±0.67
Serum AST (U/L)	230.50±6.27	225.41±6.87	221.16±4.48	218.91±3.23	216.11±5.95
Serum creatinine (mg/dl)	0.40 ^b ±0.02	0.38 ^b ±0.01	0.36 ^{ab} ±0.01	0.35 ^{ab} ±0.02	0.31 ^a ±0.01
Serum uric acid (mg/dl)	7.29±0.79	7.25±0.81	7.35±0.83	7.27±0.60	7.20±0.72

ALT: Alanine Aminotransferase, AST: Aspartate Aminotransferase ^{a,b,c,d and e} Mean with different superscript differ significantly within rows (p≤0.05)

profitability of the diet, while a value less than 1 reflects a loss.

Results and Discussion

Statistical analyses: Experimental data were analyzed using SPSS software product version 22. One-way ANOVA was applied and differences were considered statistically significant at P≤0.05. Variances showing significant differences in the ANOVA table were compared with Duncan's Multiple Range Test.

The proximate composition of *Moringa oleifera* leaf meal (MOLM) and experimental diets is presented in Table 2. The observed dry matter (90.19%) and crude protein (30.21%) values of MOLM align with previous reports, confirming its potential as a high-protein feed source (Melesse et al., 2013). Variation in fibre, ether extract, and ash contents may result from differences in

Table 4: Effect of different inclusion levels of *Moringa oleifera* leaf meal on carcass traits (Mean \pm SE) of broiler Japanese quails

Carcass traits	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂
Live weight (g)	257.00 \pm 10.37	228.00 \pm 12.42	254.00 \pm 10.22	253.33 \pm 11.53	245.00 \pm 11.08
Breast weight (g)	65.33 \pm 5.05	61.00 \pm 3.21	64.30 \pm 2.98	64.16 \pm 3.38	56.33 \pm 6.72
Heart weight (g)	2.03 \pm 0.02	1.95 \pm 0.02	2.02 \pm 0.03	1.98 \pm 0.04	1.96 \pm 0.03
Giblet weight (g)	15.64 ^b \pm 1.32	11.95 ^c \pm 0.89	14.30 ^{ab} \pm 0.47	14.23 ^{ab} \pm 0.52	13.96 ^{ab} \pm 0.94
Thigh weight (g)	16.33 ^a \pm 1.30	18.00 ^{ab} \pm 1.36	20.36 ^{bc} \pm 0.60	20.29 ^{bc} \pm 0.63	22.00 ^c \pm 1.71
Gizzard weight (g)	5.88 ^b \pm 0.66	3.66 ^a \pm 0.33	4.34 ^a \pm 0.38	4.34 ^a \pm 0.42	3.66 ^a \pm 0.21
Liver weight (g)	7.72 \pm 0.76	6.33 \pm 0.80	7.93 \pm 0.19	7.90 \pm 0.15	8.33 \pm 0.95
Drumstick weight (g)	19.79 \pm 1.32	16.00 \pm 1.78	18.55 \pm 0.83	18.51 \pm 0.94	18.00 \pm 0.89
Wing weight (g)	12.44 \pm 0.80	14.00 \pm 1.36	13.34 \pm 0.74	13.33 \pm 0.84	11.00 \pm 1.23
Neck weight (g)	8.11 ^{ab} \pm 0.52	7.00 ^a \pm 0.68	9.73 ^b \pm 0.44	9.67 ^b \pm 0.31	9.33 ^b \pm 1.23
Back weight (g)	42.17 ^{ab} \pm 2.68	41.00 ^a \pm 1.00	50.07 ^{bc} \pm 1.92	49.78 ^{bc} \pm 1.26	56.00 ^c \pm 5.19
Small intestine weight (g)	5.09 \pm 0.37	3.89 \pm 0.52	4.62 \pm 0.34	4.61 \pm 0.38	4.34 \pm 0.67
Total edible weight (g)	179.83 \pm 8.84	168.95 \pm 8.78	190.67 \pm 5.43	189.99 \pm 5.61	186.62 \pm 9.81
Small intestine length (cm)	61.00 \pm 1.53	61.11 \pm 2.20	55.05 \pm 3.78	54.98 \pm 4.22	51.95 \pm 4.18
Dressed yield (%)	70.49 \pm 4.16	74.28 \pm 1.87	75.26 \pm 1.24	75.26 \pm 1.25	76.70 \pm 4.53

