Poultry Science

Growth, carcass criteria, and blood biochemical parameters of growing quails fed *Arthrospira platensis* as a feed additive

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ABSTRACT This study investigated the impact of *Arthrospira platensis* (***A. platensis***) as a dietary supplement on growth, carcass criteria, liver and kidney function, lipid profile, and immunity of growing Japanese quails. In a 28-day experiment, 240 unsexed 7-day-old quail chicks were used. The quail chicks were divided into 4 treatment sets, each comprising 6 replicates and 10 quail chicks. Group (1) fed the basal diet with no supplements, group (2) fed the basal diet supplemented with 0.25 g *A. platensis*/kg diet, group (3) fed the basal diet supplemented with 0.50 g *A. platensis*/kg diet, and group (4) fed the basal diet supplemented with 1.00 g *A. platensis*/kg diet. The results of this study revealed that the birds that were fed 0.50 g. or 1.00 g *A. platensis*/kg diet had superior final body weights, body weight gains, feed conversion ratios, and carcass criteria compared to control, furthermore, had significant ($P < 0.05$) lower levels of liver enzymes and kidney function markers compared to control. Furthermore, birds fed 0.50 g or 1.00 g *A. platensis*/kg diet had significantly ($P < 0.05$) reduced cholesterol, triglycerides, and LDL cholesterol levels compared to control. Dietary supplementation of *A. platensis* at 0.50 and 1.00 g/kg diet significantly ($P < 0.05$) increased total antioxidant capacity, total immunoglobulin, and lysozyme activity levels. Using *A. platensis* at 0.5 or 1 g/kg diet levels during the Japanese quails' growth period can improve growth, carcass criteria, liver and kidney function, lipid profile, and immunity.

Key words: *Arthrospira platensis*, growth, antioxidant status, blood metabolites, growing quail

2023 Poultry Science 102:103205
https://doi.org/10.1016/j.psj.2023.103205

INTRODUCTION

Studying the usage of different feed additives in chicken production has improved due to the ban on antibiotics as feed additives (Kiczorowska et al., 2016; Abd El-Hack et al., 2020, 2022). According to Windisch et al. (2008) and Kiczorowska et al. (2016), phytogenic additives are plant substances that help farmed animals perform better. The feed industry has recently paid much attention to the relatively new category of feed additives known as phytogenic feed additives (**PFA**) originating from spices, herbs, or aromatic plants (Windisch et al., 2008; Abd El-Hack et al., 2016; Alagawany et al., 2016, 2021; Salah et al., 2021). Broilers' production performance can be improved by phytogenic supplements, such as enhancing nutritional digestibility or activating the gastrointestinal system's microbiota (Abdel-Wareth et al., 2012; Cho et al., 2014; Abdelnour et al., 2019, 2020; Attia et al., 2020).

A cyanobacterium known as *Spirulina platensis* and according to Gutiérrez-Salmán et al. (2015), *Spirulina* is an excellent source of amino acids, protein, fatty acids, carotene, minerals, vitamins, and xanthophyll phytopigments, as well as phycocyanins, phenolic acids, chlorophyll, and gamma linoleic acid (Mariey et al., 2012; Aladaileh et al., 2020; Dosoky et al., 2023). *Spirulina platensis* is generally considered safe by the European Food Safety Authority and the American Food and Drug Administration (**FDA**) (Gong and Bassi, 2016). According to studies by Neumann et al. (2017) and Altmann et al. (2018) *Spirulina platensis* may be one

Received September 24, 2023.
Accepted October 12, 2023.

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potential protein source used in poultry diets. Numerous other pharmacological characteristics of *Spirulina* have been discovered in recent years. Moreover, research indicates that *Spirulina* may have medicinal benefits, enhance intestinal lactobacilli, lessen nephrotoxicity from medicines and heavy metals, and shield against radiation (Khan et al., 2005; Youssef et al., 2023).

