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Impact of Bee Pollen Supplementation on Growth Performance, Blood Parameters, Antioxidant Status, And Immune Response in Quail

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تأثير إضافة حبوب لقاح النحل على أداء النمو وبعض صفات الدم وحالة مضادات الأكسدة والاستجابة المناعية في طائر السمان

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Abstract:
The objective of the study was to assess the impact of pollen supplementation (BP) on the growth performance, certain hematological parameters, antioxidant capacity, and immune response of Japanese quail throughout the growth phase (7-42 days). A total of 270 Japanese quail chicks, aged 7 days, were allocated into three experimental groups (90 birds per treatment) with three replicates (30 birds per replicate). The chicks were classified into three treatment groups as follows: T1: received a basal diet devoid of any additives (control), while T2 and T3 were administered a basal diet augmented with 4 g and 8 g of pollen per kg of diet, respectively.
The outcomes of the statistical evaluation revealed that variations in the weight of the quail commenced at 21 days of age and persisted until the conclusion of the study at 42 days. The body weight recorded at the end of the experiment was significantly greater than that of the quails that did not receive bee pollen (control group), and indicated a notable increase in the levels of total protein, albumin, globulin, and glucose in diets containing bee pollen. The findings suggested that the total weight gain of the quails exhibited considerable improvement in the two supplemented treatments following the second week of the experiment, and there were no significant disparities in the coefficients regarding feed consumption rates. Conversely, the impact of supplementation on the cholesterol levels in the quail's blood was pronounced, as there was a decrease observed in the two supplemented treatments; furthermore, a significant reduction in the total lipid levels of the supplemented group was noted in comparison to the control group. Additionally, the results indicated that the diets enriched with bee pollen did not exert a significant influence on the concentrations of the enzymes AST and ALT in the serum. A marked decrease in the concentration of MDA was observed, concluding that the incorporation of bee pollen enhanced the performance, certain hematological parameters, antioxidant status, and immune response of the Japanese quail.

Keywords: pollen, quail, productive performance, antioxidants, immune response.

الملخص:
استهدفت الدراسة تقييم تأثير إضافة حبوب اللقاح (BP) على أداء النمو وبعض صفات الدم وحالة مضادات الأكسدة والاستجابة المناعية لطائر السمان الياباني خلال فترة النمو (7-42) يوماً، تم توزيع (270) من طيور السمان الياباني بعمر 7 أيام على 3 معاملات تجريبية (90/ طائر/ معاملة)، 3 مكررات (30/طائر/مكرر)، تم تقسيم الكتاكيت إلى ثلاث معاملات على النحو التالي:T1 : تمت تغذيته على علف أساسي بدون أي إضافات (السيطرة)، T2، T3 تم تغذيتهم على علف أساسي مكمل ب 4جم و8جم من حبوب اللقاح /كجم من العليقة.
أظهرت نتائج التحليل الإحصائي أن التغيرات في وزن طائر السمان كانت بداية من عمر 21 يوم واستمرت حتى عمر 42 يوماً (نهاية التجربة) وزن الجسم في نهاية التجربة كان أعلى من وزن جسم السمان الذي لم يتغذى على حبوب لقاح النحل

(مجموعة السيطرة) وأظهرت أن مستوى البروتين الكلي والألبومين والجلوبيولين والجلوكوز زاد معنويا في العلائق المحتوية على حبوب لقاح النحل.

وأشارت النتائج أن الزيادة الوزنية الكلية لطيور السمان قد تحسنت معنوياً في معاملتي الإضافة من بعد الأسبوع الثاني للتجربة، ولم يكن هناك فروقات معنوية بين المعاملات في معدل استهلاك العلف. بينما كان تأثير الإضافة على مستوى الكوليسترول يشكل معنوي في دم طائر السمان حيث انخفض في معاملتي الإضافة، كذلك نلاحظ انخفاض معنوي في مستوى الليبيدات الكلية لمجموعة الإضافة مقارنة مع مجموعة السيطرة. ولوحظ ارتفاع نسبة الكالسيوم والفوسفور في المعاملات المضاف إليها حبوب لقاح النحل مقارنة بمجموعة السيطرة، وحيث أظهرت النتائج أيضا أن العلائق المحتوية على حبوب لقاح النحل لم تؤثر معنوياً في مستويات تركيز إنزيمي AST، ALT في مصل الدم، كما أن هناك انخفاض معنوي في تركيز MDA. وخلصت هذه الدراسة إلى أن إضافة حبوب لقاح النحل أدت لتحسين معدل الأداء وبعض صفات الدم ومضادات الأكسدة والاستجابة المناعية لطائر السمان الياباني.

