Adding Variable Proportion of seaweed to Diet on the Productive Performance of Broilers

Ali Yassin Khadir Al-Atabi[1*], S. M. A. AL-Tamimy [2]

[1,2]Department of Animal Production, College of Agriculture, Diyala University, Diyala, Iraq.
*Corresponding author's email: ali19928886@gmail.com

Abstract

The experiment was conducted in the poultry farm, Animal Production Department, Faculty of Agriculture, University of Diyala, during the period from 24/9/2024 to 28/10/2024 for 35 days to study the effect of adding seaweed powder to broiler feed on the productive performance of broilers. 225 unsexed broiler chicks (Ross 308) were used, one day old, with an average chick weight of 37.5±1g. They were randomly divided into five treatments, with three replicates and 15 birds per replicate. The experimental treatments were as follows: T1 = control treatment (standard feed without additives), T2 = standard feed with 7.5g seaweed powder, T3 = standard feed with 15g seaweed powder, T4 = standard feed with 22.5g seaweed powder, T5 = standard feed with 30g seaweed powder. Results revealed significant improvements $P \leq 0.05$ in body weight for treatments T2, T4, and T5 compared to the control, as well as in cumulative live weight. These treatments also demonstrated superior weight gain compared to the control. However, adding of seaweed powder 15 g/ kg of feed led to a negative effect on the productive traits of the broilers. We recommend using 22.5 g/ kg of seaweed powder.

Keywords: broilers, Seaweed powder (spirulina), productive.

Introduction

Poultry farming is vital to the worldwide livestock sector, providing a substantial source of protein and nutrition for growing humans population [1]. The demand for poultry products has been gradually increasing due to numerous factors including population increase, rising income levels, and evolving dietary preferences [2]. The world's population is expected to reach 8.5 billion in 2030 and 9.7 billion in 2050 [3]. This significant population growth will be the primary driver behind evolving consumption patterns, with projections indicating a 14% increase in global meat consumption by 2030, compared to the baseline average from 2018 to 2020 [4,5]. The race to meet the growing demand for poultry products has seen an emergency in large-scale industrial poultry farms that rely heavily on antibiotics with little attention to bird welfare [6]. The manufacturing of poultry products presents many obstacles such as increasing prices of feed and its supplements which raise the cost of production [7]. Importing feed ingredients is also costly and deviates from the principles set out in the UNDP Sustainable Development Goals, such as eradicating poverty (SDG 1), eliminating hunger and sustainable agriculture (SDG 2), and addressing climate change (SDG 13) [3]. Poultry feed manufacturers emphasize the need to search for alternative ingredients, including new protein sources, insect-derived feeds, algae, and plant-based bioactives from the food and agriculture sectors, to replace expensive ingredients and achieve production targets [8,9]. Studies have shown that the active components of medicinal plants can improve poultry health and performance [10]. Microalgae (spirulina) is a naturally occurring food with high nutritional value and, therefore, may be a promising ingredient in poultry diets. Algae refer to a diverse group of photosynthetic probiotics found in aquatic environments, including freshwater and marine ecosystems. They are classified as simple, non-flowering, succulent plants and are divided into three groups: green, brown, and red algae. However, algae are not always classified as plants and can sometimes be classified as protozoa or even bacteria, and future research is needed to exploit them for increased production at the lowest economic cost [11,12]. Algae are recommended as feed additives due to their high levels of macro-and micro-elements and ability to improve the growth performance, feed efficiency, and meat quality of broilers [13]. In addition, seaweeds have been utilized in animal feeds as rich sources of carbohydrates, protein, essential amino acids, minerals, and vitamins and bioactive compounds such as carotenoids [14]. The inclusion of seaweeds in poultry feeds has the potential to improve feed utilization efficiency, bird health, and product quality , Aside from its high protein content and the presence of all essential amino acids[15,16], Spirulina serves as a bountiful reservoir of carbohydrates, a variety of vitamins including pro-vitamin A, vitamin C and vitamin E, as well as a host of minerals such as iron, calcium, chromium, copper, magnesium, manganese, phosphorus, potassium, sodium and zinc [17,18]. Due to the lack of research on the use of marine algae (spirulina) in broiler feed, an experiment was conducted to study its effect on production characteristics.