The benefits of *Spirulina*'s antioxidants are also widely recognized, attributed to substances like phycocyanin, beta-carotene, and tocopherol. Additionally, due to its antioxidant qualities, *Spirulina* can inhibit the development of cancer and organ-specific damage (Kuhad et al., 2006). *Spirulina* has also been utilized worldwide as an ingredient in the diet of high-quality broilers (Yoshida and Hoshi, 1980) and the diet of layers to boost flesh and yolk color (Toyomizu et al., 2001). It also enhances immunological function, reproduction, and growth (Lu et al., 2006). Microalgae supplementation has been suggested for chickens to improve growth rate, survival rate, feed utilization, and carcass quality. High amounts of *Spirulina platensis* supplementation were advised by Zaghari and Hajati (2018) for enhancing the immunological responses and growth performance of Japanese quail. Studies have revealed that microalgae may play a role in broilers' good growth and feed effectiveness, ultimately improving. According to Doreau et al. (2010), dried *Spirulina* is unique as a new animal feed because it provides roughly 60% protein. *Spirulina*'s antibacterial properties, cell-mediated and humoral immunological responses, and promotion of disease resistance all helped chickens live longer and grow faster (El-Shall et al., 2023).

The present study hypothesized that the dietary supplementation of *A. platensis* would positively affect performance of Japanese quails. Therefore, it evaluated the impact of various dried *Arthrospira platensis* powder concentrations on growth performance, carcass criteria, liver and kidney function, lipid profile, and immunity of growing quails.

MATERIALS AND METHODS

A total of 240 unsexed 7-day quail chicks were allotted into 4 groups, each consisting of 6 replicates and 10 quail chicks in each. Group (1) fed the basal diet with no supplements, group (2) fed the basal diet supplemented with 0.25 g *A. platensis*/kg diet, group (3) fed the basal diet supplemented with 0.50 g *A. platensis*/kg diet, and group (4) fed the basal diet supplemented with 1.00 g *A. platensis*/kg diet.

Birds and Housing

The quail chicks were kept in well-ventilated cages. The trial lasted for 35 d following hatching. The diets provided were typical broiler rations (NRC, 1994). Water and food were available ad libitum. From 0 to 5 wk of age, the feed (in pellet form) was provided to every group of birds. Table 1 indicates the formulation and composition of the quail ration. The consistency of the housing's ventilation and temperature was continuously observed.

Table 1. Ingredients and nutrient contents of the basal diet of growing Japanese quail.

Ingredient (%)	(%)
Maize 8.5%	51.80
Soybean meal 44%	36.70
Maize gluten meal 62%	5.21
Soybean oil	2.90
Limestone	0.70
Di-calcium phosphate	1.65
Salt	0.30
Premix[1]	0.30
L-Lysine	0.13
DL-Methionine	0.11
Choline chloride (50%)	0.20
Calculated	
ME, kcal/kg	2995
Crude protein	24.00
Calcium	0.80
Nonphytate P	0.45
Lysine	1.30
TSAA	0.92

[1]Provides per kg of diet: vitamin A, 12,000 IU; vitamin D3, 5,000 IU; vitamin E, 130.0 mg; vitamin K3, 3.605 mg; vitamin B1 (thiamin), 3.0 mg; vitamin B2 (riboflavin), 8.0 mg; vitamin B6, 4.950 mg; vitamin B12, 17.0 mg; niacin, 60.0 mg; D-biotin, 200.0 mg; calcium D-pantothenate, 18.333 mg; folic acid, 2.083 mg; manganese, 100.0 mg; iron, 80.0 mg; zinc, 80.0 mg; copper, 8.0 mg; iodine, 2.0 mg; cobalt, 500.0 mg; and selenium, 150.0 mg.

Growth Performance

Quail chick body weights were measured at 0, 3, and 5 wk to determine body weight variations and weight gain. Also, feed consumption and conversion ratio were measured at the age of 1, 3, and 5 wk.

