

Sustainable Nutritional Strategy in Laying Japanese Quail Using a Mixture of Enzymes and Feed Restriction

Mohammed Noori Al-Nema¹ and Nawaf Gaze Al-Tamee¹

¹ Department of Animal Production, College of Agriculture and Forestry, University of Mosul, Iraq

*Corresponding author E-mail: mohammednoori.24agp92@student.uomosul.edu.iq

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ABSTRACT. *This study aimed to evaluate the effects of two feeding regimes—ad libitum feeding and feed restriction at 20% below the daily ad libitum intake—combined with two levels of a dietary enzyme mixture (0% and 0.075%) on the productive performance of laying Japanese quail. A total of 96 sexed quail, aged 15 to 27 weeks, were used in the experiment. The birds were randomly assigned to four dietary treatments with four replicates per treatment (six birds per replicate) according to a 2 × 2 factorial design. The results showed that supplementation with the enzyme mixture significantly ($P \leq 0.05$) improved the total egg number compared with the non-supplemented treatment. In addition, enzyme supplementation did not result in significant differences ($P \leq 0.05$) in average feed intake. Regarding feed restriction, no significant adverse effects were observed on average egg production or egg weight. However, feed restriction improved feed conversion ratio during certain periods, indicating enhanced feed utilization efficiency and reduced feed wastage. A significant reduction in average feed intake was also observed compared with ad libitum feeding, without affecting egg quality traits or dressing percentage. This reflects the ability of quail to adapt to reduced feed availability while maintaining essential physiological requirements. Furthermore, the interaction between feed restriction and enzyme supplementation showed that their combination improved egg production while maintaining lower feed intake and enhancing feed conversion ratio, without any negative effects on dressing percentage or egg quality traits. These findings indicate that the integration of feed restriction and enzyme supplementation represents an effective strategy for improving the productive performance of laying Japanese quail.*

Keywords: Japanese quail, enzyme mixture, feed intake, egg indices, feed conversion ratio

1. INTRODUCTION

he pace of innovation and scientific research in the field of animal production is rapidly accelerating to enhance both the quantity and quality of animal protein, which represents an indispensable component of human nutrition [1], Feed costs represent the major economic constraint in the poultry industry, accounting for the largest proportion of total production expenses. This challenge is further compounded by competition for primary feed resources that are also utilized for human consumption, particularly in developing countries [2], The challenge lies in ensuring sufficient food supply to meet the needs of a growing population while preserving natural resources and maintaining their sustainability [3] However, the reliance on corn and soybean meal in poultry diets imposes environmental and economic constraints, highlighting the urgent need for more efficient and sustainable alternative feeding strategies [4] Since the early development of agriculture, poultry have represented a fundamental component of food production systems due to their important role in providing meat, eggs, and feathers. This is largely attributed to their high capacity to utilize a wide range of feed resources, from agricultural and household by-products to agro-industrial residues [5], The poultry production sector is considered one of the fastest-growing agricultural sectors, owing to its ability to supply diverse food products that meet the increasing global demand. The most important poultry species include broiler chickens, laying hens, turkeys, ducks, and quail [6], Japanese quail occupy a prominent position within poultry production systems due to their distinctive productive and physiological characteristics, including high egg production efficiency, good disease resistance, and high reproductive performance[7].

Interest in quail eggs has increased due to their high nutritional value, as they are rich in proteins, vitamins, and minerals, in addition to possessing bioactive properties such as anti-inflammatory effects and immune-modulating functions, which may help reduce allergic responses and regulate immune activity [8], In addition, quail are characterized by rapid growth and low requirements for feed and housing space.

Moreover, it contributes to reducing feed wastage, lowering nitrogen excretion, and minimizing harmful environmental emissions, while maintaining immune competence and digestive health [9], Poultry products are among the most widely consumed sources of animal protein worldwide, and this sector has experienced rapid growth compared with other livestock industries due to continuous advancements in production and management systems.

