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Impact of date palm (*Phoenix dactylifera*) pollen supplementation on growth performance, carcass traits, cecal microbial composition, and blood parameters in Japanese quail (*Coturnix coturnix Japonica*)☆

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ABSTRACT

This study aimed to evaluate the effects of date palm pollen (DPP) supplementation in the diet of Japanese quail on growth performance, carcass characteristics, blood biomarkers, and intestinal bacterial load. A total of 360 unsexed one-day-old Japanese quail chicks were randomly assigned to four experimental groups using a completely randomized design. Each group was further subdivided into three replicates, each consisting of 30 chicks. In the experiment, the first group was given control (basal diet); the second group was given the same basal diet plus 3 g/kg of DPP; the third group was given the same basal diet plus 5 g/kg of DPP; and the fourth group was given the same basal diet plus 7 g/kg of DPP. The results revealed significant differences between treatments, with DPP supplementation leading to increased body weight (BW) and body weight gain (BWG) during the initial weeks ($P < 0.05$), and these differences became more pronounced ($P < 0.01$) in the later stages of the study. Additionally, the DPP-treated groups demonstrated lower feed intake (FI) and improved feed conversion ratio (FCR) than the control group. Supplementation with DPP significantly ($P < 0.05$) influenced carcass, liver, spleen, thymus, and bursa percentage. The addition of DPP to the quail diet significantly impacted ($P < 0.01$) all hematological parameters, except for red blood cell concentration. Biochemical analysis showed a significant increase ($P < 0.01$) in total protein, albumin, globulin, and high-density lipoprotein (HDL) levels in the DPP groups. In contrast, alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea, creatinine, cholesterol, triglycerides, and low-density lipoprotein (LDL) levels were significantly reduced ($P < 0.01$). DPP supplementation had a significant impact on antioxidant enzyme activities, with the 5 g/kg and 7 g/kg DPP groups showing significant increases ($P < 0.01$) in total antioxidant capacity (TAC), superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) levels. Furthermore, malondialdehyde (MDA) and nitric oxide (NO) concentrations were significantly reduced ($P < 0.01$). According to microbiological tests, the DPP-treated groups had reduced *Escherichia coli* and *Staphylococcus aureus* levels. In summary, adding DPP to the diet of Japanese quail enhances their gut microbiota composition, growth performance, carcass characteristics, and biochemical markers.

☆ **Section/Category: Management and Production**

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Introduction

The growing global population and rising levels of wealth are amplifying the demand for animal protein. With the global population expected to exceed 10 billion by 2050, there is an urgent need for effective and environmentally sustainable production methods (Bist et al., 2024). Poultry products, particularly those derived from Japanese quail, are a crucial source of animal protein (Abd El-Hack et al., 2024; Mohamed et al., 2024). These birds have become increasingly important in various sectors due to their economic efficiency, rapid production cycle, and significant nutritional value (Egila et al., 2023; Abou-Kassem et al., 2024; Ashour et al., 2024). Traditional poultry farming practices face growing ecological and economic challenges as chicken production continues to expand, necessitating improvements in broiler growth, health, and environmental sustainability to meet consumer demand for healthier and more natural products (El-Ratel et al., 2024; Kleyn and Ciacciariello, 2025). The widespread use of conventional feed additives, such as antibiotics, to enhance chicken growth and efficiency has contributed to developing antibiotic-resistant bacteria, posing significant public health risks. This situation has prompted the exploration of safe, natural alternatives (Okaiyeto et al., 2024; Ashour et al., 2025a).

Using herbs and plants as alternatives to antibiotics for improving efficiency and immune function in poultry has been widely recommended (Cimrin et al., 2020; Ashour et al., 2025b; Farag et al., 2024). Certain bioactive compounds found in phytogenic feed additives have been shown to enhance animal health, improve feed quality, and elevate the quality of animal-derived products (Kamal et al., 2023a; Ashour et al., 2025a). A prominent phytogenic feed additive is date palm (*Phoenix dactylifera*) pollen (DPP), a member of the Arecaceae family. The date palm is extensively cultivated in North Africa and the Middle East (Ashour et al., 2022). DPP has demonstrated potent antibacterial, antifungal, antiparasitic, antiviral, and antioxidant properties, as well as anti-apoptotic and hepatoprotective effects (Refaie et al., 2019; Laghouati et al., 2021). Additionally, DPP contains various bioactive compounds, including fatty acids, amino acids, sterols, saponins, flavonoids, volatile unsaturated fatty acids, vitamins, polyphenolic components, and minerals (Abdel-Shaheed et al., 2021; Saleh et al., 2021).