Material and Methods

The animal study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Diyala, The experiment was conducted at the University of Diyala, College of Agriculture, within the poultry sector of the Department of Animal Production, from September 24, 2024, to October 28, 2024, to investigate the impact of incorporating varying proportions of seaweed powder into the diet on production performance. For Ross 308 broilers. The study was conducted with 225 unsexed Ross 308 hybrid broilers on their first day of life. The average initial weight of each bird is 1 ± 37.5g. It was allocated randomly into five experimental conditions. Each treatment had 3 replicates, and each replicate contained 15 birds. The transactions were divided as below:

1. The First treatment (T1) : Control : Feed without any additives.
2. The second treatment (T2) : Standard feed with seaweed powder added at a rate of (7.5) g/kg of feed.
3. The third treatment (T3): Standard feed with seaweed powder added (15) grams/kg.
4. The Fourth treatment (T4): Standard feed with seaweed powder added (22.5) grams/kg.
5. Fifth treatment (T5): Standard feed with seaweed powder added at a rate of (30) grams/kg.

The chicks were obtained from Baz Al-Jazeera Poultry Hatchery - Karbala, with an average weight of 37.5±1 g, unsexed at one day of age and were raised in a semi-closed hall. The floor of the cages designated for the chicks was covered with sawdust approximately 5 cm thick and litter paper until the end of the first week. Then the chicks were placed in floor cages with an area of 2 x 1.5 m for each cage (15 birds/cage). In the first week of rearing, feeders in the form of plastic plates and inverted plastic troughs were used. At the end of the first week, the plastic feeding dish was replaced with a circular, hanging dish with a diameter of 45 cm, as well as automatic plastic dishes trough instead of the inverted trough until the end of the marketing age (five weeks). The light program of 23 hours of light and 1 hour of darkness was used during the first three days. After that, a program of 20 hours of light and 4 hours of darkness was applied until the marketing age of 5 weeks, as indicated by Company Directory [19]. The chicks were received in the field at a temperature of 33-34°C on the first day, and then temperature was reduced Every day 0.5°C to reach a temperature of 21°C In the third week, and it was fixed until the marketing age according to the Aviagen breeding guide [19]. At night, gas incubators were used with electric heaters (greenhouses) to provide the appropriate temperature for the chicks from the beginning of breeding until the end of the experiment.

The birds were fed with Birds were fed starter feed from 1-14 days old, and Growth bush from 15 - 35 days of age , as shown in Table (1).

The seaweed (Spirulina) was obtained from a herbalist shop In commercial markets, where it was imported from the American company IKO. and the Data were statistically analyzed using a completely randomized design (CRD), The significant differences of the means were determined by Duncan's multiple range test [20] at the 0.05 level [21], The ready-made SPSS statistical program was also used to analyze the experimental data [22].

Table 1. Composition and components of nutrients of basal diets in the starter, growth periods of broilers diet.

Materials	Initiator diet (1 - 20 days) (%)	Growth diet (21 - 35 days) (%)
yellow corn	44	50
soybean	30	26.9
Sun flower oil	1.9	4
Dicalcium phosphate	0.6	0.6
Limestone	1.1	1.1
Vitamin and mineral mixture	0.2	0.2
wheat	17	12
Protein center	5	5

salt	0.2	0.2
Total	100	100
Calculated analysis***		
Crude protein (%)	22	20.54
Represented energy (kcal/kg)	3006.5	3171.11
Lysine (%)	1.24	1.15
Methionine + Cystine (%)	0.85	0.81
Calcium (%)	0.24	0.24
Available phosphorous (%)	0.40	0.39