Despite this progress, the poultry industry continues to face several challenges, most notably reducing production costs and improving feed efficiency in line with consumer demands and environmental sustainability [10], Feed cost remains one of the major economic challenges for poultry producers, as it represents the largest proportion of total production costs. This issue is further compounded by competition with human food resources for key feed ingredients, particularly in developing countries.

In light of global challenges related to food security and the United Nations Sustainable Development Goals (SDGs), poultry production—especially quail—plays a crucial role in providing a sustainable source of high-quality animal protein [11].

However, the heavy reliance on corn and soybean meal in poultry diets poses environmental and economic constraints, necessitating the adoption of more efficient and sustainable feeding

strategies [12][13], In this regard, enzyme supplementation has gained increasing scientific attention due to its role in enhancing nutrient bioavailability, improving digestive efficiency, and achieving economic benefits by reducing dependence on high-cost feed ingredients while improving the nutritional quality of diets [14] , A feeding system can be defined as a management approach that regulates the timing and quantity of feed provided to birds, thereby directly influencing their productive performance compared with ad libitum feeding. Feed restriction may be applied quantitatively by limiting daily feed intake or qualitatively by reducing nutrient density in the diet. It is considered an effective strategy in poultry nutrition management to improve production efficiency [15].

2. MATERIALS AND METHODS

2.1 Experimental birds

The practical component of this study was conducted in the research facility of the Department of Animal Production, College of Agriculture and Forestry, University of Mosul. All experimental procedures were carried out in accordance with standard research practices. A total of 96 Japanese quail at 15 weeks of age were randomly assigned, after determining the average body weight, to four dietary treatments, with four replicates per treatment (six birds per replicate), The birds were reared separately by treatment in a semi-open room measuring 3 × 4 m, equipped with windows on two sides, air-cooling units, and exhaust ventilation fans. The housing system consisted of wooden cages arranged in three tiers, with each tier containing four cages measuring 50 × 50 × 50 cm (length × width × height). Each cage was provided with a 1 kg feeder and an automatic drinker placed the cage, A 2 × 2 factorial experimental design was applied, including two levels of an enzyme mixture (0 and 0.075%) and two feeding regimes (ad libitum feeding and feed restriction at 20% below the daily ad libitum intake).

2.2 Multi-enzyme source

The multi-enzyme product Kemzyme Plus P Dry was purchased from Al-Hijara Al-Bayda Company Office, a specialized supplier of feed and veterinary requirements in Erbil city. The product is manufactured by Kemin (Belgium) and is supplied as a fine white powder packed in 1-kg bags. Due to the low inclusion rate per kilogram of feed, the enzyme supplementation and mixing process was carried out using a stepwise dilution method. The required amount of the multi-enzyme preparation was accurately weighed using a sensitive electronic balance (0.01 g precision), then initially mixed thoroughly with a small quantity of feed. This premix was subsequently blended with progressively larger amounts of feed until the desired final feed quantity was achieved, ensuring uniform distribution of the enzymes throughout the diet.

2.3 Nutrition

The basal experimental diet was formulated to meet the nutritional requirements of laying Japanese quail as recommended by the National Research Council (NRC, 1994), from the first day of the experiment until the end of the twelfth week, as shown in Table (1), Throughout the experimental period, the quail were maintained under uniform management, hygienic, and environmental conditions. A photoperiod of 17 hours of light per day was provided, and clean water was available continuously. Excreta trays and feeding equipment were cleaned daily, and the ambient temperature was maintained at a constant level of 25 °C throughout the study period.

2.4 Experimental Design

A total of 96 sexed Japanese quail were used in this experiment and reared from 15 to 27 weeks of age. The birds were randomly assigned to four dietary treatments, with four replicates per treatment, consisting of four males and two females per replicate.