Incorporating DPP into the diet has been shown to enhance appetite, boost immune function, increase vitality, improve feed conversion ratio, and elevate final body weight, humoral immunity, and hematological parameters (Rafaei et al., 2019). Date palm pollen has also improved fertility rates in male rabbits (Al-Samri et al., 2017). Moreover, Tomaszewska et al. (2020) observed that Japanese quails fed a diet supplemented with 1.0 % pollen exhibited reduced mineralization, length, weight, and wall thickness of bone. In a study by Al-Taie and Shanoon (2023), supplementation with Egyptian DPP in broiler chicks increased glutathione (GSH) levels and reduced malondialdehyde (MDA) levels. It lowered Escherichia coli bacteria counts while Lactobacillus levels increased. Additionally, Saleh et al. (2021) reported that DPP supplementation in laying hen diets increased white blood cell count and decreased the heterophil-to-lymphocyte (H/L) ratio.

The present study aimed to investigate the beneficial effects of dietary DPP supplementation on performance, carcass characteristics, cecal microbiota composition, and blood parameters in Japanese quails.

Materials and methods

The present investigation was conducted on a private chicken farm under the supervision of the Department of Animal Production, Faculty of Agriculture, Tanta University, Egypt. This study adhered to the ethical guidelines of scientific research (No. AY2019-2020/Session 6/2020.01.13) approved by Tanta University, Egypt.

experimental design, birds, and diets

A total of 360 unsexed one-day-old Japanese quail chicks were randomly allocated into four experimental treatments, each consisting of 90 chicks, with each treatment subdivided into three replicates of 30 chicks. The chicks were housed in floor pens with wood shavings as bedding. The building was closed, with no windows and no run. Each replicate (30 birds) was housed in a wire cage (50 × 100 × 110 cm). The experimental period lasted until the birds reached 6 weeks of age, with a lighting regime of 23 hours of light and 1 hour of darkness. The birds were exposed to White LED light at 20 lux. The temperature was maintained at approximately 32 ± 1 °C for the first 3 days, then gradually decreased by 1°C every 3 days until reaching 24 ± 1 °C, which was maintained for the remainder of the study. Throughout the experimental period, relative humidity ranged between 56-62 %. The birds had ad libitum access to mash feed and water throughout the experimental period. Managerial and hygienic conditions were standardized for all experimental groups. The chicks were fed a grower diet from 1 to 42 days of age. As indicated in Table 1, the basal diet was formulated to satisfy the nutritional guidelines suggested by the NRC, 1994 for growing Japanese quail. The control group received the basal diet, while treatments 1–3 (T1–T3) were supplemented with DPP at 3, 5, and 7 g/kg of the basal diet, respectively.

Growth efficiency

The birds were weighed individually each week, and body weight (BW) was recorded by an electronic balance scale (Johnson, 0.01g calibrated) to assess body weight to the nearest 0.1g. Body weight gain (BWG) was calculated weekly from 1 to 42 days of age. This process was conducted consistently at the same time each week. BWG was calculated by subtracting the initial BW at the start of each period from the final BW at the end. Feed intake (FI) was determined by subtracting the remaining feed from the amount supplied. The feed conversion ratio (FCR) was calculated as the grams of feed consumed per unit of body weight gain. Mortality and health status were monitored daily, and mortality percentages were recorded for each replicate during the experimental period.

Table 1
Ingredients and chemical composition of the experimental basal diets fed during the experiment stages.

Ingredients	Starter and grower diet (1–42 days)
Yellow corn	55.40
Soybean meal (44 %)	30.40
Corn gluten meal (62 %)	9.10
Wheat bran	2.30
Limestone	1.0
Dicalcium phosphate	1.10
NaCl	0.30
Premix*	0.30
L. Lysine	0.10
Total	100.0
Calculated Composition	
Crude protein (%)	24.09
Metabolizable Energy (Kcal/Kg)	2902.24
Ether extract (%)	2.65
Crude fiber (%)	3.72
Calcium (%)	0.72
Available phosphorus (%)	0.35
Methionine (%)	0.43
Lysine (%)	1.17

* Premix. Each Kg of premix contains Vitamin A, 130,000 IU; Vitamin D3, 26,000 IU; Vitamin E, 120 IU; Vitamin B12,150 µg; Vitamin K3, 16 mg; Vitamin B2, 50 mg; Vitamin B3, 120 mg; nicotinic acid, 250 mg; Thiamine, 25 mg; folic acid, 15 mg; Vitamin B6, 15 mg; Betain-Choline-, 5000 mg; manganese, 70 mg; zinc, 60 mg; iron, 40 mg; copper, 40 mg; Iodine, 7 mg; cobalt, 2 mg; selenium, 1.5 mg; and Zinc bacitracin, 150 mg.

Carcass traits

At 42 days of age, six birds (3 males and 3 females) from each group were randomly selected, weighed, slaughtered, and then scalded and defeathered. The carcasses were manually eviscerated and weighed. The liver, gizzard, heart, spleen, thymus, and bursa were separated and weighed individually. All organ weights were expressed as percentages of live body weight.