^{a, b and c} Mean with different superscript differ significantly within rows ($P \leq 0.05$)

agro-climatic conditions, harvest maturity, and processing methods (Sanchez-Machado *et al.*, 2010; Gopalakrishnan *et al.*, 2016). Incremental inclusion of MOLM slightly increased dietary crude fibre and ash levels. Moderate fibre elevation can enhance gut motility and nutrient assimilation, while excess may reduce digestibility. At $\leq 2\%$ inclusion, no adverse effects were observed, indicating effective nutrient utilization. Comparable findings in broilers suggest that low MOLM levels improve feed efficiency and growth without impairing digestibility (Akinyemi *et al.*, 2022; Akib *et al.*, 2024). The higher ash fraction provided essential minerals beneficial for growth and metabolism, though excessive inclusion may elevate anti-nutritional factors (Egbu *et al.*, 2024). Overall, the diets remained nutritionally balanced, supporting previous evidence that 1–2% MOLM inclusion enhances performance and economic efficiency in quails (Yadav *et al.*, 2024). These findings affirm MOLM's value as a sustainable, locally available protein alternative in quail nutrition. Feed intake did not differ among groups on a weekly basis ($P > 0.05$), but cumulative feed intake decreased progressively and significantly with increasing MOLM levels ($P \leq 0.05$) (Table 3). Reduced cumulative intake at higher MOLM inclusion is consistent with reports that increased dietary fibre and the presence of certain phytochemicals can lower voluntary intake by altering feed bulk and palatability (Akib *et al.*, 2024; Maqsood *et al.*, 2024).

Despite lower intake, birds on higher-inclusion diets exhibited improved nutrient utilization including higher dry matter metabolizability and nitrogen retention. This suggests efficient feed use and that MOLM supplied readily digestible protein, essential amino acids, and functional phytochemicals that enhanced digestion and absorption efficiency. Consistent with improved utilization, overall weekly body weight and total weight gain increased with MOLM inclusion, being highest in the 2.0 % group (M₂) and following the order M₂ > M_{1.5} > M₁ > M_{0.5} > M₀ (Table

3). These gains are in agreement with recent controlled trials reporting positive growth responses in poultry at low-to-moderate MOLM inclusion when diets are otherwise balanced (Akib *et al.*, 2024; Kursun, 2025).

Mechanistically, enhanced growth performance may result from improved amino acid supply, antioxidant protection against oxidative stress during rapid growth, and modulation of gut microbiota promoting nutrient absorption. However, higher inclusion levels can introduce anti-nutritional factors such as tannins and phytates, which may reduce feed efficiency if not mitigated (Egbu *et al.*, 2024). Feed conversion ratio (FCR) showed numerical improvement with increasing MOLM levels, with the best FCR observed in M₂, although weekly differences were statistically non-significant ($P > 0.05$) (Table 3). The combination of reduced cumulative feed intake and higher weight gain led to a practical enhancement in feed efficiency, corroborating earlier studies demonstrating that modest MOLM inclusion enhances feed utilization and growth performance in poultry (Akinyemi *et al.*, 2022; Yadav *et al.*, 2024).