Carcass Traits

Six birds in each group were chosen randomly, weighed (Sartorius 1202 MP balance with precision 0.01 g), and slaughtered at the end of the experiment (42 d of age). According to Malaysian institutes' Halalslaughter protocol, the slaughter method was used (JAKIM, 2011). Without any anesthetics, the major jugulars of birds were severed to produce effective bleeding. The carcasses were properly drained for 5 min after evisceration and internal organ removal, and then chilled at 2°C for 30 min. The carcass yield (dressing percentage) was estimated as an actual carcass weight relative to the live body weight. The heart, gizzard, and liver were weighed and expressed in grams per kilogram of killing weight (**KW**). The weights of the carcass yield (dressing percentage) and giblets were computed. The dressed weight was obtained by dividing the sum of the carcass and giblet weights by the live body weight.

Blood Chemistry

Blood samples (6 birds in each group) were taken at d 42 of age via the brachial vein method and placed in plain tubes. Sera were extracted from the samples by centrifuging them as quickly as possible (3,000 rpm for 15 min), and they were kept at −20°C for analysis. The following biochemical parameters were determined using commercial diagnostic kits from Biodiagnostic Co. Giza (Egypt): alanine aminotransferase (**ALT**), aspartate aminotransferase (**AST**), albumin (**ALB**), total protein (**TP**), creatinine, urea grades, total cholesterol (**TC**), high-density lipoprotein (**HDL**), cholesterol, triglyceride (**TG**), complement 3 (**CP3**), and lysozyme. Friedewald et al. (1972) provided the model used to study low-density lipoprotein (**LDL**) cholesterol: LDL = TC-HDL-TG/5.

Statistics

One-way ANOVA was used to examine the variances between sets statistically. The SPSS Software Program (2008) version 11.0 was applied for all studies. Using the test of Tukey multiple range, it was established which intergroup variances were significant. The following statistical model was used:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where Y_{ij} = value of any observed traits; μ = the overall mean; H_i = effect of dietary treatment; e_{ij} = experimental random error.

RESULTS

Growth Parameters

Table 2 displayed no variations in live body weight or weight gain that were statistically nonsignificant ($P >$ 0.05), and the group that received 1 g of *A. platensis* per kg of diet showed the largest final live body weight and weight gain. Moreover, the differences across the treatment groups were not significant ($P > 0.05$) in growing quail feed intake (Table 3). Also, the group supplemented with 0.25 g *A. platensis*/kg diet presented the highest feed intake level. The groups supplemented with 1 g of *A. platensis*/kg diet showed a significantly ($P < 0.05$) lower feed conversion ratio (**FCR**) than the control group.

Carcass Traits

As described in Table 4, supplementing *A. platensis* at dosages of 0.25 or 0.5 g/kg in the growing quail diet boosted the birds' carcass yield quantitatively but not significantly ($P > 0.05$). The group supplemented with a 0.5 g *A. platensis*/kg diet showed the highest giblet weight (gizzard, heart, and liver). Moreover, the weight of the gizzard did not differ significantly ($P > 0.05$) from that of the control group. According to the heart weight in each group, a significant difference ($P < 0.05$) was reported between the groups, and the group supplemented by 0.5 g *A. platensis*/kg diet showed the highest value. The weight of the liver did not differ significantly ($P > 0.05$) across the groups.

Blood Parameters

The effects of *A. platensis* supplementations on serum biochemical parameters, liver enzymes (ALT and AST), and kidney function markers (creatinine and urea) are provided in Table 5. Serum total protein (**TP**) was significantly ($P < 0.05$) affected by *A. platensis* supplementation, and the groups supplemented with a 0.5 g *A. platensis*/kg diet showed the highest value. Meanwhile, albumin (**ALB**) and globulin (**GLOB**) were not found to be significant ($P > 0.05$). The liver enzyme (ALT) was significantly ($P < 0.05$) affected by *A. platensis* supplementation between the treatments, while (AST) was not found to be significant ($P > 0.05$) between groups. The dietary *A. platensis* supplements have significant impacts on growing quail's serum urea levels ($P < 0.05$) and the group treated with 1 g *A. platensis*/kg diet showed the lowest values for urea (35.61 mg/dL).