Blood indicators

At 42 days of age, blood samples were collected from the wing veins of six birds from each treatment immediately before slaughter. Blood was drawn into two distinct tubes. White blood cell (WBC) counts were measured in fresh blood samples using an NIHON KOHDEN automated hematology analyzer. A preliminary sample was collected in a heparinized tube for hematological analysis, which included measurements of red blood cells, hemoglobin (Hb), and packed Cell Volume (PCV). The mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were calculated according to the formulas of Harvey (2011). A second sample was collected into a non-heparinized tube for serum separation and centrifuged at 3,000 rpm for 15 minutes. The serum was analyzed for total protein, albumin, triglycerides, total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), creatinine, and uric acid levels, as well as for liver enzyme activity, specifically alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels, according to the methods of Young and Friedman (2001). The difference between serum total protein and albumin calculated serum globulin. In addition to traditional biological indicators, oxidative stress markers were assessed to evaluate the effects of dietary supplements on the antioxidant system. Total oxidant capacity (TAC) was measured using a spectrophotometer (Hitachi spectrophotometer, Tokyo, Japan) and a commercial kit (Randox Labs, Crumlin, UK), as described by Erel (2004). The activities of antioxidant enzymes, including glutathione peroxidase (GPx), superoxide dismutase (SOD), and catalase (CAT), were evaluated according to Wang et al. (2011). Oxidative stress indicators, including serum malondialdehyde (MDA) and nitric oxide (NO), were assessed following the protocols outlined by Wang et al. (2011) and Miranda et al. (2001), respectively.

Microbiological analyses

After 42 days, cecal contents were collected from six birds per treatment, placed in sterile plastic tubes, and stored at -20 °C for microbiological testing. Standardized microbiological methods outlined by Sheiha et al. (2020) were used to detect *E. coli*, Salmonella spp., and Staphylococcus spp. Microbial colonies were counted using a colony counter (Scan 300, Interscience, France). Microbial counts were expressed as colony-forming units per gram of cecal contents (CFU/g).

Statistical analysis

Data were statistically analyzed by one-way ANOVA, utilizing the general linear model procedure (SAS, 2003). Tests of sustainability for differences between treatments were done according to the Duncan test. The statistical model was utilized for the analysis of variation to evaluate the influence of different amounts of DPP as follows:

$$Y_{ij} = U + T_i + e_{ij}$$

where Y_{ij}, observation; μ, observed mean; T_i, effect of treatments; e_{ij}, experimental random error.

Results

Growth performance

Data presented in Table 2 illustrate the effects of date palm pollen (DPP) supplementation in the feed of Japanese quails on body weight (BW) and body weight gain (BWG). Significant differences were observed between the diets for BW and BWG across most experimental periods. At weeks 1, 3, and 4, including DPP, resulted in statistically significant changes in BW ($P < 0.05$). At weeks 5 and 6, the changes became even more pronounced ($P < 0.01$). During this period, quails receiving 7 g/kg of DPP demonstrated a substantial improvement in BWG compared to other treatments. These findings suggest that DPP positively influences growth efficiency in Japanese quails. During the experimental period, no mortality was registered in all treatments. Therefore, results were not tabulated.

Feed conversion ratio

The addition of DPP to the feed significantly affected both feed intake (FI) throughout the experimental periods and feed conversion ratio (FCR) during the experimental periods, except for the interval periods from 1-2, 3-4, and 4-5 weeks of age, as shown in Table 3. Throughout the whole experimental period (0-6 weeks of age), birds fed a 7g DPP /Kg diet had significantly ($P \leq 0.01$) the lowest FI (12.39 °C%) and a better FCR (20.06 %) compared to the control birds. Notably, the DPP-supplemented groups exhibited the lowest FI and the most efficient FCR compared to the control group. This indicates that incorporating DPP into quail diets can enhance feed efficiency.

Carcass characteristics

The effects of DPP supplementation on carcass traits are summarized in Table 4. Supplementing the diet with DPP significantly influenced several carcass characteristics, including carcass, liver, spleen, thymus, and bursa percentage ($P < 0.05$), except the gizzard and heart percentage. Specifically, the relative weights of the carcass, liver, and spleen were significantly higher ($P < 0.05$) in the 5 and 7 g/kg DPP treatments compared to the other groups. Additionally, the relative weights of the thymus and bursa were significantly increased ($P < 0.01$) in the 5 and 7 g/kg DPP treatments.

Blood parameters

As shown in Table 5, adding DPP to the quail diet significantly impacted ($P < 0.01$) all hematological parameters, except for red blood cell concentration. Generally, the values for hemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were numerically higher in the groups receiving DPP. Conversely, the white blood cell (WBCs) counts insignificantly decreased by DPP supplementation in diets at 5 and 7 g/kg.