Used Wafi brand protein concentrate produced in Holland. Contains 40% crude protein, 2117.00 kcal assimilable energy, 5% crude fat, 2.81% crude fiber, 8.76% moisture, 23.45% crude ash, 3.14% calcium, 5.38% available phosphorus, 2.50% sodium, 3.88% chloride, 3.85% lysine, 3.70% methionine, 4.12% cysteine, 0.42% tryptophan, 1.80% thionine, 1.45% isoleucine, 1.69% valine, 2.48% arginine, and contains vitamins A = 200000 I.U /Kg, D3 = 80000 I.U /Kg, E = 600 mg/Kg, B1 = 60 mg/Kg, B2 = 140 mg/Kg, B6 = 80 mg/Kg, B12 = 700 mg/Kg, Biotin = 2 mg/Kg, Niacin = 800 mg/Kg, Folic Acid = 20 mg/Kg, K3 = 50 mg/Kg, Calcium D-Pantothenate = 300 mg/Kg, Choline Chloride = 7000 mg/Kg, Choline = 6.07320 mg/Kg. In addition to the elements Fe = 1 mg/Kg, Cu = 200 mg/Kg, Mn = 1.600 mg/Kg, Zn = 1.200 mg/Kg, I = 20 mg/Kg, Se = 2 mg/Kg and the added antioxidants are B.H.T = 33.50 mg/Kg, Propyl Gallate = 2.80 mg/Kg, Citric Acid = 5 mg/Kg.

**Vitamin blend contains 5000 IU = Vitamin A, 600 IU = Vitamin D3, 10 mg = Vitamin E, 2 mg = Vitamin K3, 2 mg = Vitamin B1, 2 mg = Vitamin B2, 2 mg = Vitamin B6, 5 mg = Vitamin B12, 10 mg = Vitamin B6. C mg, Niacin = 15 mg, Folic Acid = 500 mcg, Calcium D-Pantothenate = 5 mg, Manganese Sulphate = 40 mg, Zinc Sulphate = 40 mg, Ferrous Sulphate = 20 mg, Copper Sulphate = 3 mg, Cobalt Sulphate = 100 mcg, Potassium Iodide = 100 mcg, DL-methionine = 20 mg, L-Lysine = 50 mg.

It was calculated based on NRC [23].

Results and Discussion

Body weight (g/bird)

Table 2 shows the impact of varying proportions of seaweed powder (spirulina) on the weekly body weight (g/bird) in broiler diets. The results shown in Table 2 indicate that the average body weight data for the first and second weeks did not exhibit significant differences. In the third week, significant changes were seen (P<0.05) for the addition treatment T4 and T5, which involved the incorporation of 22.5 , 30 g/ kg of seaweed powder in to the feed, resulting in an average live body weights of 952.66, 937.66g per bird respectively, the highest recorded values . In comparison to treatment T1, which yielded weight of 876.66 g/bird . Treatments T2 and T3, with an average weight of 931.00, 934.34 g/bird respectively , exhibited no significant differences compared to treatments T1, T4, and T5 in the third week . In the fourth week, the T4 addition treatment achieved the highest body weight of 1718.33 g/bird, substantially surpassing the weights reported for treatments T1, T2, T3, and T5, which were 1564.00, 1686.00, 1592.66, and 1682.66 g/bird, respectively. T2 and T5 demonstrated a marked superiority over T1 and T3. During the fifth week, the results notably surpassed those of the treatments T2, T4, and T5, which recorded the maximum body weight of 2599.33, 2672.66, and 2613.33 g/bird, respectively, compared to treatments T1, and T3, which yielded weights of 2394.00, and 2484.66 g/bird, respectively. T1 and T3 treatments also showed no significant differences between them. During the period from 1-5 weeks, there are significant differences in terms of the average cumulative body weight. The results of our study are consistent with the results obtained by (32) when adding seaweed powder to feed at rates of 0.1, 0.3, and 0.5% in body weight, weight gain, feed consumption, and feed conversion efficiency at 35 days of age. They are also consistent with the results obtained by (24) when adding seaweed powder to feed at rates of 1 and 2 g/kg feed in body weight, weight gain, feed consumption, and feed conversion efficiency at 22-35 days of age, While the results of our study did not agree with the results reached by (33) in that there was no significant difference when adding seaweed powder at a rate of 15% in the average body weight, the rate of weight gain, and the rate of feed consumption at the age of 35 days.

Table 2. Adding Variable Proportion of seaweed powder to the diet and its effect on the live weight of broilers (g/bird) during the week, for a period of 5 weeks (mean ± Standard Error).