Lipid Profile

The impact of *A. platensis* supplementations on lipid profile is provided in Table 6. The variations in serum triglyceride, total cholesterol, LDL cholesterol, and HDL, were significantly ($P < 0.05$) affected by *A. platensis* supplementation, and the group treated with 0.5 g *A. platensis*/kg diet showed the lowest value of TC (51.40 mg/dL), TG (44.50 mg/dL), while group supplemented with 1 g *A. platensis*/kg diet showed the highest value of HDL (38.02 mg/dL) and the lowest value of LDL (2.98 mg/dL), respectively.

Table 2. Live body weight and body weight gain of grower quail as affected by dietary levels of *Arthrospira platensis*.

	Live body weight (g)			Body weight gain (g/d)		
Treatments	1 wk	3 wk	5 wk	1−3 wk	3−5 wk	1−5 wk
Arthrospira platensis level (g/kg diet)						
0	31.85	90.9333	176.7833	4.2431	6.1033	5.1793
0.25	31.86	92.4800	188.3100	4.3307	6.8450	5.5879
0.50	31.85	98.7200	158.0400	4.7764	4.2371	4.5068
1.00	31.87	102.2933	193.2000	5.0317	6.4933	5.7625
SEM[1]	0.001	2.45	5.42	0.17	0.41	0.19
P value	0.985	0.353	0.070	0.380	0.089	0.071

[1]SEM: standard error means.

Table 3. Feed intake and feed conversion ratio (FCR) of grower quail as affected by dietary levels of *Arthrospira platensis*.

Treatments	Feed intake (g)			FCR (g feed/g gain)		
	1 wk	3 wk	5 wk	1–3 wk	3–5 wk	1–5 wk
Arthrospira platensis level (g/kg diet)						
0	16.34	23.32	20.86	4.00	3.84	4.02[a]
0.25	16.36	23.85	21.09	3.79	3.49	3.78[b]
0.50	16.07	24.05	20.97	3.39	6.60	4.75[a]
1.00	16.33	23.41	20.89	3.26	3.61	3.63[b]
SEM[1]	0.11	0.32	0.17	0.16	0.53	0.16
P value	0.832	0.874	0.976	0.371	0.094	0.033

[a,b]Bearing different superscript letters within the same column differ significantly ($P < 0.05$).
[1]SEM: standard error means.

Table 4. Carcass traits of grower quail as affected by dietary levels of *Arthrospira platensis*.

Treatments	Carcass %	Gizzard %	Heart %	Liver %
Arthrospira platensis level (g/kg diet)				
0	78.27	2.13	0.78[b]	2.39
0.25	83.55	2.06	0.97[a]	2.44
0.50	86.50	2.28	1.10[a]	2.83
1.00	77.02	2.12	0.97[a]	2.56
SEM[1]	1.50	0.05	0.04	0.12
P value	0.067	0.643	0.034	0.684

[a,b]Means bearing different superscript letters within the same column differ significantly ($P < 0.05$).
[1]SEM: standard error means.

Immunity

Data reported in Table 6 showed that dietary *A. platensis* supplementation had numerically improved ($P > 0.05$) the immunity responses of growing quails, with an increase in Complement 3 (**C3**) and lysozyme levels in the blood, as well as an increase in antibody production.

DISCUSSION

In the present study, quails aged 1 to 35 d gained more body weight when fed a diet containing 1 g *A. platensis*/kg diet ($P < 0.05$). In broiler chicks, Jamil et al. (2015) utilized 2, 4, or 8 g of *Spirulina*/kg of feed, revealing that the algae boosted feed conversion ratio (**FCR**) and bird's body weight. According to Shanmugapriya et al. (2015), broilers' growth performance increased by including 1% *Spirulina* in their feed. *Spirulina* increased intestinal villi height, which raised the absorptive surface area of the gut of broilers. Dietary algae supplements of up to 16% can reduce the rate at which nutrients travel through the gut while increasing their digestibility (Evans et al., 2015). Additionally, quails fed a diet containing 2.5 g/kg of *Spirulina platensis* increased the European production efficiency factor (**EPEF**). Hence, poultry farmers should take note of this important economic indicator before beginning their investments. Park et al. (2018) showed that *Spirulina*

Table 5. Liver and kidney functions of grower quails as affected by dietary levels of *Arthrospira platensis*.