The varying levels of DPP in the diet also had a significant effect ($P < 0.01$) on all biochemical blood parameters (Table 6). Birds fed diets containing 5 and 7 g/kg of DPP had higher total protein (TP), albumin, globulin, and HDL levels than the control group. Moreover, quails fed DPP-enriched diets displayed significantly lower levels of AST, uric acid, triglycerides (TG), and LDL than those fed the control diet. A significant decrease in ALT, creatinine, and total cholesterol (TC) values of quails received diets supplemented with DPP at 5 and 7 g/kg occurred, with an insignificant decrease at the level of 3 g DPP per kg diet as versus control group.

Table 2
The effect of different levels of date palm pollen on the average weekly live body weight and feed intake of Japanese quails.

Items	weeks	Control	Treatments (DPP g/kg diet)			Significance	*P value*
			3 g	5 g	7 g		
BW (g)	0	9.09 ± 0.19	9.12 ± 0.14	9.08 ± 0.12	9.01 ± 0.15	NS	0.856
	1	31.32 ± 0.1[b]	34.45 ± 0.88[ab]	34.38 ± 0.41[ab]	37.48 ± 1.96[a]	*	0.021
	2	73.67 ± 0.71	78.73 ± 0.35	79.93 ± 0.75	80.27 ± 0.83	NS	0.641
	3	114.23 ± 0.57[b]	118.73 ± 0.80[b]	120.77 ± 0.64[ab]	127.23 ± 0.41[a]	*	0.025
	4	174.37 ± 0.07[c]	177.87 ± 0.44[bc]	184.47 ± 0.6[ab]	187.77 ± 0.14[a]	*	0.035
	5	220.60 ± 0.70[c]	224.27 ± 0.62[bc]	228.53 ± 0.82[b]	236.07 ± 0.40[a]	**	0.050
	6	255.72 ± 0.6[d]	263.63 ± 0.63[c]	271.17±0.74[b]	279.43 ± 0.16[a]	**	0.030
BWG (g/day)	0-1	22.23 ± 0.07[b]	25.33 ± 0.84[ab]	25.3 ± 0.38[ab]	28.47 ± 1.81[a]	*	0.031
	1-2	42.35 ± 1.59	44.28 ± 0.87	45.55 ± 0.94	42.79 ± 1.04	NS	0.569
	2-3	40.56 ± 1.51[b]	40.00 ± 0.57[b]	40.84 ± 0.94[b]	46.96 ± 0.25[a]	*	0.041
	3-4	60.14 ± 1.15[b]	59.14 ± 0.69[b]	63.70 ± 2.37[a]	60.54 ± 0.86[ab]	*	0.032
	4-5	46.23 ± 1.01[ab]	46.40±1.15[ab]	44.06 ± 0.51[b]	48.30 ± 0.75[a]	*	0.021
	5-6	35.12 ± 1.32[b]	42.70 ± 0.86[a]	42.64 ± 0.46[a]	43.36 ± 0.98[a]	**	0.015
	0-6	246.63 ± 1.44[d]	254.51 ± 0.86[c]	262.09 ± 1.32[b]	270.42 ± 0.98[a]	**	0.011

DPP, date palm pollen; BW, body weight; BWG, body weight gain.
[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.05$, or $P \leq 0.01$).
[*] Indicate $P < 0.05$;
[**] indicate $P < 0.01$; NS, indicate not significant.

Table 3
Effect of different levels of date palm pollen on the average weekly feed intake and feed conversion ratio of Japanese quails.

Items	weeks	Control	Treatments (DPP g/kg diet)			Significance	*P value*
			3 g	5 g	7 g		
FI (g)	0-1	36.00 ± 2.31[a]	31.10 ± 0.52[ab]	30.20 ± 1.73[b]	29.10 ± 1.33[b]	*	0.021
	1-2	91.01 ± 1.79[a]	87.30 ± 0.75[a]	81.10 ± 1.85[b]	74.10 ± 1.44[c]	**	0.002
	2-3	109.00 ± 0.52[a]	106.00 ± 0.87[a]	106.20 ± 1.62[a]	102.20 ± 0.81[b]	*	0.041
	3-4	157.04 ± 0.87[a]	149.20 ± 2.02[b]	141.14 ± 2.08[c]	136.00 ± 1.96[c]	**	0.002
	4-5	180.05 ± 1.21[a]	165.20 ± 1.96[b]	154.63 ± 0.69[c]	158.10 ± 2.21[c]	**	0.001
	5-6	189.02 ± 0.92[a]	179.10 ± 1.56[b]	171.02 ± 0.80[c]	168.20 ± 1.39[c]	**	0.002
	0-6	762.12 ± 2.02[a]	717.90 ± 1.62[b]	684.29 ± 1.67[c]	667.70 ± 2.37[d]	**	0.002
FCR	0-1	1.62 ± 0.18[a]	1.23 ± 0.17[ab]	1.19 ± 0.03[ab]	1.02 ± 0.05[b]	*	0.032
(g feed/ g gain)	1-2	2.15 ± 0.17	1.97 ± 0.05	1.78 ± 0.12	1.73 ± 0.23	NS	0.665
	2-3	2.69 ± 0.03[a]	2.65 ± 0.03[a]	2.60 ± 0.07[a]	2.17 ± 0.09[b]	**	0.005
	3-4	2.61 ± 0.17	2.52 ± 0.12	2.22 ± 0.13	2.25 ± 0.13	NS	0.665
	4-5	3.89 ± 0.29	3.56 ± 0.25	3.51 ± 0.17	3.27 ± 0.13	NS	0.454
	5-6	5.38 ± 0.17[a]	4.19 ± 0.03[b]	4.01 ± 0.04[b]	3.88 ± 0.02[b]	**	0.002
	0-6	3.09 ± 0.12[a]	2.82 ± 0.04[ab]	2.61 ± 0.17[ab]	2.47 ± 0.23[b]	*	0.043