The treatments included a control group, feed restriction at 20% below the daily feed intake of the control diet, supplementation with an enzyme mixture at a level of 720 g/ton of feed, and a combined treatment that included both enzyme supplementation and feed restriction.

2.5 Statistical Analysis

Data were analyzed using a Completely Randomized Design (CRD) within a 2 × 2 factorial experiment to evaluate the effects of supplementation with a mixed enzyme preparation, feed restriction, and their interaction (two levels of enzyme mixture × two levels of feed restriction). The statistical analysis was performed in accordance with the procedures described by Snedecor and Cochran (1982) using SAS software (SAS Institute, 2011).

Table 1 Components of the experimental diet and its calculated chemical analysis

Feed material	percentage (%)
Soybean meal	32
Yellow corn	40
Wheat	18.2
Sunflower oil	3.3
Limestone %	6
Salt %	0.25
Premix %	0.25
Calculated Chemical Analysis	
Metabolic energy kcal/kg	2900
Crude protein %	20
Crude fat %	6.5
Crude fiber %	3.7
Calcium %	2.8
Available phosphorus %	0.4
Lysine %	1.05
Methionine %	0.38

* Premix composition: Vitamin A (8,128,831 IU), Vitamin D₃ (1,035,316.54 IU), Vitamin E (1004.780 mg/kg), Vitamin B₁ (434.32 mg/kg), Vitamin B₂ (514.63 mg/kg), Vitamin B₆ (187.44 mg/kg), niacin (5678.31 mg/kg), folic acid (43.69 mg/kg), cobalt (4.71 mg/kg), copper (24.36 mg/kg), iron (162.09 mg/kg), manganese (294.96 mg/kg), zinc (129.32 mg/kg), glutamic acid (0.015%), glycine (0.030%), alanine (0.014%), arginine (0.011%), aspartic acid (0.001%), threonine (<0.01%), serine (<0.01%), valine (<0.01%), methionine (<0.01%), isoleucine

(<0.01%), leucine (<0.01%), tyrosine (<0.01%), phenylalanine (<0.01%), histidine (<0.01%), lysine (<0.01%), cystine (<0.01%), and proline (<0.01%).

3. Results and discussion

3.1 Discussion of egg production characteristics

The results presented in Table (2) indicate that the addition of the enzyme mixture led to improvements in certain productive traits of laying Japanese quail. A numerical increase was observed in egg production percentage (H.D.P%), total egg number, average egg weight, and egg mass compared with the non-supplemented treatment; however, these differences did not reach statistical significance for most traits. This improvement may be attributed to the role of enzymes in enhancing the digestion of nutrients, particularly proteins and complex carbohydrates, thereby increasing feed utilization efficiency and positively influencing productive performance. These findings are consistent with previous studies on quail and laying poultry, including [16], who reported that enzyme supplementation improved productive performance and egg production by enhancing nutrient utilization and reducing feed losses, Regarding the effect of feed restriction, the results showed a numerical reduction in egg production percentage, total egg number, and egg mass under restricted feeding compared with ad libitum feeding, while average egg weight remained relatively similar between the two treatments. These findings suggest that reduced feed intake may limit the energy available for production, without markedly affecting egg size. This indicates that birds tend to maintain egg weight at the expense of egg number under reduced feeding levels. These results are in agreement with recent studies, including [17], which reported that well-managed feed restriction does not significantly reduce egg weight, particularly when dietary protein and metabolizable energy are not limiting, With respect to the interaction between enzyme supplementation and feed restriction, the results showed that the treatment combining enzyme supplementation with ad libitum feeding recorded the highest values for most productive traits, particularly egg production percentage, egg number, and egg mass, whereas the treatment without enzyme supplementation under restricted feeding recorded the lowest values. However, these differences were not statistically significant, indicating that the interaction effect was limited. This suggests that enzyme supplementation may partially mitigate the negative impact of feed restriction, although it does not fully compensate for it, Overall, it can be concluded that enzyme supplementation, through improving digestive efficiency, may support productive performance in laying Japanese quail, while feed restriction tends to reduce production to some extent without clearly affecting egg weight. The combination of both treatments does not result in significant effects on the studied traits.