الكلمات المفتاحية: حبوب اللقاح، السمان، الأداء الإنتاجي، مضادات الأكسدة، الاستجابة المناعية.

Introduction

Domestic avian species serve as a significant source for fulfilling the human demand for animal protein and attaining food security within the community, in addition to functioning as a contributor to the national income for the economies of numerous nations, owing to the nutritional benefits derived from birds with a brief productive cycle and high efficiency in nutritional conversion when compared to other livestock species [1]. The quail is recognized as one of the most pivotal alternative sources of animal protein, possessing numerous advantages such as early onset of sexual maturity, compact size, substantial egg production, rapid growth rates, abbreviated incubation periods, minimal feeding requirements, and reduced floor space in contrast to various avian species [2]. Notwithstanding its diminutive stature, the quail is noted for its swift growth and remarkable efficiency in nutritional conversion, achieving a weight of 222 grams at merely six weeks of age [3], and quails exhibit robust immunity along with resistance to numerous poultry diseases [4]. In recent years, a variety of contemporary methodologies have been employed in the breeding of quails, including the incorporation of feed additives, where the utilization of alternative additives, regarded as natural substitutes for antibiotics and occasionally deemed detrimental, has escalated to enhance the immunity and overall performance of the animals. A potential candidate for such additives is bee pollen [5].

Bee pollen constitutes a product derived from bees, created through the amalgamation of flower pollen, which is harvested by worker bees, along with digestive enzymes such as beta-glycosidase [6].
Rich in carbohydrates (13-55%), proteins (10-40%), fatty acids (1-20%), vitamins (0.02-0.10%), minerals (0.5-3%), and flavonoids (0.04-3%) [7], bee pollen serves as a valuable nutritional supplement.

Nevertheless, the composition of nutrients and bioactive compounds present in bee pollen is subject to variation depending on the floral sources accessible, or in other terms, contingent upon the vegetation surrounding the hive [8, 9]. Drawing upon these advantageous attributes, pollen has the potential to enhance nutrient utilization and absorption, thereby facilitating improved productive outcomes in animals, including enhanced weight gain, increased feed consumption, and better feed convertibility in quails [10, 11]. Furthermore, bee pollen may augment egg quality attributable to its abundant concentration of antioxidants, which encompasses flavonoids, carotenoids, and phenolic compounds [12, 13].

Research conducted by [14] has indicated that the supplementation of broiler diets with 1.5% bee pollen significantly promotes the early growth of the small intestine. Moreover, preceding investigations have substantiated that bee pollen bolsters the absorption capacity of the digestive system in broilers by enhancing both the thickness and length of intestinal villi [15]. Additionally, bee pollen has been demonstrated to improve digestive health, safeguard renal function, and diminish blood lipid and creatinine levels in broilers [16].

Material and methods

This research was undertaken in a private barn situated on a farm in the city of Surman during the timeframe from May 21, 2023, to June 27, 2023, spanning a duration of five weeks, with the objective of examining the impact of incorporating bee pollen into the diet. This study seeks to assess the influence of the addition of bee pollen on the productive performance, blood quality, immune response, and antioxidant status of quail. A total of 270 non-naturalized birds, consisting of both white and gray quails, were utilized at the age of one week, with the birds being randomly allocated into three experimental treatments, each comprising three replicates per treatment, at a density of 30 birds per replicate. The caged birds were reared in a controlled environment which adhered to the administrative standards required for quail breeding; electric fans were installed to ensure adequate ventilation, while the lighting regimen consisted of 16 hours of illumination and 8 hours of darkness each day. A balanced diet was provided ad libitum throughout the duration of the experiment. Pollen grains were procured from local markets for incorporation into the diet. The experimental design encompassed three treatments: the first treatment served as the control (without additives), the second treatment consisted of 0.4% bee pollen combined with the basic diet, and the third treatment involved 0.8% bee pollen in conjunction with the basic diet, with the diets

formulated in accordance with the guidelines provided in reference [17]. and **Table (1)** shows the approximate chemical composition of bee pollen.