DPP, date palm pollen; FI, feed intake; FCR, feed conversion ratio.
[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.05$, or $P \leq 0.01$).
[*] Indicate $P < 0.05$;
[**] indicate $P < 0.01$; NS, indicate not significant.

Table 4
Effect of different levels of the date palm pollen on weight of carcass and organs (relative to pre-slaughter weight).

Traits	Control	Treatments (DPP g/kg diet)			Significance	*P value*
		3 g	5 g	7 g		
Carcass %	71.05 ± 0.91[c]	72.50 ± 0.09[bc]	73.48 ± 0.43[ab]	74.32 ± 0.23[a]	*	0.021
Liver %	2.11 ± 0.10[b]	2.13 ± 0.10[b]	2.57 ± 0.15[a]	2.54 ± 0.12[a]	*	0.033
Gizzard %	1.59 ± 0.08	1.65 ± 0.03	1.72 ± 0.11	1.75 ± 0.04	NS	0.845
Heart %	0.96 ± 0.02	0.91 ± 0.02	0.91 ± 0.03	0.97 ± 0.04	NS	0.645
Spleen %	0.05 ± 0.01[b]	0.05 ± 0.01[b]	0.08 ± 0.02[b]	0.13 ± 0.01[a]	*	0.026
Thymus %	0.38 ± 0.01[c]	0.39 ± 0.01[bc]	0.42 ± 0.01[ab]	0.43 ± 0.02[a]	**	0.001
Bursa %	0.10 ± 0.01[b]	0.12 ± 0.02[b]	0.17 ± 0.01[a]	0.21 ± 0.02[a]	**	0.001

[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.05$, or $P \leq 0.01$).
[*] Indicate $P < 0.05$;
[**] indicate $P < 0.01$; NS, indicate not significant.

Antioxidant indicators

Table 7 presents the effects of dietary DPP on serum antioxidant activities in quails. The data show that DPP supplementation alleviated total antioxidant capacity (TAC), superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase (CAT), malondialdehyde (MDA), and nitric oxide levels ($P < 0.01$). The highest concentrations of TAC, SOD, GPx, and CAT were observed in the birds that received 7 g of DPP, while the lowest values for MDA and nitric oxide were recorded in the same group.

Microbial analysis

Table 8 outlines the effects of dietary treatments on the cecal microbiota composition. The results show that the dietary treatments affected all bacterial populations, except Salmonella spp., significantly ($P < 0.01$). *Salmonella* spp. was absent in all groups. Birds that received diet-supplemented DPP possessed significantly decreased numbers of *E. coli* and *Staphylococcus aureus* compared with control. The lowest counts of *Staphylococcus aureus* and *E. coli* were observed in the 7 g DPP group. These findings suggest that DPP, especially at higher inclusion levels, modulates gut microbiota by inhibiting pathogenic populations, thereby enhancing intestinal health in quails.

Table 5
Effect of different levels of the date palm pollen on hematological parameters of Japanese quails at 6 weeks of age.