Table 2 Effect of supplementing a mixture of enzymes, feed restriction, and their interaction on egg production percentage (H.D.P%), total egg number, average egg weight (g/egg), and egg mass (g egg/female) of laying Japanese quail (means \pm standard error).

Transactions	H.D.P%	Total egg number	average egg weight (g/egg)	egg mass (g egg/female)
Effect of a mixture of some enzymes				
Without supplementation	54.16 \pm 6.75 a	45.5 \pm 5.67 b	11.96 \pm 0.19 a	545.9 \pm 72.78 a
With supplementation	62.95 \pm 5.4 a	52.875 \pm 4.54 a	12.57 \pm 0.52 a	660.2 \pm 48.96 a

Effect of feed restriction					
Ad libitum feeding		64.93 ± 5.87 a	54.54 ± 4.94 a	12.25 ± 0.29 a	668.23 ± 60.45 a
Restricted feeding		52.18 ± 5.62 a	43.83 ± 4.72 a	12.28 ± 0.51 a	537.86 ± 60.39 a
Interaction effect					
Without supplementation	Ad libitum	58.73 ± 7.6 a	49.33 ± 6.39 a	12.09 ± 0.39 a	601.8 ± 98.26 a
Without supplementation	Restricted	49.6 ± 8.7 a	41.66 ± 10.26 a	11.82 ± 0.15 a	490 ± 117.08 a
With supplementation	Ad libitum	71.13 ± 12.21 a	59.75 ± 7.36 a	12.4 ± 0.51 a	734.66 ± 64.83 a
With supplementation	Restricted	54.76 ± 1.5 a	46 ± 1.28 a	12.74 ± 1.03 a	585.73 ± 47.32 a

* Each group consisted of 26 birds, and the data are presented as mean ± standard error. Indicates a significant difference compared with the control group. Different superscript letters (a, b) denote significant differences among groups at $P \leq 0.05$.

3.2 Discussion of Egg Quality Traits

The results of Table (3) indicate that the addition of the enzyme mixture to the diet did not have a significant effect on most of the egg quality traits. Values for egg weight, the relative weight of albumen, yolk, and shell, as well as yolk index, shell thickness, yolk height, and yolk diameter were similar between the enzyme-supplemented and non-supplemented groups. However, slight numerical improvements were observed in some traits, such as thick albumen height and egg shape index, with enzyme addition, which may be attributed to enhanced digestion and absorption of nutrients, particularly amino acids and minerals involved in egg component formation. This agrees with [18], Regarding the effect of feed restriction, the results showed no significant differences in most of the measured traits, with only minor numerical changes noted. Birds maintained stable egg quality traits despite reduced feed intake, indicating that quail possess a physiological ability to allocate nutrients to preserve egg quality even under feed restriction conditions, prioritizing egg formation over other production traits such as egg number, as reported by [19]. These findings suggest that the level of feed restriction applied was moderate and did not adversely affect egg quality, Concerning the interaction between enzyme addition and feed restriction, the results showed no significant effects on most traits. Nevertheless, the enzyme-supplemented group under ad libitum feeding exhibited higher numerical values in certain indicators, such as thick albumen height and yolk index, whereas the feed-restricted group without enzyme addition showed relatively lower values in some of these traits. This indicates that enzyme supplementation may partially improve some egg quality characteristics, particularly under adequate feeding conditions, but does not have a clear effect when combined with feed restriction, Overall, these results indicate that the qualitative traits of quail eggs are more stable and less affected by dietary changes compared to production traits, and that enzyme supplementation or moderate feed restriction does not cause substantial alterations in egg quality, reflecting the stability of the physiological processes responsible for egg component formation.