Treatments	Liver and kidney functions[1]						
	TP (mg/dL)	ALB (mg/dL)	GLOB (mg/dL)	ALT (U/L)	AST (U/L)	Urea (mg/dL)	Creatinine (mg/dL)
Arthrospira platensis (g/kg diet)							
0	6.52[a]	3.20	3.29	10.33[b]	121.21	44.51[a]	0.52[c]
0.25	6.49[a]	3.25	3.24	10.19[b]	118.10	39.43[b]	0.57[b]
0.50	6.55[a]	3.56	2.99	9.95[b]	123.97	38.50[b]	0.54[c]
1.00	6.37[b]	3.33	3.04	11.07[a]	118.49	35.61[c]	0.62[a]
SEM[2]	0.02	0.08	0.08	0.13	1.05	0.98	0.01
P value	<0.001	0.466	0.545	<0.001	0.166	<0.001	<0.001

[a-c]Means bearing different superscript letters within the same column differ significantly ($P < 0.05$).
[1]TP: total protein; ALB: albumin; ALT: alanine aminotransferase; AST: aspartate aminotransferase.
[2]SEM: standard error means.

Table 6. Lipid profile and immunoglobulins of grower quails as affected by dietary levels of *Arthrospira platensis*.

Treatments	Lipid profile and immunoglobulins[1]					
	TC (mg/dL)	TG (mg/dL)	HDL (mg/dL)	LDL (mg/dL)	C3 (mg/dL)	Lysozyme (mg/dL)
Arthrospira platensis level (g/kg diet)						
0	72.19[a]	89.16[a]	29.99[c]	24.31[a]	158.23	1.64
0.25	54.71[b]	52.02[c]	35.00[b]	9.31[b]	180.90	1.11
0.50	51.40 [b]	44.50[c]	38.00[a]	7.60[b]	149.90	1.64
1.00	52.75 [b]	67.27[b]	38.02[a]	2.98[c]	183.72	1.09
SEM[2]	2.70	5.15	0.42	3.21	8.19	0.14
P value	0.001	<0.001	<0.001	<0.001	0.420	0.412

[a-c]Means bearing different superscript letters within the same column differ significantly ($P < 0.05$).
[1]TC: total cholesterol; TG: triglycerides; HDL: high-density lipoprotein; LDL: low-density lipoprotein, C3: Complement 3.
[2]SEM: standard error means.

platensis increased the EPEF in broilers, which is consistent with our findings. This can be attributed to the high nutrient composition of *Spirulina platensis* and its physiological properties, which favorably impact body metabolism and growth performance (Park et al., 2018).

According to Abouelezz (2017), the *Spirulina platensis* supplementation (1 and 2.5%) considerably raised the BWG of Japanese quail. Previous experiments showed that supplementing animals' diets with 4% *Spirulina platensis* had no adverse effects on their growing ability (Ross and Dominy, 1990; Venkataraman et al., 1994). In another investigation, Toyomizu et al. (2001) found that adding 50 to 100 g/kg of *Spirulina platensis* had no apparent effects on the growth rate but that supplementation ratios >200 g/kg were associated with growth inhibition. The impact of *Spirulina* on growing quail performance indicators in the current study, including average dressing percentage, was consistent with findings from earlier studies (Mountzouris et al., 2007; Samli et al., 2007). Additionally, Bellof and Alarcon (2013) studied the effects of dietary.