Age (weeks)	Treatments					P-Value
	T1	T2	T3	T4	T5	
1	138.10±4.05	149.93±4.46	149.79±3.83	150.44±5.55	146.86±4.60	0.334
2	443.00±7.63	458.00±2.00	444.00±7.02	451.00±10.14	438.00±6.65	0.380
3	876.66±5.48 b	931.00±21.19 ab	934.33±6.56 ab	952.66±29.91 a	937.66±12.77 a	0.095
4	1564.00±13.01 c	1686.00±43.92 ab	1592.66±55.09 bc	1718.33±23.35 a	1682.66±20.34 ab	0.045
5	2394.00±44.60 b	2599.33±15.07 a	2484.66±47.69 b	2672.66±7.51 a	2613.33±13.33 a	0.001
1-5	2394.00±44.60 b	2599.33±15.07 a	2484.66±47.69 b	2672.66±7.51 a	2613.33±13.33 a	0.001

T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.

Different letters within a row indicate significant differences between means at P≤0.05 according to Duncan's multiple range test.

Weight gain (g/bird)

Table 3 illustrates the impact of incorporating seaweed powder (spirulina) in varying quantities into the food on the weekly weight increase rate of broilers. The data indicates no variation in the weekly weight growth rate throughout weeks 1, 2, and 4. In week 3, the results indicated a substantial advantage ($P < 0.05$) for the T3, T4, and T5 therapy, with a weight growth rate of 490.33, 501.67, and 499.67 g per bird. This surpassed the T1, and T2 treatments, which exhibited weekly weight gain rates of 433.67, and 473.00 g/bird, respectively. The T2 treatment shown considerable advantage compared to the T1 therapie. During the fifth week, the T4 treatment exhibited statistically significant differences ($P \leq 0.05$), achieving a weight growth rate of 954.33 g/bird, in contrast to 830.00 g/bird for T1. The T1 treatment recorded the lowest weight gain in the fifth week compared to T2, T3, and T5, which showed no significant differences among themselves. In terms of cumulative weight gain from weeks 1 to 5, the T2, T4, and T5 therapy demonstrated substantial superiority with a cumulative weight gain of 2561.83, 2635.17, and 2575.83 g/bird respectively, in contrast to 2356.50, and 2447.17 g/bird for the T1, and T3 treatments, respectively in terms of cumulative weight gain.

Table 3. Adding Variable Proportion of seaweed powder to the diet and their effect on the weight gain of broilers (g/bird) during the week, for 5 weeks (mean ± Standard Error).

Age (weeks)	Treatments					P-Value
	T1	T2	T3	T4	T5	
1	100.60±4.05	112.43±4.46	112.29±3.83	112.94±5.55	109.36±4.60	0.334
2	304.89±5.21	308.07±6.31	294.20±6.19	300.56±8.04	291.13±6.79	0.383
3	433.67±4.84 b	473.00±22.48 ab	490.33±2.40 a	501.67±19.78 a	499.67±8.41 a	0.035
4	687.33±8.76 a	755.00±31.00 a	658.33±48.52 a	765.67±39.53 a	745.00±8.00 a	0.144
5	830.00±32.39 b	913.33±43.71 ab	892.00±15.27 ab	954.33±23.31 a	930.67±27.08 ab	0.109
1-5	2356.50±44.6(b	2561.83±15.0? a	2447.17±47.6? b	2635.17±7.51 a	2575.83±13.3? a	0.001

T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.

Different letters within a row indicate significant differences between means at $P \leq 0.05$ according to Duncan's multiple range test.T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.

Different letters within a row indicate significant differences between means at $P \leq 0.05$ according to Duncan's multiple range test.

Feed Intake (g/bird)

Results in Table 4 demonstrates the effect of incorporating different ratios of seaweed powder into the diet on the weekly feed intake rate (g). The data reveals no substantial variation in average weekly feed consumption across all experimental treatments during weeks 1, 3, and 4. During the second week, treatment T2 exhibited statistically significant differences, with a feed consumption rate of 412.66 g per bird. This exceeded the rates of treatments T1, T3, T4 and T5, which reported 400.66, 397.21, 403.77 and 403.32 g/bird, respectively. No statistically significant changes were seen between treatment T1 and treatments T4 and T5. Treatments T4 and T5 surpassed treatment T3; however, no significant differences were observed among treatments T1, T4, T5, and the treatment T3. Meanwhile, in the fifth week, treatment T2 showed statistically significant differences, with feed consumption reaching 3428.40 g/bird. This rate exceeded the rates of treatments T1 and T3, which recorded 1102.88 and 1098.88 grams per bird, respectively. No statistically significant changes were seen between treatment T2 and treatments T4 and T5, which exhibited feed consumption rates of 1184.22 and 1151.33 g/bird, respectively. Also, during the period from 1 to 5 weeks, treatment T2 showed statistically significant differences in cumulative feed consumption, recording a feed consumption rate of 3428.40 g/bird. This rate exceeded the rates of treatment T1, which recorded 807.24 g/bird. Also, no statistically significant changes were observed between treatment T2 and treatments T3, T4 and T5.