Mortality decreased significantly in the higher inclusion groups ($P \leq 0.05$). The reduced mortality may be attributed to the antioxidant and immunomodulatory properties of *M. oleifera* bioactives, which improve disease resistance and oxidative balance (Gopalakrishnan *et al.*, 2016). Similar reductions in mortality and improved resilience have been reported in birds fed antioxidant-rich plant supplements under controlled trials (Lungu *et al.*, 2024). Nutrient utilization data further support improved metabolic efficiency. Nitrogen retention increased significantly in M₁–M₂ groups ($P \leq 0.05$), while dry matter metabolizability showed a non-significant upward trend (Table 3). Higher nitrogen retention and protein efficiency ratio (PER) indicate superior conversion of dietary protein to body tissue, consistent with

Table 5: Effect of different inclusion levels of *Moringa oleifera* leaf meal on feed cost per kilogram of live weight gain in Japanese quails

Attributes	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂
Starter feed consumption (kg) per bird during 1-3 weeks	0.358	0.351	0.347	0.325	0.312
Starter feed cost (Rs.) per kg feed	39.62	40.52	41.10	41.80	42.53
Starter feed cost (Rs.) per bird for feed consumed during 1-3 weeks	14.18	14.22	14.26	13.59	13.27
Grower feed consumption (kg) per bird during 4-6 weeks	0.641	0.625	0.604	0.588	0.578
Grower feed cost (Rs.) per kg feed	36.44	37.16	37.82	38.59	39.31
Grower feed cost (Rs.) per bird for feed consumed during 4-6 weeks	23.36	23.23	22.84	22.69	22.72
Total feed consumption per bird (kg) during 1-6 weeks	0.999	0.976	0.951	0.913	0.890
Total feed cost (Rs.) per bird for feed consumed during 1-6 weeks	37.54	37.45	37.10	36.28	35.99
Total live weight gain (kg) per bird during 1-6 weeks	0.213	0.225	0.246	0.262	0.276
Feed cost (Rs.) per kg live weight gain	176.24	166.44	150.81	138.47	130.40
Reduction in feed cost (Rs.) per kg live weight gain in comparison to M ₀	-	9.8	25.43	37.77	45.84
Per cent reduction in feed cost per kg live weight gain in comparison to M ₀	-	5.56	14.43	21.43	26.01

Cost (₹) of per kg feed ingredients used to prepare broiler diets: Maize: 25, Soybean meal: 44, Soybean oil: 163.33, Limestone powder: 5, Di calcium phosphate: 45, Methionine: 325, Salt: 12, TM premix: 450, Vitamin premix: 1500, B complex: 600, Choline chloride: 150, Toxin binder: 100, Vitamin C: 350, Dry Moringa leaves: 180 and Coccidiostat: 120

Table 6: Estimation of benefit cost ratio (BCR) at different levels of *Moringa oleifera* leaf meal fed to Japanese quails

Attributes	M ₀	M _{0.5}	M ₁	M _{1.5}	M ₂
Total feed cost (₹/bird)	37.54	37.45	37.10	36.28	35.99
Total live weight gain (kg/bird)	0.213	0.225	0.246	0.262	0.276
BCR at ₹240/kg	1.362	1.442	1.591	1.733	1.841
Net return at ₹240/kg (₹/bird)	13.58	16.55	21.94	26.60	30.25

earlier evidence that MOLM enhances protein digestibility and retention through improved enzymatic activity and nutrient bioavailability (Egbu *et al.*, 2024). Serum biochemical parameters revealed biologically coherent changes.

Serum glucose increased with MOLM inclusion ($P \leq 0.05$), reflecting higher energy availability and growth. Serum total protein remained unaffected, while serum albumin decreased ($P \leq 0.05$) without a compensatory rise in globulins, possibly due to transient effects of plant metabolites on plasma protein synthesis. Serum total cholesterol decreased significantly ($P \leq 0.05$), aligning with the hypocholesterolemic effects of *M. oleifera* phytosterols and saponins, which can inhibit intestinal cholesterol absorption. Decrease in liver enzymes (ALT and ALP), particularly ALT in M₁-M₂, alongside normal liver morphology, suggest hepatoprotective antioxidant effects rather than hepatotoxicity. These findings agree with the previous reports linking *M. oleifera* supplementation to improved lipid metabolism and hepatic function in poultry (Maqsood *et al.*, 2024).