Table 1: Approximate Chemical Composition of Bee Pollen [12].

Component	Proximate Analysis (%)
Crude Protein	21.8
Crude Fat	5.2
Ash	2.9
Carbohydrates	67.7

Studied qualities:

1- Live body weight: The quails were meticulously weighed at the conclusion of each week, commencing from the initiation of the experiment until the termination of the sixth week, with the measurements being conducted utilizing a precision scale.

2- Weight gain: The weight gain of the avians was determined in accordance with the equation delineated in reference [18].

Weight gain (g) = live body weight at the conclusion of the experiment – live body weight at the commencement of the experiment.

3- Total consumed feed: The quantity of feed allocated at the commencement of the week subtracted by the residual feed at the conclusion of the week.

4- Food conversion factor: This metric elucidates the grams of feed ingested requisite to facilitate a weight gain of grams.

Biochemical components of blood:

At the conclusion of the study, four avians from each replicate were euthanized, blood samples were procured, blood serum was separated, and the levels of total protein, albumin, globulin, glucose, cholesterol, LDL, HDL, and triglycerides were quantified utilizing commercially available analysis kits produced by (Biolabo, France) in accordance with the protocols and directives provided by the manufacturer, employing a spectrophotometer. In alignment with the prescribed wavelength for each analysis, the concentrations were computed utilizing the equations formulated by the producing entity, in addition to the enzymes Alanine Transaminase (ALT) and Aspartate Transaminase (AST) which were evaluated using various pre-prepared analyses developed by Biomerieux, France, following its guidelines. Furthermore, the levels of immunoglobulins IgA and IgG were subjected to analysis. The concentrations of malondialdehyde (MDA) and glutathione (GSH) within the blood were also analyzed.

Statistical analysis:

SPSS version 27 software was used to analyze the data obtained by analysis of variance, and the average of the coefficients was compared by a test [19].

The mathematical model used was $yi = \mu + Ti + Eijk$.

Where Yi=: response; = μ general mean; = Ti effect of the transaction; = Eijk experimental error.

Results and discussion

Production Performance:

1 - Body weight and weight gain:

The findings presented in Table (2) elucidated the impact of incorporating bee pollen on the live weight of quails throughout the duration of the experimental period. It is observed that no significant disparities existed in the initial body weight among the various experimental treatments; furthermore, there were no statistically significant distinctions among the other body weight coefficients at the age of 14 days. However, the results derived from the statistical analysis revealed that there were notable differences ($P \leq 0.05$) in body weight between the addition coefficients (T2, T3) and the control coefficient (T1), commencing from the age of 21 days, where the weights recorded were (97.47, 99.11, 92.14) g respectively. Moreover, it is noteworthy that no statistically significant differences were detected between the two addition coefficients, as the variations observed were merely numerical. Table 2 further indicates that both addition coefficients exhibited a statistically significant superiority over the control treatment ($P \leq 0.05$) in terms of live body weight at both the age of 28 days and the age of 35 days, which persisted until the age of 42 days (the conclusion of the experiment), where the final live body weights were recorded as (208.88, 222.14, 235.15 g for the control treatment (T1) and the two addition coefficients (T2 and T3), respectively. The outcomes of this study align with the assertions made by [20, 21], who demonstrated a significant influence on body weight and weight gain in quails nourished with a diet enriched with bee pollen. Furthermore, this is consistent with the observations made by [22], who underscored the physiological role of bee pollen when incorporated into broiler feed, noting that the body weight at the conclusion of the feeding period

was superior to that of chickens which were not administered bee pollen. Additionally, it concurs with [10], who assessed the effects of bee pollen grains on the Japanese quail birds and their growth rate, where the findings indicated that the inclusion of bee pollen as a feed additive at a concentration of 5 g/kg diet is advantageous in enhancing the performance of quail trays.

Table 2: Effect of Bee Pollen on Live Body Weight of Japanese Quail (g/bird/week).