Spirulina supplementation under organic farming and reported a significant ($P < 0.05$) enhancement of the carcass criteria metrics in broilers. Nevertheless, dried *Spirulina platensis* supplementation showed a more potent effect as growth-promoting and raised carcass output percentage (Zaghari and Hajati, 2018). *Spirulina platensis* supplementations had no significant impact on the quail carcass yield compared to the control. These results are also supported by Cheong et al. (2016), who recorded no significant ($P > 0.05$) effects of *Spirulina platensis* on the breast and carcass yield percentage. *Spirulina* supplementation has substantial effects ($P < 0.05$) in serum biochemical markers of treatment groups. Serum total protein in the group supplied with 0.5 g *A. platensis*/kg diet presented the highest level (6.55 mg/dL). At the same time, albumin and globulin show no significance. *Spirulina* supplementation has been found to improve the lipid profile of quail.

In our results, quail fed a diet supplemented with 0.5 g or 1 g *Spirulina* had ($P < 0.05$) lowered levels of triglycerides, total cholesterol significantly, and LDL cholesterol compared to control. The current findings were consistent with those of earlier research by Kanagaraju and Omprakash (2016) and Cheong et al. (2016), which discovered *Spirulina* supplementation at level 1% to quail diets had a significant decrease ($P < 0.05$) in blood serum cholesterol levels compared to the control. Meanwhile, additional findings contradict these results (Kannan et al., 2005; Abou-Gabal et al., 2015). Furthermore, supplementing with *Spirulina platensis* at 1% significantly enhanced the blood parameters (Shanmugapriya et al., 2015).

The current findings are supported by the results of Sugiharto et al. (2018) for *Spirulina platensis* supplements to broiler diets. Consistent with Zaghari and Hajati (2018), *Spirulina platensis* reduced cholesterol levels. Mahmoud et al. (2016) reported that adding *Spirulina* to broiler's diets significantly ($P < 0.05$) reduced cholesterol and triglyceride levels. *A. platensis* supplementation has positively impacted kidney and liver function in quails. In this study, quails fed a diet supplemented with 0.5 g or 1 g *A. platensis*/kg diet significantly ($P < 0.05$) decreased liver enzymes and kidney function markers levels compared to the control. This result agreed with Jamil et al. (2015); they discovered that when animals received *Spirulina platensis*, ALT and AST levels significantly ($P < 0.05$) reduced in comparison to the control group. Previous studies illustrated *Spirulina*'s hepatoprotective and nephroprotective impacts (Avdagić et al., 2008; Ismail et al., 2009). *Spirulina*'s β-carotene and C-phycocyanins can rebuild damaged liver cells and guard renal tissues against toxicity by removing free radicals (Karadeniz et al., 2009).

The high concentration of functional chemicals in *Spirulina*, including C-phycocyanins, β-carotene, minerals and vitamins, which have an immunomodulatory role, is thought to be responsible for the rise of immunity in birds (Upasani and Balaraman, 2003). By stimulating the mononuclear phagocytic system, has been shown to boost the capacity for disease resistance in chickens (Lokapirnasari et al., 2016). This greater Zn concentration in *Spirulina* could explain the enhancement in cellular immunity observed after dietary treatment with *Spirulina* (Abou-Gabal et al., 2015).

CONCLUSIONS

According to the experiment's findings, it is concluded that growth efficiency, carcass criteria, kidney and liver function, immunity and lipid profile in growing quail were considerably impacted by the different degrees of *A. platensis* incorporation. A dietary inclusion level of 0.50 g and 1.00 g *A. platensis*/kg diet was very effective.

ACKNOWLEDGMENTS

The authors extend their appreciation to the Researchers Supporting Project number (RSPD2023R971), King Saud University, Riyadh, Saudi Arabia for funding this research. This research was also supported in part by funds provided by USDA-NIFA, Sustainable Agriculture Systems, grant no. 2019-69012-29905. Title of project: Empowering U.S. Broiler Production for Transformation and Sustainability USDA-NIFA (Sustainable Agriculture Systems): no. 2019-69012-29905.

DISCLOSURES

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

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