Carcass traits (Table 4) were largely unaffected by MOLM inclusion. No consistent detrimental changes were observed in breast, heart, liver, drumstick, wing, small-intestine weight, total edible weight and dressed yield. Some organs and cuts exhibited within-row differences (giblet, thigh, gizzard, neck, back) but without a coherent pattern of toxicity. The lack of hepatic

atrophy/hypertrophy and stable dressed yield indicate that MOLM up to 2% does not compromise carcass quality in broiler Japanese quails. Such preservation of carcass parameters while growth improves has been observed in studies of Yadav *et al.* (2024). Economic analysis (Tables 5–6) demonstrates clear feed-cost advantages with MOLM inclusion. Feed cost per kg live-weight gain declined progressively from ₹176.24 (M₀) to ₹130.40 (M₂), representing a 26.0% reduction relative to the control (Table 5). Benefit-Cost ratios (at ₹240/kg) increased from 1.36 (M₀) to 1.84 (M₂), and net return per bird rose from ₹13.58 to ₹30.25 (Table 6). The improved BCR and net returns are primarily driven by better weight gain and practical FCR improvements and are consistent with field and experimental reports that species-appropriate MOLM use can reduce feed cost when local MOLM price and processing are economical (Egbu *et al.*, 2024; Lungu *et al.*, 2024). Nevertheless, economic benefits are context-dependent: large scale procurement, local processing costs and soybean market dynamics will influence whether MOLM inclusion remains advantageous.

Overall, graded replacement of soybean meal with MOLM up to 2% improved growth performance, protein utilization and farm-level profitability in broiler Japanese quails without adverse carcass or biochemical outcomes. At the same time, published evidence emphasizes species and process-specific thresholds for anti-nutritional effects. Therefore, while a 2% inclusion appears beneficial here, further work should examine ileal digestibility,

longer-term health markers, and cost-benefit sensitivity under varying market scenarios and processing methods.

Acknowledgments

The authors would like to thank the staff of the Poultry Demonstration and Experimental Unit of the College of Veterinary Science and Animal Husbandry, Anjora, Durg, C.G., India, for rearing and caring for the experimental birds and for their assistance in the experiments.

Authors' contribution: A. Yadav, A. Kumar Santra, A. Jain, A.K. Chaturvedani: Conceptualization; A. Yadav, A.K. Santra, A. Jain: Experimental procedure and data collection; A. Yadav, A. Jain: Data processing; A.K. Santra: Funding acquisition; A.K. Santra: Project administration; A. Yadav, A. Jain: Statistical analysis; A. Yadav, A. Dubey, A.K. Chaturvedani: Writing-original draft; A. Yadav, A.K. Santra, A.K. Chaturvedani: Writing-review and editing.

Funding: The work was funded by the College of Veterinary Science and Animal Husbandry, Durg, Chhattisgarh, India.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: The trial includes table birds which are exempted from the guidelines of the Institutional Animal Ethics Committee.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Datasets used in the trial are available from the corresponding author on request.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology*.

References

Akib, M.G., A. Rifat, C. Bormon, A. Dutta, M.S. Ataher, M. Azzam, M.H. Farouk, R. Das, M.A.K. Azad and S. Mahfuz: Effects of *Moringa oleifera* leaf powder on the growth performance, meat quality, blood parameters, and cecal bacteria of broilers. *Vet. Sci.*, **11**, 374 (2024).

Akinyemi, M.O., G.O. Adeyemo and O.A. Adedeji: Effects of *Moringa oleifera* leaf meal on growth performance and carcass characteristics of broiler chickens. *Trop. Anim. Hlth. Prod.*, **54**, 185 (2022).