Table 3 Effect of supplementing a mixture of enzymes, feed restriction, and their interaction on selected egg quality traits of Japanese quail (means \pm standard error).

Transactions	Egg weight	Albumen relative weight	Yolk relative weight	Shell relative weight	Shell thickness	Yolk height (mm)	Yolk diameter (mm)	Thick albumen height	Thin albumen height	Egg shape index	
Effect of a mixture of some enzymes											
Without supplementation	11.96 ± 0.25 a	60.36 ± 0.74 a	30.18 ± 0.65 a	9.4 ± 0.25 a	0.31 ± 0.01 a	11.2 6 ± 0.1 2 a	23.76 ± 0.25 a	4.11 ± 0.18 a	2.38 ± 0.09 b	76.43 ± 0.87 a	
With supplementation	12.5 ± 0.23 a	61.46 ± 0.83 a	29.91 ± 0.71 a	8.58 ± 0.46 a	0.33 ± 0.02 a	11.5 1 ± 0.1 1 a	24.56 ± 0.4 a	4.43 ± 0.14 a	3.1 ± 0.12 a	77.06 ± 0.76 a	
Effect of feed restriction											
Ad libitum feeding	12.21 ± 0.24 a	60.18 ± 0.74 a	30.5 ± 0.65 a	9.28 ± 0.45 a	0.33 ± 0.02 a	11.4 8 ± 0.1 4 a	24.35 ± 0.36 a	4.2 ± 0.12 a	2.91 ± 0.19 a	76.48 ± 0.86 a	
Restricted feeding	12.25 ± 0.29 a	61.65 ± 0.77 a	29.6 ± 0.66 a	8.7 ± 0.31 a	0.31 ± 0.01 a	11.3 ± 0.1 a	23.98 ± 0.37 a	4.35 ± 0.21 a	2.56 ± 0.16 b	77.01 ± 0.78 a	
Interaction effect											
Without supplementation	Ad libitum	12.13 ± 0.38 a	59.93 ± 0.68 a	30.6 ± 0.11 a	9.43 ± 0.56 a	0.3 ± 0 a	11.36 ± 0.23 a	24.16 ± 0.2 a	4.03 ± 0.12 a	2.53 ± 0.0 8 bc	75.76 $\pm 1.$

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Without supplementation	Restrict ed	11.8 ±0.37 a	60.8 ±1.44 a	29.76 ±1.39 a	9.36 ±0.06 a	0.33 ±0.03 a	11.16 ±0.13 a	23.36 ±0.33 a	4.2 ± 0.37 a	2.23 ±0.1 2 c	77.1 ±0.95 a
With supplementation	Ad libitum	12.3 ±0.37 a	60.43 ±1.48 a	30.4 ±1.45 a	9.13 ±0.84 a	0.36 ±0.03 a	11.6 ± 0.2 a	24.53 ±0.76 a	4.36 ± 0.2 a	3.3 ± 0.17 a	77.2 ±0.85 a
With supplementation	Restrict ed	12.7 ±0.32 a	62.5 ±0.45 a	29.43 ±0.46 a	8.03 ±0.24 a	0.3 ± 0 a	11.43 ±0.14 a	24.6 ±0.46 a	4.5 ± 0.25 a	2.9 ± 0.1 ab	76.93 ±1.48 a

* Each group consisted of 26 birds, and the data are presented as mean ± standard error. Indicates a significant difference compared with the control group. Different superscript letters (a, b) denote significant differences among groups at $P \leq 0.05$.