Age (days)	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
Initial (7 days)	29.25 ± 0.04a	30.14 ± 0.03a	30.29 ± 0.06a	0.086
14	63.68 ± 1.03a	65.98 ± 1.02a	66.90 ± 1.05a	0.072
21	92.14 ± 1.26b	97.47 ± 1.42a	99.11 ± 1.60a	0.043
28	138.70 ± 2.14b	146.11 ± 2.02a	153.60 ± 2.45a	0.024
35	176.11 ± 2.67b	188.16 ± 2.46a	200.15 ± 2.64a	0.0001
Final (42 days)	208.88 ± 2.80c	222.14 ± 2.77b	235.15 ± 2.89a	0.0001

(Means followed by different letters in the same row indicate significant differences P≤0.05).

The outcomes delineated in Table (3) elucidated the influence of incorporating pollen grains on the weight augmentation of quail, as they signified the absence of noteworthy discrepancies between the two addition treatments in comparison to the control treatment. Conversely, the findings from the statistical analysis revealed that there exist significant differences (P≤0.05) between the two addition coefficients (T2), (T3), and the control coefficient (T1) commencing from the second week of the experiment, wherein the weight gains recorded were (31.49, 32.21, 28.46) g respectively. Furthermore, it was observed that no significant differences were evident between the two addition coefficients; however, a noteworthy superiority (P≤0.05) for the addition treatment (T3) was observed in comparison to the addition treatment (T2) as well as in relation to the control treatment during the third and fourth weeks of the experiment, and the results derived from the statistical analysis indicated that statistically significant differences (P≤0.05) existed between the addition and control coefficients during the fifth week of the experiment, where the weight gains attained were (35.98, 35.00, 32.77) g respectively. Additionally, it is noteworthy that the overall weight increment of quail birds has significantly improved in the addition coefficients in contrast to the control treatment, reaching values of (195.00, 204.86, 179.63) g respectively, and the findings of this investigation concurred with the results presented in [23], which reported a continuous weight gain when beef chickens were fed with bee pollen over a duration of six weeks, with the enhanced body weight gain attributed to the nutritional profile of pollen as a rich source of proteins, amino acids, lipids, vitamins, unsaturated fatty acids, carbohydrates, and minerals including sodium, calcium, phosphorus, zinc, manganese, iron, and copper, in addition to flavonoids, accompanied by various phenolic compounds and other compounds such as antibiotics [9]. This is further substantiated by the results obtained from the addition of bee pollen and its beneficial effects on the intestinal structure, as it resulted in an increase in both the length and width of the villi, which subsequently augmented the percentage of intestinal nutrient absorption, thereby contributing to an increase in the body weight of the birds, and this aligns with another investigation conducted by [24], which asserted that the incorporation of bee pollen at concentrations of 1% or 2% into the quail diet yielded favorable outcomes on weight gain and performance rates, attributable to the high nutritional value of bee pollen, which serves as a source of lipids, unsaturated fatty acids, proteins, essential amino acids, minerals, and carbohydrates.

Table 3: Effect of Bee Pollen on Weight Gain of Japanese Quail (g/bird/week).

Age (days)	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
7–14	34.43 ± 0.34a	35.84 ± 0.45a	36.61 ± 0.63a	0.089
14–21	28.46 ± 0.29b	31.49 ± 0.32a	32.21 ± 0.54a	0.045
21–28	46.56 ± 0.62b	48.64 ± 0.36b	54.49 ± 0.41a	0.0001
28–35	37.41 ± 0.32b	42.05 ± 0.37b	46.55 ± 0.28a	0.0001
35–42	32.77 ± 0.26b	35.98 ± 0.42a	35.00 ± 0.48a	0.031
Total (7–42)	179.63 ± 2.58c	195.00 ± 2.68b	204.86 ± 3.42a	0.0001

(Means followed by different letters in the same row indicate significant differences P≤0.05).

2- The amount of feed consumed and the efficiency of food conversion:

The findings of the present investigation, as delineated in Table (4), elucidate the impact of incorporating bee pollen on the feed consumption rate, wherein it was observed that no statistically significant discrepancies existed in the rate of feed consumption between the treatments with the addition of bee pollen and the control treatments. Furthermore, there were no statistically significant differences discernible among the various addition coefficients concerning the overall feed consumption rate at the conclusion of the experiment for the experimental coefficients (T1, T2, T3) which were recorded as (542.95, 544.96, 550.85) g respectively.