Traits	Control	Treatments (DPP g/kg diet)			Significance	*P value*
		3 g	5 g	7 g		
WBCs (10^3/uL)	9.37 ± 0.97[ab]	10.10 ± 1.16[a]	7.93 ± 0.13[ab]	7.06 ± 0.03[b]	*	0.022
RBCs (10^3/uL)	4.21 ± 0.29	4.28 ± 0.24	4.35 ± 0.12	4.79 ± 0.10	NS	0.086
Hb (g/dl)	9.00 ± 0.35[c]	10.37 ± 0.91[c]	12.23 ± 0.32[b]	14.13 ± 0.42[a]	**	0.002
PCV %	23.93 ± 1.21[c]	27.93 ± 2.07[bc]	31.47 ± 1.13[ab]	35.63 ± 0.64[a]	**	0.001
MCV (fl)	56.84 ± 0.08[d]	65.26 ± 0.13[c]	72.34 ± 0.76[b]	74.38 ± 0.32[a]	**	0.001
MCH (pg)	21.43 ± 0.35[d]	24.23 ± 0.32[c]	28.11 ± 0.38[b]	29.50 ± 0.53[a]	**	0.003
MCHC %	37.61 ± 0.39[bc]	37.13 ± 0.51[c]	38.86 ± 0.51[ab]	39.67 ± 0.18[a]	**	>0.001

DPP, date palm pollen; WBC, white blood cell; RBC, red blood cell; Hb, hemoglobin; PCV, packed cell volume; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration.
[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.05$, or $P \leq 0.01$).
[*] Indicate $P < 0.05$;
[**] indicate $P < 0.01$; NS, indicate not significant.

Discussion

Economic feed additives present promising alternatives for poultry diets, potentially reducing feed formulation costs (Alyileili et al., 2020; Kamal et al., 2023b). However, it is important to recognize that the effects of these feed additives on poultry production can vary across different studies (Alyileili et al., 2020; Iqbal et al., 2022; El-Abbasy et al., 2025). The results of the current study indicate that the addition of DPP significantly improved BW in Japanese quail. Quails receiving 5 g/kg and 7 g/kg of DPP notably increased BW and BWG. Incorporating DPP into their diet also improved feed efficiency, with birds consuming DPP displaying lower FI and better FCR than the control group. These findings are consistent with a previous study by ElDeeb et al. (2024), which demonstrated that including DPP in Japanese quail feed enhanced growth efficiency. Similarly, Ouyang et al. (2016) suggested that the growth-promoting effects of DPP could be attributed to its flavones, enzymes, and coenzymes, which may stimulate the upregulation of growth hormone and hepatic growth hormone receptors. This, in turn, could increase the production of insulin-like growth factor 1, promoting growth. AL-Tamimy et al. (2024) also reported that DPP and pellet feed treatments significantly improved FCR and egg quality in quails, supporting the notion that DPP positively affects poultry growth.

Conversely, Refaie et al. (2019) observed a reduction in final body weight at higher DPP levels, which they attributed to the potential mutagenic effects of elevated flavonoids. Furthermore, Shanoon et al. (2019) reported a significant reduction in body weight in birds fed higher concentrations of DPP (0, 6, 8, and 10 g/kg diet). This reduction may be due to impaired nutrient absorption at higher DPP concentrations. In contrast, our findings suggest that DPP improves digestion and intestinal nutrient absorption, explaining the observed increase in BWG.

The present study also demonstrated that quails receiving DPP had

Table 6
Effect of different levels of the date palm pollen on blood constituents of Japanese quails at 6 weeks of age.

Traits	Control	Treatments (DPP g/kg diet)			Significance	*P value*
		3 g	5 g	7 g		
TP (g/dl)	5.83 ± 0.04[d]	6.11 ± 0.04[c]	6.43 ± 0.01[b]	7.17 ± 0.07[a]	**	0.002
Albumin (g/dl)	2.86 ± 0.04 [b]	2.83 ± 0.06[b]	2.91 ± 0.03[b]	3.15 ± 0.05[a]	**	>0.001
Globulin (g/dl)	2.97 ± 0.04[d]	3.28 ± 0.03[c]	3.52 ± 0.01[b]	4.02 ± 0.07[a]	**	>0.001
AST (U/L)	36.66 ± 0.44[a]	35.33 ± 0.16[b]	32.83 ± 0.33[c]	29.75 ± 0.25[d]	**	0.001
ALT (U/L)	20.80 ± 0.33[a]	20.83 ± 0.66[a]	19.16 ± 0.16[b]	17.50 ± 0.50[c]	**	>0.001
Creatinine (mg/dl)	0.83 ± 0.01[a]	0.76 ± 0.00[a]	0.66 ± 0.03[b]	0.58 ± 0.00[c]	**	0.003
Uric acid (mg/dl)	5.23 ± 0.10[a]	4.58 ± 0.08[b]	4.16 ± 0.01[c]	3.00 ± 0.05[d]	**	0.005
TG (mg/dl)	100 ± 1.66[a]	86.66±2.20[b]	74.16 ± 1.66[c]	53.75±3.75[d]	**	>0.001
TC (mg/dl)	183.00 ± 2.00[a]	176.00 ± 4.04[a]	164.83±3.11[b]	140.00 ± 0.50[c]	**	>0.001
HDL (mg/dl)	47.83 ± 0.60[c]	53.67 ± 0.17[b]	49.00±0.29[c]	60.75 ± 0.25[a]	**	0.003
LDL (mg/dl)	114.66 ± 1.92[a]	100.67 ± 0.88[b]	98.50 ± 1.00[b]	68.50 ± 0.50[c]	**	>0.001

DPP, date palm pollen; TP, total protein; AST, aspartate transaminase; ALT, alanine transaminase; TG, triglycerides; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein.
[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.05$, or $P \leq 0.01$).
[**] indicate $P < 0.01$.