3.3 Discussion of Total Feed Intake, Feed Conversion Ratio, and Protein Excretion in Feces

The results presented in Table (4) indicate that the addition of the enzyme mixture did not significantly affect feed intake, as values were comparable between the supplemented and non-supplemented treatments, suggesting that enzyme inclusion does not directly influence bird appetite. However, a numerical improvement in feed conversion ratio was observed with enzyme supplementation, where its value decreased from 4.06 in the non-supplemented treatment to 3.15 in the supplemented treatment, indicating enhanced efficiency of feed conversion into production. This improvement may be attributed to the role of enzymes in enhancing the digestion and utilization of nutrients, particularly protein and energy. Furthermore, the percentage of protein excreted in the feces decreased significantly with enzyme supplementation, reflecting improved protein digestibility and reduced nutrient losses. This improvement may be explained by the role of enzymes in degrading complex compounds and enhancing the availability of energy and protein, which is positively reflected in feed conversion efficiency, in agreement with [20]. Regarding the effect of feed restriction, it resulted in a significant reduction in feed intake compared with ad libitum feeding. However, no significant differences were observed in feed conversion ratio between the two treatments, **Table 4 Effect of supplementing a mixture of enzymes, feed restriction, and their interaction on total feed intake (g), feed conversion ratio, and the percentage of protein excreted in the feces (means ± standard error).**

Treatments	Total feed intake (g)	feed conversion ratio	Protein%
Effect of a mixture of some enzymes			
Without supplementation	2008.88 ± 87.72 a	4.06 ± 0.62 a	25.26 ± 0.77 a

With supplementation		2045.88 ± 93.66	a	3.15 ± 0.15	a	21.12 ± 0.29	b
Effect of feed restriction							
Ad libitum feeding		2217.37 ± 41.8	a	3.45 ± 0.27	a	24.34 ± 1.17	a
Restricted feeding		1837.38 ± 20.46	b	3.76 ± 0.63	a	22.04 ± 0.69	b
Interaction effect							
Without supplementation	Ad libitum	2196.60 ± 49.7	a	3.8 ± 0.47	a	0.35 ± 26.94a	
Without supplementation	Restricted	1821.15 ± 27.71	b	4.33 ± 1.28	a	0.17 ± 23.57	b
With supplementation	Ad libitum	2238.13 ± 76.4	a	3.1 ± 0.2	a	0.17 ± 21.74c	
With supplementation	Restricted	1853.62 ± 32.6	b	3.2 ± 0.26	a	0.17 ± 20.51d	

* Each group consisted of 26 birds, and the data are presented as mean ± standard error. Indicates a significant difference compared with the control group. Different superscript letters (a, b) denote significant differences among groups at $P \leq 0.05$.

although a slight numerical improvement was recorded under ad libitum feeding. Meanwhile, the percentage of protein excreted in the feces decreased under feed restriction, indicating improved protein utilization efficiency under reduced feed intake conditions. This reflects the ability of birds to adapt to a moderate reduction in feed without compromising feed efficiency, as reported by [21]. With respect to the interaction effect, the results showed that the treatment combining enzyme supplementation with restricted feeding recorded one of the best values for feed conversion ratio (3.2) compared with the non-supplemented restricted treatment (4.33), reflecting a clear improvement in feed conversion efficiency when both factors were combined. This treatment also showed a reduction in the percentage of protein excreted in the feces, indicating a complementary effect between enzyme supplementation and feed restriction in enhancing feed utilization efficiency. Overall, it can be concluded that the addition of the enzyme mixture plays a significant role in improving feed conversion ratio and reducing protein losses, particularly when combined with feed restriction, thereby enhancing productive efficiency and minimizing nutrient wastage.