The outcomes of this investigation align with the assertions made by [25], who noted the absence of differences among the groups regarding the quantity of feed consumed when bee pollen was added at concentrations of 500, 1000, and 1500 mg/kg feed. Similar conclusions were reached by [20, 5, and 25], who indicated that the incorporation of bee pollen into the quail diet did not influence the amount of feed consumed. However, numerous studies that contradict the findings of this research, such as [24, 26, and 27], reported a decrease in feed intake when elevated levels of pollen (10 g/kg) were introduced into the diet, which was attributed to the reduced palatability of the pollen.

Moreover, this contradicts the observations of [20], who documented that the addition of pollen at a rate of 20 g/kg to broiler diets resulted in a reduction in feed intake (FI), while [30] demonstrated that the incorporation of bee pollen at a rate of 2 g/kg feed resulted in an increase in the quantity of feed consumed.

Table 4: Effect of Bee Pollen on Feed Intake of Japanese Quail (g/bird/week)

Age (days)	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
7–14	85.68 ± 1.35a	84.92 ± 1.32a	86.13 ± 1.21a	0.0876
14–21	95.92 ± 1.12a	96.13 ± 1.45a	97.11 ± 1.32a	0.0956
21–28	105.16 ± 1.45a	106.32 ± 1.34a	107.15 ± 1.47a	0.0934
28–35	118.35 ± 1.54a	117.43 ± 1.56a	118.15 ± 1.75a	0.0879
35–42	138.16 ± 1.78a	140.16 ± 1.88a	142.31 ± 1.84a	0.0768
Total (7–42)	542.95 ± 1.89a	544.96 ± 1.97a	550.85 ± 1.90a	0.0798

(Means followed by different letters in the same row indicate significant differences P≤0.05).

Table (5) delineates the impact of incorporating bee pollen on the efficacy of nutritional conversion in the Japanese quail, wherein a notable enhancement (P≤0.05) in food conversion efficiency is observed as a consequence of the addition of bee pollen, which was recorded during the initial week of the experiment (2.48, 2.36, 2.35) g for the control treatment and the addition coefficients (T2, T3), respectively. Furthermore, there were no statistically significant variations between the two addition coefficients, and the influence of introducing pollen grains exhibited a marked improvement in food conversion efficiency (P≤0.05) throughout all experimental periods. At the conclusion of the experiment, the nutritional conversion efficiency was quantified at (3.02, 2.79, 2.86) for the control treatment and the addition coefficients at concentrations of 0.4% and 0.8%, correspondingly. The findings of this investigation align with the observations made by [28], who affirmed that the incorporation of bee pollen into the avian diet resulted in an enhancement of the feed's nutritional conversion efficiency, as corroborated by [10, 29], who indicated that bee pollen is abundant in advantageous nutrients, thereby facilitating improved absorption and digestion of nutrients, which in turn leads to enhanced productivity and performance outcomes, such as weight gain, feed intake, and an elevated nutritional conversion rate in quail.

Table 5: Effect of Bee Pollen on Feed Conversion Ratio (FCR) of Japanese quail (g feed/g gain)

Age (days)	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
7–14	2.48 ± 0.14a	2.36 ± 0.22b	2.35 ± 0.11b	0.045
14–21	3.35 ± 0.22a	3.05 ± 0.11b	3.01 ± 0.13b	0.035
21–28	2.25 ± 0.12a	2.18 ± 0.24b	1.96 ± 0.21c	0.034
28–35	3.16 ± 0.14a	2.79 ± 0.15b	2.53 ± 0.14c	0.022
35–42	4.21 ± 0.23a	3.89 ± 0.13c	4.06 ± 0.15b	0.023
Total (7–42)	3.02 ± 0.12a	2.79 ± 0.17b	2.86 ± 0.11b	0.001

(Means followed by different letters in the same row indicate significant differences P≤0.05).

Blood Components:

The findings presented in Table (6) elucidated the impact of the incorporation of pollen on various blood biometric indicators associated with chemotherapy in Japanese quail.