Table 7
Effect of different levels of the date palm pollen on serum antioxidant indices and oxidative stress of Japanese quails at 6 weeks of age.

Traits	Control	Treatments (DPP g/kg diet)			Significance	*P value*
		3 g	5 g	7 g		
TAC (U/L)	695.67 ± 8.85[c]	950.00 ± 7.45[b]	1093.50 ± 9.09[a]	1137.50 ± 9.8[a]	**	>0.001
SOD (U/mL)	13.18 ± 0.07[c]	14.83 ± 0.2[b]	15.60 ± 0.31[b]	20.72 ± 0.36[a]	**	>0.001
GPX (U/mL)	18.50 ± 0.57[d]	24.00 ± 0.29[c]	30.33 ± 0.44[b]	34.33 ± 0.93[a]	**	>0.001
CAT (U/mL)	7.75 ± 0.2[c]	9.95 ± 0.10[b]	10.33 ± 0.04[b]	12.85 ± 0.17[a]	**	>0.001
NO ((µmol/L)	2.45 ± 0.05[a]	1.22±0.03[b]	0.83 ± 0.01[c]	0.75 ± 0.02[c]	**	>0.001
MDA (nmol/L)	10.03 ± 0.42[a]	6.48 ± 0.09[b]	4.13 ± 0.08[c]	3.00 ± 0.09[d]	**	>0.001

DPP, date palm pollen; TAC, total oxidant capacity; SOD, superoxide dismutase; GPX, glutathione peroxidase; CAT, catalase; NO, total nitric oxide; MDA, malondialdehyde.
[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.01$).
[**] indicate $P < 0.01$.

Table 8
Effect of different levels of the date palm pollen on caecal bacterial populations (CFU/g) of Japanese quails at 6 weeks of age.

Traits	Control	Treatments (DPP g/kg diet)			Significance	*P value*
		3 g	5 g	7 g		
Salmonella spp	Absent	Absent	Absent	Absent	NS	0.865
Staphylococcus aureus	$0.9 \times 10^4 \pm 7.35^a$	$0.33 \times 10^4 \pm 5.03^b$	$0.23 \times 10^2 \pm 2.18^c$	$0.013 \times 10^2 \pm 3.04^d$	**	>0.001
Escherichia coli	$2.67 \times 10^4 \pm 5.17^a$	$0.18 \times 10^4 \pm 6.58^b$	$0.01 \times 10^4 \pm 4.24^c$	$0.95 \times 10^2 \pm 3.33^c$	**	>0.001

[a,b,c,d] Means within a row followed by different superscripts are significantly different ($P \leq 0.01$).
** indicate $P < 0.01$; NS, indicates not significant.

increased relative weights of the carcass, liver, spleen, and thymus compared to the control group. These results align with those of Jam and Abbas (2022), who observed significant variations in the thigh, breast, carcass, and liver weights between DPP-treated and control groups. ElDeeb et al. (2024) reported that a lower concentration of DPP led to increased liver and bursa weights, though the changes were not statistically significant compared to higher concentrations. A diet containing 1.2 g/kg of DPP increased heart, gizzard, and spleen weights at elevated levels. This suggests that DPP may contribute to enhanced lean meat deposition, possibly due to its influence on organ development.

Hematological markers are essential indicators of an animal's physiological condition, and changes in these markers provide insight into how animals respond to different physiological environments (Adeyeye et al., 2020). Alterations in hematological indicators are commonly used to assess the impact of environmental, nutritional, and pathogenic factors on animal health (Kamal et al., 2023c). In this study, quails receiving DPP exhibited significant changes in all hematological parameters except RBCs. The Hb, PCV, and MCHC values were higher, and WBC counts were lower in the DPP-treated groups. These findings suggest that DPP supplementation may improve overall health and performance in quails. This is consistent with Attia et al. (2021), who highlighted DPP's nutritional and antioxidant benefits.

A high PCV value typically reflects the presence of harmful substances that may affect blood formation (Ifelayo et al., 2020). The PCV values observed in this study are within the normal range of 28–35 % for birds aged 5 to 7 weeks, as Onyishi et al. (2017) reported. The improved WBC count in the DPP-fed quails may indicate enhanced immune function, particularly at lower concentrations. DPP has been shown to stimulate WBC formation and bolster immunity by scavenging free radicals and acting as an antioxidant (Attia et al., 2021). When evaluating anemia, hemoglobin, MCH, and MCHC are essential (Kari et al., 2022). Given that the study's data fall within normal ranges, it may be concluded that DPP positively affects erythropoiesis, possibly due to its high iron content (Baliga et al., 2011).