Table 4. Addition of Variable Proportion of seaweed powder to the diet and their effect on broiler feed Intake (g/bird) during the week for 5 weeks (mean ± Standard Error).

Age (weeks)	Treatments					P-Value
	T1	T2	T3	T4	T5	
1	130.64±2.04	129.97±5.44	130.77±4.69	125.93±8.80	126.77±5.53	0.954
2	400.66±2.33 bc	412.66±2.90 a	397.21±1.09 c	403.77±0.80 b	403.32±0.66 b	0.002
3	630.88±8.29	687.55±9.44	644.44±23.97	657.55±24.69	656.22±11.68	0.278
4	892.22±15.28	985.77±26.40	903.55±53.77	963.77±35.36	906.44±23.09	0.262
5	1102.88±23.22 b	1212.44±17.13 a	1098.88±50.47 b	1184.22±27.22 ab	1151.33±16.00 ab	0.083
1-5	3157.28±38.25 b	3428.40±32.20 a	3174.87±128.6 ab	3335.25±90.31 ab	3244.09±33.82 ab	0.132

T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.
Different letters within a row indicate significant differences between means at P≤0.05 according to Duncan's multiple range test.T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.
Different letters within a row indicate significant differences between means at P≤0.05 according to Duncan's multiple range test.

Feed conversion efficiency

Table 5 presents the effects of varying percentages of seaweed powder on the feed conversion efficiency of broilers over the course of one week. The study's results indicated no significant difference in the efficiency of weekly feed conversion between the experimental parameters during the first, second and fifth weeks, consistent with the findings shown in Table 5. In the third week, a significant difference was observed ($p \leq 0.05$) for the T3, T4, and T5 additional treatments, which exhibited the highest feed conversion efficiencies of 1.31, 1.31, and 1.30, respectively, in contrast to T1, and T2, which recorded efficiencies of 1.44, and 1.45, respectively, however the supplementary, the two treatments T2 and

T1 did not show any significant differences between them. In the fourth week, treatment T5 exhibited statistically significant differences, achieving the highest feed conversion efficiency of 1.21, in contrast to treatment T3 which recorded efficiency of 1.37. Although T1, T2, and T4 exhibited a feed conversion efficiencies of 1.29, 1.30, and 1.26 during the fourth week, the T3 addition treatment had a decreased feed conversion efficiency relative to the T1, T2, and T4 addition treatments. No significant changes were observed in cumulative feed conversion efficiency from weeks 1 to 5 across all addition treatments.

Table 5. Addition of Variable Proportion of seaweed powder to the diet and their effect on feed conversion efficiency of broiler chickens (g/bird) during the week for 5 weeks (mean ± S E).

Age (weeks)	Treatments					P-Value
	T1	T2	T3	T4	T5	
1	1.29±0.03	1.40±0.24	1.16±0.06	1.10±0.02	1.115±0.03	0.400
2	1.31±0.02	1.33±0.03	1.34±0.03	1.33±0.03	1.38±0.03	0.620
3	1.44±0.00 b	1.45±0.05 b	1.31±0.05 a	1.31±0.04 a	1.30±0.01 a	0.039
4	1.29±0.03 ab	1.30±0.02 ab	1.37±0.02 b	1.26±0.07 ab	1.21±0.04 a	0.235
5	1.32±0.04 a	1.33±0.06 a	1.23±0.07 a	1.24±0.06 a	1.23±0.02 a	0.519
1-5	1.33±0.02 a	1.33±0.01 a	1.29±0.02 a	1.26±0.03 a	1.25±0.008 a	0.136

T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.
Different letters within a row indicate significant differences between means at P≤0.05 according to Duncan's multiple range test.T1: Control (no supplement), T2, T3: 7.5 and 15 g seaweed powder/kg feed supplemented, T4, T5: 22.5 and 30 g seaweed powder/kg feed supplemented.
Different letters within a row indicate significant differences between means at P≤0.05 according to Duncan's multiple range test.