The findings indicated that the concentrations of total protein, albumin, and globulin exhibited a significant increase (P≤0.05) in the diets augmented with bee pollen when juxtaposed with the control cohort. These findings are in concordance with [24], who documented an elevation in the levels of total proteins and albumin in chicks that were administered diets inclusive of 0.6% bee pollen. This phenomenon may be attributed to the substantial protein concentration of 22.7% and the presence of essential amino acids prevalent in bee pollen. Additionally, [30] concurs with [31], who asserted that the introduction of bee pollen at a ratio of 0.5% in quail feed resulted in an elevation of both total protein and albumin levels in the avian subjects' blood. This observation is further corroborated by [32], where an increase in serum total protein was noted upon the incorporation of pollen in the diet of broiler chickens. However, these findings stand in contrast to those reported by [33], as their results demonstrated no noteworthy differences in total protein and globulin levels among the treatment groups in the

blood of laying hens. This suggests an enhancement of renal and hepatic functions, which may be reflected in the well-balanced and antioxidant nutritional attributes of bee pollen, as proposed by [34].

Table 6: Effect of Bee Pollen on Biochemical Blood Parameters of Japanese quail.

Parameter	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
Total Protein (g/dl)	4.27 ± 0.2c	4.65 ± 0.3b	4.80 ± 0.2a	0.037
Albumin (g/dl)	1.43 ± 0.06b	1.68 ± 0.05a	1.70 ± 0.07a	0.025
Globulin (g/dl)	2.84 ± 0.05b	3.07 ± 0.04a	3.10 ± 0.03a	0.031
Glucose (mg/dl)	274 ± 6.5b	286 ± 5.7a	290 ± 6.1a	0.001
Cholesterol (mg/dl)	213 ± 6.4a	196 ± 6.7b	179 ± 5.8c	0.001
Total Lipids (mg/dl)	631 ± 15a	348.8 ± 13b	267.4 ± 6.0c	0.001
AST (U/L)	98.2±2.5a	97.2±1.6a	97.8±1.78a	0.001
ALT (IU/L)	12.48±0.5a	12.28±0.65	11.5±0.45a	0.001

(Means followed by different letters in the same row indicate significant differences P≤0.05).

Table (6) also shows the effect of adding bee pollen on the level of glucose in the blood, where it is clear that the addition has a significant effect P≤0.05)) on increasing the level of glucose, where the addition groups outperformed compared to the control group, where the level of glucose (274, 286, 290) for each of the control group and the two addition coefficients 4%, 8%, respectively.

Table (6) also elucidates the impact of supplementation on the cholesterol levels in the blood of quail, where a notable superiority of the supplementation coefficients is observed in comparison to the control treatment; specifically, the cholesterol levels in both supplementation coefficients exhibited a decline, alongside the existence of a statistically significant superiority (P≤0.05) for the supplementation treatment at 8% relative to the supplementation treatment at 4% [5, 25, and 35]. Furthermore, a significant reduction (P≤0.05) in the total lipid levels of the supplementation group, as opposed to the control group, is noted, and these findings align with the assertions made by [36, 32], who indicated that bee pollen possesses the capability to diminish blood lipid levels, potentially attributed to its saponin content which impedes intestinal cholesterol absorption and subsequently reduces blood cholesterol levels [37]. Moreover, the enhancements in lipid profiles resulting from the incorporation of pollen are correlated with the activation and increased expression of activated peroxisomes. Table (6) further delineates the influence of the addition of bee pollen grains on the enzymatic activities of AST and ALT in the blood of quail birds, where significant differences (P≤0.05) in the levels of AST and ALT are observed, reflecting a marked decline in the blood of birds that were administered pollen in comparison to the control group; these outcomes are consistent with the findings of [24], who reported a significant reduction in AST and ALT levels in chicks that were fed a feed containing pollen grains at concentrations of 0.2%, 0.4%, and 0.6% in relation to the control group [38]. In light of this, various natural extracts and honey bee products, such as pollen, have been employed in the treatment of hepatic disorders in laboratory animals [39], wherein pollen has been demonstrated to encompass numerous phenolic compounds that confer protective effects on the liver; this may be attributable to the protective attributes of supplementation on hepatic function in the context of the presence of phenolic compounds, as well as antioxidant and lipid-inhibitory effects [40]. The levels of the enzymes AST and ALT in plasma diminished with the addition of bee pollen, given that the liver harbors these enzymes, which are released into the bloodstream upon infection; consequently, the significant differences (P≤0.05) observed among the coefficients. The levels of the enzymes AST and ALT in plasma decreased with the addition of bee pollen, given that the liver contains these enzymes, which are released into the blood during infection; therefore, the significant differences (P≤0.05) concerning the parameters measuring AST and ALT levels in this study reflect the normal hepatic function among the groups of birds consuming diets inclusive of bee pollen, thereby indicating that these additives possess attributes that may enhance hepatic health. The results presented in **Table 7** illustrate the impact of bee pollen supplementation on the levels of IgA and IgG in 42-day-old quails. This study analyzed the levels of IgA and IgG, revealing significant differences (P≤0.05) between the two supplementation groups and the control group. Specifically, the level of IgA increased in response to the addition of bee pollen grains in both the T2 and T3 groups. In contrast, the effect on IgG levels was less pronounced; however, a notable increase in IgG was observed when bee pollen was incorporated at 8 g/kg of feed compared to 4 g/kg .