AOAC: Official Methods of Analysis. 19th Edn., **Vol. I & II**. Association of Official Analytical Chemists, Washington DC, USA (2012).

Egbu, C.F., A. Mulaudzi, L.E. Motsei and C.M. Mnisi: *Moringa oleifera* products as nutraceuticals for sustainable poultry production. *Agric. Food Secur.*, **13**, 54 (2024).

Foidl, N., H.P.S. Makkar and K. Becker: The potential of *Moringa oleifera* for agricultural and industrial uses. In: The Miracle Tree: The Multiple Attributes of Moringa. (Eds.: R. Sawhney and S. Singh). National Academy of Agricultural Sciences, New Delhi. pp. 45-76 (2001).

Gopalakrishnan, L., K. Doriya and D.S. Kumar: *Moringa oleifera*: A review on nutritive importance and its medicinal application. *Food Sci. Hum. Wellness.*, **5**, 49-56 (2016).

ICAR: Nutrient Requirements of Poultry. Indian Council of Agricultural Research, New Delhi, India, pp. 25-26 (2013).

Kursun, K.: The influence of *Moringa oleifera* leaf powder on body weight MYF5 and IGF1 gene expression in Japanese quails. *Vet. Med. Sci.*, **11**, 1-8 (2025).

Lungu, N.S., J.G. Maina, M. Dallimer and E. Van Marle-Koster: The potential of *Moringa oleifera* as a sustainable broiler feed additive: Investigating awareness, perceptions and use by broiler farmers and *Moringa* farmers in South Africa. *Sustainability*, **16**, 2208 (2024).

Makkar, H.P.S. and K. Becker: Nutritional value and nutritional components of whole and extracted *Moringa oleifera* leaves. *Anim. Feed Sci. Technol.*, **63**, 211-228 (1996).

Melesse, A., H. Steingass, M. Schollenberger and M. Rodehutschord: Effects of *Moringa stenopetala* and *Moringa oleifera* leaf meals on growth, carcass traits and blood constituents of broilers. *Livest. Sci.*, **157**, 475-483 (2013).

Maqsood, S., S. Naz, A. Sikandar, S. Arooj, A. Fahad Alrefaei and M. Israr: Additive effect of *Moringa oleifera* leaf meal and pomegranate (*Punica granatum*) peel powder on productive performance, carcass attributes and histological morphology of ileum in Japanese quails. *J. Appl. Anim. Res.*, **52**, 1-7 (2024).

Nkukwana, T.T., V. Muchenje, E. Pieterse, P.J. Masika, T.P. Mabusela, L.C. Hoffman and K. Dzama: Effect of *Moringa oleifera* leaf meal on growth performance, apparent digestibility, digestive organ size and carcass yield in broiler chickens. *Livest. Sci.*, **161**, 139-146 (2014).

Olugbemi, T.S., S.K. Mutayoba and F.P. Lekule: Evaluation of *Moringa oleifera* leaf meal inclusion in cassava chip based diets fed to laying birds. *Livest. Res. Rural Dev.*, **22**, 1-6 (2010).

Sanchez-Machado, D.I., J.A. Nunez-Gastelum, C. Reyes-Moreno, B. Ramirez-Wong and J. Lopez-Cervantes: Nutritional quality of edible parts of *Moringa oleifera*. *Food Anal. Methods.*, **3**, 175-180 (2010).

Yadav, A., A.K. Santra, O.P. Dinani, N. Singh, R. Pathak, K. Parveen, A. Dubey and V. Kumar: Dietary inclusion of *Moringa oleifera* leaf meal improves egg fertility and hatchability in Japanese quails (*Coturnix coturnix japonica*). *Int. J. Agric. Sci.*, **14**, 11469-11471 (2022).

Yadav, S.K., R. Singh and A. Kumar: Evaluation of *Moringa oleifera* leaf meal as a partial substitute for soybean meal in quail diets. *Indian J. Poultry Sci.*, **59**, 145-152 (2024).