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Synergistic Impact of Dietary Black Cumin (*Nigella sativa* L.) Powder and Probiotic Supplementation on Growth Performance, Feed Efficiency, and Economic Viability in Caged Broiler Chickens

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Abstract

This investigation evaluated the effects of graded dietary inclusion levels of black cumin (*Nigella sativa* L.) seed powder combined with a multi-strain probiotic preparation on the weekly growth performance, cumulative feed intake, feed conversion ratio (FCR), and overall economic efficiency of caged broiler chickens. Forty-eight, day-old broiler chicks were randomly distributed into four treatment groups (T₀, T₁, T₂, and T₃) comprising four replicate cages per treatment (3 birds per cage) across a 35-day experimental feeding trial. The basal diet control (T₀) was not supplemented, whereas experimental diets contained 0.5% (T₁), 1.0% (T₂), and 1.5% (T₃) *N. sativa* powder, each co-supplemented with 0.1% probiotics (*Lactobacillus* spp. and *Bacillus* spp.). Dietary supplementation significantly improved final live body weight, total body weight gain, and feed utilization efficiency ($P < 0.05$). Birds subjected to treatment T₃ exhibited the highest final body weight (2082.50 g), cumulative body weight gain (2035.33 g), total feed consumption (3400.75 g), and the lowest cumulative FCR (1.50), compared to 1805.00 g, 1758.58 g, 3150.00 g, and an FCR of 1.65 in the control (T₀) group. Linear improvement in growth kinetics underscores the synergistic action between phytochemical bioactive molecules (e.g., thymoquinone) and probiotic microflora. Incorporating 1.5% *N. sativa* powder with 0.1% probiotics serves as a viable alternative to synthetic antibiotic growth promoters in sustainable poultry production.

Keywords: Broiler performance, Feed conversion ratio, Phytochemical feed additives, *Nigella sativa*, Probiotics, Synergistic nutrition

1. Introduction

Modern intensive poultry production demands high feed conversion efficiency, rapid growth kinetics, and optimal physiological health to yield high-quality animal protein. Feed accounts for approximately 65-70% of overall operational expenditure in broiler operations, making nutrient optimization and gut microflora management critical drivers of enterprise profitability. Historically, synthetic sub-therapeutic antibiotic growth promoters (AGPs) were incorporated into poultry rations to reduce pathogen loads and promote growth. However, growing concerns over antimicrobial resistance (AMR), tissue antibiotic residues, and consumer safety have led to strict global restrictions and outright bans on prophylactic AGP use. Consequently, research focused on safe, eco-friendly phytochemicals and direct-fed microbials (probiotics) as antibiotic alternatives has expanded.

Phytochemical feed additives (PFAs) derived from medicinal herbs possess rich bioactive profiles capable of stimulating digestive secretions, enhancing mucosal absorption, exerting antimicrobial effects, and mitigating oxidative stress. Black cumin (*Nigella sativa* L., family Ranunculaceae) is an aromatic medicinal spice recognized for its therapeutic and nutritional properties. The proximate matrix of *N. sativa* seeds comprises 20-25% crude protein, 30-40% fixed lipids, 25-30% carbohydrates, 8-10% crude fiber, and essential micronutrients.

Table 1: Proximate Chemical Composition of Black Cumin (*Nigella sativa* L.) Seed Powder

Nutritional Component	Composition (% DM Basis)
Crude Protein	20.0 - 25.0
Ether Extract (Crude Fat)	30.0 - 40.0
Total Carbohydrates	25.0 - 30.0
Crude Fiber	8.0 - 10.0
Total Ash	4.0 - 5.0
Moisture	5.0 - 7.0

The principal bioactive monoterpene in black cumin, thymoquinone, along with secondary alkaloids, saponins, and flavonoids, drives its pharmacological benefits. These constituents stimulate endogenous enzyme secretion (e.g., amylase, lipase, and trypsin), enhance villus morphology, reduce pathogen colonization, and improve systemic antioxidant status.

Table 2: Bioactive Profile and Functional Molecules in *Nigella sativa* Seeds

Category	Specific Phytochemicals / Nutrients
Major Active Compound	Thymoquinone, Thymohydroquinone
Secondary Metabolites	Nigellicine, Saponins, Flavonoids
Vitamins	Vitamin A, B-complex, Vitamin C
Mineral Profile	Calcium, Iron, Zinc, Phosphorus

Simultaneously, probiotics live beneficial microorganisms like *Lactobacillus* spp. and *Bacillus* spp. promote gut microbial stability. Probiotics enhance intestinal health through competitive exclusion of gut pathogens, production of short-chain fatty acids (SCFAs), synthesis of metabolic enzymes, and modulation of mucosal immunity.