The significant differences in AST and ALT between the control and DPP groups suggest that DPP may improve liver function. Creatinine, a metabolic by-product of muscle activity, is excreted by the kidneys, and elevated levels typically indicate impaired renal function (Oke et al., 2017). The reduced creatinine levels observed in this study suggest that DPP has a beneficial impact on kidney function. Furthermore, the significantly lower cholesterol levels in the DPP-treated birds support the idea that DPP may reduce lipid metabolism disorders, likely due to its effect on lipogenic enzyme activity in the liver (ElDeeb et al., 2024). The elevated total protein levels observed in the DPP groups may be attributed to the high protein content of DPP (42.9 % crude protein), which makes it a valuable dietary supplement (Attia et al., 2021).

Malondialdehyde is an index of the oxidation of polyunsaturated fatty acids and oxidative stress caused by reactive oxygen species (ROS). Enzymatic antioxidants (superoxide dismutase, glutathione peroxidase, and catalase) protect the cells against lipid peroxidation and reactive oxygen species (Yang et al., 2010). In the body, nitric oxide is synthesized from L-arginine (Kaur Gill et al., 2015). Nitric oxide concentration increases in pathologic infection and acts as a free radical (Jung et al., 2010). The current study significantly enhanced antioxidant capacity in the quails receiving DPP. Birds supplemented with 7 g of DPP exhibited significantly elevated levels of TAC, SOD, GPx, and CAT. This indicates that DPP supplementation improved the antioxidant systems of the quails. Furthermore, the reduction in MDA and NO levels suggests that DPP may provide protective effects against oxidative damage.

These findings concur with those of Khalifa et al. (2018), who discovered that DPP supplementation dramatically raised GPx activity in rabbits while lowering MDA and NO levels. The antioxidant qualities of DPP, which include phenolic components including ferulic and sinapic acids, flavonoids, and procyanidins, probably caused the drop in MDA levels (Al-Alawi et al., 2017).

Finally, microbial analysis showed that DPP supplementation reduced the concentrations of harmful microbes, such as *Staphylococcus aureus* and *E. coli*. In our findings, the reduction of harmful bacteria levels in group's treatment with DPP may be due to the biologically active components in DPP, particularly Phenolic substances, which prevent the growth of pathogenic bacteria. Phenolic compounds are effective against pathogenic bacteria or reduce the harmful bacteria ' ability to form bonds in the intestine (Kasprzak-Drozd et al., 2021). These findings suggest that DPP, particularly at higher inclusion levels, modulates gut microbiota by reducing pathogenic bacteria, thereby promoting intestinal health. This is consistent with the results of Raza et al. (2023), who reported that dried date meal inclusion in broiler diets increased beneficial Lactobacillus levels while reducing pathogenic *E. coli*. Maintaining a balanced gut microbiota is essential for optimal growth and overall health in poultry (Khan et al., 2024). Plant-derived additives like DPP may have prebiotic and/or probiotic effects on gut microbiota, improving nutrient absorption and enhancing bird health (LeBlanc et al., 2017).

The results of this study suggest that DPP supplementation can improve growth performance, feed efficiency, immune function, antioxidant status, and gut health in Japanese quail. These findings provide valuable insights into the potential of DPP as a natural feed additive in poultry nutrition.

Conclusion

The results demonstrate that the supplementation of DPP, particularly at levels of 5 and 7 g, positively influenced most measures of growth efficiency in quails. DPP supplementation led to significant improvements in various physiological parameters, including enhanced blood biochemical markers, increased antioxidant activity through the up-regulation of antioxidant enzymes, and favorable changes in gut microbiota, such as reducing harmful bacteria like *E. coli* and *Staphylococcus aureus*. These findings suggest that DPP could be an effective natural feed additive, boosting growth performance while promoting overall quality health and gut integrity.

Author contribution

Conceptualization and supervision, Soha A. Farag, Ahmed A. Elolimy and Ayman A. Swelum; Methodology and investigation, Waleed M. Dosoky, Abdelrahim A. Moussa, Mohamed M.F. El-Mekkawy and Mohamed E. Abd El-Hack; Lab. Analysis: Soha A. Farag, Waleed M. Dosoky, Mohamed M.F. El-Mekkawy and Mohamed E. Abd El-Hack; Data curation and statistical analysis: Ahmed A. Elolimy, Mahmoud

Kamal and Ayman A. Swelum; Original draft writing, Abdelrahim A. Moussa, Mahmoud Kamal, Ahmed A. Elolimy and Ayman A. Swelum; Writing – review and editing: Mohamed M.F. El-Mekkawy and Mohamed E. Abd El-Hack. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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