3.4 Discussion of Initial Body Weight, Final Body Weight, and Weight change

The results presented in Table (5) indicate that the addition of the enzyme mixture did not result in significant differences in initial or final live body weight, nor in Weight change, as values were comparable between the supplemented and non-supplemented treatments. However, a slight numerical increase was observed in initial body weight under enzyme supplementation,

whereas the non-supplemented treatment recorded relatively higher values in final body weight and Weight change. This suggests that the effect of enzymes at this stage was not clearly reflected in bird growth, possibly due to the adequacy of the basal diet in meeting nutritional requirements, Regarding the effect of feed restriction, the results similarly showed no significant differences in all studied traits, including initial body weight, final body weight, and Weight change. Nevertheless, a numerical increase in Weight change was observed in birds subjected to restricted feeding compared with those fed ad libitum. This may indicate a partial compensatory growth response resulting from improved feed utilization efficiency under feed restriction conditions. These findings are consistent with those reported by [22], With respect to the interaction between enzyme supplementation and feed restriction, no significant differences were observed among treatments for any of the studied traits. However, the treatment combining enzyme supplementation with feed restriction recorded relatively higher numerical values for final body weight and Weight change compared with the other treatments, while the enzyme-supplemented ad libitum group showed the lowest value for Weight change. This suggests that the effect of enzymes may be more pronounced when combined with feed restriction, where they contribute to improved utilization of limited feed resources, Overall, these results indicate that live body weight and Weight change in growing Japanese quail are relatively stable traits and are not markedly influenced by enzyme supplementation or feed restriction. However, a tendency toward improved performance is observed when both treatments are combined, reflecting their role in enhancing feed utilization efficiency without causing significant changes in growth.

Table 5 Effect of supplementing a mixture of enzymes, feed restriction, and their interaction on initial and final live body weight and the change between them in laying Japanese quail (means \pm standard error).

Treatments		Average initial live weight (g/bird) at 15 weeks of ago	Average final live weight (g/bird) at 27 weeks of ago	Weight change (g/bird)
Effect of a mixture of some enzymes				
Without supplementation		237.75 \pm 6.76	261.08 \pm 17.04	23.33 \pm 14.15
With supplementation		238.41 \pm 7.82	253.25 \pm 4.36	14.83 \pm 5.95
Effect of feed restriction				
Ad libitum feeding		243.41 \pm 3.12	258.16 \pm 13.14	14.75 \pm 13.8
Restricted feeding		232.75 \pm 9.26	256.16 \pm 11.94	23.41 \pm 6.71
Interaction effect				
Without supplementation	Ad libitum	241.66 \pm 2.18	266.5 \pm 28.07	24.83 \pm 28.89
Without supplementation	Restricted	233.83 \pm 14.45	255.66 \pm 25.2	21.83 \pm 12.82
With supplementation	Ad libitum	245.16 \pm 6.39	249.83 \pm 2.42	4.66 \pm 3.98
With supplementation	Restricted	241.66 \pm 2.18	266.5 \pm 28.07	24.83 \pm 28.89

4. CONCLUSION

This study aimed to evaluate the effect of supplementing a mixture of feed enzymes and applying feed restriction, as well as their interaction, on productive performance and the percentage of protein excreted in the feces of laying Japanese quail. The experiment included an adequate number of quail birds and was conducted from 15 to 27 weeks of age. Two feeding systems were applied: ad libitum feeding and feed restriction at 20% less than the daily intake of the ad libitum group, along with two levels of enzyme supplementation.

The results showed that enzyme supplementation did not cause significant differences in feed intake or egg quality traits; however, it contributed to improved feed utilization efficiency, an increase in egg number, and a reduction in protein excretion in the feces, indicating the safety of enzyme inclusion in quail diets.

Regarding the interaction between enzyme supplementation and feed restriction, no significant differences were observed in most of the studied traits. This suggests that combining feed enzymes with feed restriction represents a safe and effective nutritional strategy that improves feed utilization efficiency without causing physiological stress, while also reducing protein excretion in the feces.

The findings of this study enhance the scientific understanding of modern nutritional strategies in laying Japanese quail and confirm the feasibility of using enzyme supplementation in combination with moderate feed restriction as a sustainable feeding approach. This strategy improves feed efficiency and provides economic and environmental benefits while maintaining bird productivity, offering a solid scientific basis for future research and practical applications in poultry nutrition.

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Competing Interests

There are no competing interests.

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