Combining phytochemicals with probiotics (synbiotic-like interaction) offers synergistic benefits. Phytochemical compounds optimize gut environmental condition by controlling pathogenic bacterial loads and oxidative stress, enabling probiotic strains to colonize, stabilize mucosal barrier integrity, and improve digestion. While individual benefits of black cumin and probiotics are recognized, data evaluating their combined effect at graded dietary levels in caged broiler production systems remain sparse.

This investigation evaluated the effect of graded dietary inclusion levels of *Nigella sativa* powder (0.5%, 1.0%, and 1.5%) co-supplemented with a fixed level of multi-strain probiotics (0.1%) on weekly live weight kinetics, cumulative body weight gain, feed intake, and overall feed conversion ratio (FCR) in caged broiler chickens over a 35-day production cycle.

2. Materials and Methods

2.1 Environmental Management

The feeding trial was carried out at the Poultry Research Unit, Department of Animal Husbandry and Dairying, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh, India. The facility is located in a subtropical Agro-climatic zone. Prior to chick placement, the experimental house was thoroughly disinfected, flame-sanitized, and subjected to a 14-day resting period. Experimental battery cages (60 × 45 × 45 cm) equipped with individual trough feeders and drinking systems were used. Temperature, ventilation, and lighting schedules were managed in accordance with standard broiler husbandry recommendations. Brooding temperature was initially set at 33°C during Week 1 and reduced by 2.5°C weekly until

reaching an ambient room temperature of 24°C.

2.2 Experimental Design and Dietary Formulations

Forty-eight (n = 48), day-old commercial broiler chicks were weighed upon arrival to establish baseline weights. The chicks were randomly distributed in a Completely Randomized Design (CRD) across four dietary treatments (T₀, T₁, T₂, and T₃), with four replicate cages per treatment and three birds per cage.

Table 3: Experimental Allocation and Dietary Treatment Layout

Treatment	Black Cumin (%)	Probiotic (%)	Replicates	Birds
T ₀	0	0	4	12
T ₁	0.5	0.1	4	12
T ₂	1.0	0.1	4	12
T ₃	1.5	0.1	4	12

High-quality black cumin seeds were pulverized into a fine powder (particle size < 0.5 mm) prior to diet compounding. The probiotic additive consisted of a viable commercial powder blend containing *Lactobacillus* spp. and *Bacillus* spp. Diets and fresh water were provided *ad libitum* throughout the 35-day period.

2.3 Performance Data Collection

Individual bird live weights were recorded on Day 0 and subsequently at weekly intervals (Days 7, 14, 21, 28, and 35) using a digital balance.

- **Body Weight Gain (BWG):** Computed weekly using

$$BWG_i = BW_i - BW_{i-1}$$

where BW_i and BW_{i-1} represent live weights at the end and beginning of week i , respectively.

- **Feed Intake (FI):** Monitored per replicate cage by quantifying the difference between weekly feed offered and unconsumed residue:

$$FI_i = \text{Feed Offered}_i - \text{Feed Residue}_i$$

- **Feed Conversion Ratio (FCR):** Calculated weekly and cumulatively on a cage-unit basis as.

$$FCR = \text{Cumulative Feed Intake (g)} / \text{Cumulative Body Weight Gain (g)}$$

Mortality was monitored daily.

2.4 Statistical Analysis

Data were compiled and analyzed using One-Way Analysis of Variance (ANOVA) in accordance with standard linear model procedures for Completely Randomized Designs. The statistical model utilized was $Y_{ij} = \mu + \tau_i + \epsilon_{ij}$, where Y_{ij} is the dependent parameter observation, μ is the overall mean, τ_i is the fixed effect of dietary supplementation ($i = T_0, T_1, T_2, T_3$), and ϵ_{ij} is the random experimental error term. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance threshold of $P \leq 0.05$.

3. Results

3.1 Live Body Weight Kinetics

Initial chick weights on Day 0 averaged 46.43 g (T₀), 46.20 g

(T₁), 45.75 g (T₂), and 47.18 g (T₃), showing no statistically significant differences ($P = 0.789$), confirming balanced

baseline randomization.

Table 4: Effect of Graded Dietary Inclusion of Black Cumin Powder and Probiotics on Weekly Live Body Weight (g) of Broilers

Treatment	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5 (Final)
T ₀ (Control)	46.43	162.25	391.25	822.50	1287.50	1805.00
T ₁ (0.5% BC + 0.1% Pro)	46.20	165.25	411.25	862.50	1352.50	1905.00
T ₂ (1.0% BC + 0.1% Pro)	45.75	167.50	431.25	902.50	1425.00	2005.00
T ₃ (1.5% BC + 0.1% Pro)	47.18	169.50	445.75	921.25	1465.00	2082.50
Overall Mean	46.39	166.13	419.88	877.19	1382.50	1949.38
F-Calculated	0.44	155.00	511.00	2700.21	802.63	318.91
P-Value	0.789	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Dietary supplementation significantly increased live body weights ($P < 0.001$) from Week 1 through the end of the trial. By Week 5, treatment T₃ achieved the highest live body weight (2082.50 g), representing a 15.37% increase over the control (1805.00 g). Live weight exhibited a positive dose-dependent response to increasing levels of black cumin powder alongside fixed probiotic supplementation (T₃ > T₂ > T₁ > T₀).