These findings align with those reported by [33], who noted that adding bee pollen significantly influenced IgA and IgG levels in male rabbits. It is important to consider species differences when comparing these results. Furthermore, [41] indicated that the sugars in bee pollen could enhance the production of T lymphocytes, leading to improved antibody levels against viruses and bacteria. Additionally, [14] reported that bee pollen is rich in nutrients that promote the differentiation and proliferation of immune cells, thereby stimulating immune responses.

Table 7: Effect of Bee pollen on IgA and IgG in Japanese quail.

Parameter	T1 (Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
IgA	7.4 ± 0.62b	10.9 ± 0.75a	11.6 ± 0.777a	0.0001
IgG	30.2 ± 1.30c	31.9 ± 1.26b	35.2 ± 1.35a	0.0001

(Means followed by different letters in the same row indicate significant differences P≤0.05).

Antioxidants:

The outcomes delineated in Table 8 elucidated the implications of incorporating pollen into the diet on the levels of malondialdehyde (MDA) and glutathione (GSH) within quail serum. The investigation established that the inclusion of bee pollen markedly elevated the concentration of glutathione in the blood serum ($P \leq 0.05$) while concurrently diminishing the concentration of malondialdehyde in comparison to the control group. This incorporation enhanced the antioxidant capacity of the quails.

These results are in concordance with the findings of [42], which validated that bee pollen diminishes malondialdehyde levels and lipid peroxidation within blood serum. Moreover, the outcomes are consistent with [43] and corroborate the research conducted by [44], which indicated that the administration of varying levels of bee products (such as propolis and bee pollen) to Japanese quails led to a reduction in malondialdehyde levels and an elevation in glutathione levels.

These findings imply that bee pollen encompasses potent antioxidants, particularly phenolic compounds, which contribute to its robust antioxidant properties. Bee pollen is acknowledged as a natural antioxidant attributable to its abundant composition of biological constituents, including polyphenolic compounds and phenolic acid derivatives. These compounds manifest a spectrum of biological effects, encompassing antioxidant, anti-inflammatory, and anti-cancer properties [45].

Table 8: Effect of Bee Pollen on Antioxidant Status in Japanese quail.

Parameter	T1(Control)	T2 (4 g/kg)	T3 (8 g/kg)	*P*-value
MDA (µmol/L)	23.24 ± 0.58a	21.44 ± 0.78b	20.25 ± 0.74b	0.0001
GSH (µmol/L)	10.05 ± 0.34c	12.95 ± 0.24b	13.7 ± 0.36a	0.0001

*(*Means followed by different letters in the same row indicate significant differences P≤0.05).

Conclusion

This investigation elucidated that the incorporation of bee pollen into the diet significantly augmented growth performance, blood biochemical parameters, antioxidant status, and immune response in Japanese quails. The principal findings are as follows:

Growth Performance: The supplementation of bee pollen exerted a beneficial effect on body weight and weight gain, particularly notable from the second week of the experiment, while not exerting a significant influence on feed intake. Blood Lipid Profile: The inclusion of bee pollen was associated with a significant reduction in cholesterol and total lipid concentrations in the blood. Antioxidant Status: The antioxidant capacity exhibited improvement, as evidenced by elevated levels of glutathione (GSH) and diminished concentrations of malondialdehyde (MDA). Immune Response: The immune response demonstrated enhancement, as indicated by increased levels of IgA and IgG in the blood.

In conclusion, the incorporation of bee pollen into quail diets at concentrations of 4 g/kg and 8 g/kg resulted in improved overall health and productivity, thereby underscoring its potential as a natural feed additive to bolster poultry production.

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