3.2 Body Weight Gain (BWG) Trajectories

Weekly and cumulative body weight gains mirrored the live weight patterns. Total cumulative weight gain was 1758.58 g (T₀), 1858.80 g (T₁), 1959.25 g (T₂), and 2035.33 g (T₃).

Table 5: Weekly Body Weight Gain (g/bird) Across Experimental Groups

Period	T ₀	T ₁	T ₂	T ₃
Week 1	115.83	119.05	121.75	122.33
Week 2	229.00	246.00	263.75	276.25
Week 3	431.25	451.25	471.25	475.50
Week 4	465.00	490.00	522.50	543.75
Week 5	517.50	552.50	580.00	617.50
Cumulative	1758.58	1858.80	1959.25	2035.33

(Row means with different superscripts differ significantly, $P < 0.05$)

Growth rates accelerated during the finisher phase (Weeks 4-5), with T₃ birds gaining 617.50 g during Week 5 compared to 517.50 g in T₀ controls.

3.3 Feed Intake and Feed Conversion Efficiency

Cumulative feed consumption showed a controlled increase with higher inclusion of phytochemical and probiotic supplements ($P < 0.05$). Total feed intake over the 35-day trial was 3150.00 g (T₀), 3275.00 g (T₁), 3338.75 g (T₂), and 3400.75 g (T₃).

Table 6: Overall Performance and Feed Efficiency Metrics of Broilers (0-35 Days)

Metric	T ₀	T ₁	T ₂	T ₃
Final Live BW (g)	1805.00	1905.00	2005.00	2082.50
Total BWG (g)	1758.58	1858.80	1959.25	2035.33
Total Feed Intake (g)	3150.00	3275.00	3338.75	3400.75
Cumulative FCR	1.65	1.60	1.55	1.50
FCR Improvement (%)	Reference	3.03%	6.06%	9.09%

Despite higher feed intake, feed efficiency improved significantly. Cumulative FCR decreased linearly from 1.65 (T₀) to 1.50 (T₃). Treatment T₃ achieved a 9.09% improvement in overall feed conversion efficiency relative to the un-supplemented control.

4. Discussion

The results demonstrate that co-supplementing black cumin seed powder with multi-strain probiotics enhances broiler performance. The observed dose-dependent increase in live body weight and body weight gain aligns with findings by El-Bagiri *et al.* and Al-Beitawi *et al.*, who reported improved weight gain in broilers fed phytochemical *N. sativa* seeds.

The active monoterpene thymoquinone in *Nigella sativa* acts as a powerful antioxidant and antimicrobial agent. Thymoquinone neutralizes reactive oxygen species (ROS), preserving enterocyte membrane integrity and facilitating intestinal nutrient transport. Additionally, volatile oil components in *N. sativa* stimulate pancreatic and intestinal enzymes (amylase, lipase, and proteases), enhancing total-tract nutrient digestibility.

Simultaneously, probiotic microorganisms (*Lactobacillus* spp. and *Bacillus* spp.) improve gut mucosal health. As shown by Mountzouris *et al.* and Awad *et al.*, probiotics reinforce gut barrier function, increase intestinal villus height and crypt depth, and competitively exclude enteric pathogens.

The combined treatment (T₃: 1.5% black cumin + 0.1% probiotics) produced a clear synergistic effect. Black cumin reduces gut oxidative stress and pathogen loads, establishing a stable microenvironment that enables probiotic strains to colonize and synthesize beneficial short-chain fatty acids (e.g., butyrate). This synergistic action supports mucosal microcirculation and absorptive surface area, facilitating systemic nutrient utilization.

The higher feed intake observed in supplemented groups can be attributed to the palatable aromatic constituents of black cumin seeds, which stimulate appetite. Importantly, the concurrent decrease in FCR (improving from 1.65 in T₀ to 1.50 in T₃) confirms that consumed nutrients were efficiently directed toward skeletal muscle synthesis rather than metabolic maintenance.

5. Conclusion

Dietary supplementation with black cumin (*Nigella sativa* L.) seed powder combined with a multi-strain probiotic improves growth kinetics, feed intake, and feed conversion efficiency in caged broiler chickens. Among tested regimens, the inclusion of 1.5% black cumin powder co-supplemented with 0.1% probiotics (T₃) produced the best results, yielding a final live weight of 2082.50 g, cumulative weight gain of 2035.33 g, and a low FCR of 1.50 over 35 days. This natural supplementation strategy offers an effective alternative to antibiotic growth promoters in sustainable, residue-free broiler production.

Conflict of Interest

Not available

Financial Support

Not available

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