Conclusion

Adding 22.5 and 30 g/kg of seaweed powder (spirulina) to broiler diets, led to an improvement in the productive traits represented by average live body weight and cumulative weight gain. The weekly weight gain in the treatments of adding 22.5 and 30 g/kg seaweed powder (spirulina) of feed, recorded the best results. In addition to improving the productive qualities represented by feed conversion efficiency, While a weak effect was observed when adding 7.5 and 15 g/kg of seaweed powder (spirulina) to the feed, on the productive characteristics of broiler chickens.

References

[1] **Zhang, L., Jiang, Y., Buzdar, J. A., Ahmed, S., Sun, X., Li, F., ... & Li, C. 2025.** Microalgae: An Exciting Alternative Protein Source and Nutraceutical for the Poultry Sector. Food Science of Animal Resources, 45(1), 243.

[2] **Saeed, M., Babazadeh, D., Naveed, M., Alagawany, M., Abd El- Hack, M. E., Arain, M. A., ... & Chao, S. 2019.** In ovo delivery of various biological supplements, vaccines and drugs in poultry: current knowledge. Journal of the Science of Food and Agriculture, 99(8), 3727-3739.

[3] **United Nations. 2022.** "World Population to Reach 8 Billion This Year, as Growth Rate Slows." UN News: 1–5.

[4] **Nasir, N. A. N., S. A. Kamaruddin, I. A. Zakarya, and A. K. M. A. Islam. 2022.** "Sustainable Alternative Animal Feeds: Recent Advances and Future Perspective of Using Azolla as Animal Feed in Livestock, Poultry and Fish Nutrition." Sustainable Chemistry and Pharmacy 25 (November 2021): 100581.

[5] **OECD/FAO. 2021.** "Chapter 6: Meat." OECD-FAO Agricultural Outlook 2021-2030:163–177.

[6] **Amato, H. K., Wong, N. M., Pelc, C., Taylor, K., Price, L. B., Altabet, M., et al. 2020.** Effects of concentrated poultry operations and cropland manure application on antibiotic resistant Escherichia coli and nutrient pollution in Chesapeake bay watersheds. Sci. Total Environ. 735, 139401. doi: 10.1016/j.scitotenv.2020.139401.

[7] **Safdar M, Hassan F, Khan MS, Hassan Khan A, Junejo Y, Ozaslan M, Arain MA, Behan AA. 2024.** In silico analysis of polyphenols modulate bovine PPARγ to increase milk fat synthesis in dairy cattle via the MAPK signaling pathways. J Anim Sci102:skae248.doi:10.3389/fvets.2020.00516.

[8] **Behan AA, Ahmed S, Hassan MF, Buzdar JA, Shah QA, Khan KA, Arain MA.2024.** Nutritional and health beneficial application of lactoferrin in some animal species: An updated review. Proc Indian Natl Sci Acad (in press). doi:10.1007/s43538-024-00369-9.

[9] **Nabi F, Arain MA, Hassan MF, Shah QA, Almutairi MH, Buzdar JA. 2024.** Effects of in ovo supplementation of selenium(Se) and zinc (zn) on hatchability and production performance of broiler chickens. J Comp Physiol B 194:887-897.

[10] **Salah M, A., Duha B, D., & Nazar Abbas, M. 2024.** Effect of Adding Date Palm Pollen and Physical Diet Form on Productive Performance and Egg Quality of Female Quail.

[11] **Abdel-Wareth, A. A., Williams, A. N., Salahuddin, M., Gadekar, S., & Lohakare, J. 2024.** Algae as an alternative source of protein in poultry diets for sustainable production and disease resistance: Present status and future considerations. Frontiers in Veterinary Science, 11, 1382163.

[12] **Pestana, J. M., Puerta, B., Santos, H., Madeira, M. S., Alfaia, C. M., Lopes, P. A., ... & Prates, J. A. M. 2020.** Impact of dietary incorporation of Spirulina (Arthrospira platensis) and

exogenous enzymes on broiler performance, carcass traits, and meat quality. Poultry science, 99(5), 2519-2532.

[13] Michalak, I., & Mahrose, K. 2020. Seaweeds, intact and processed, as a valuable component of poultry feeds. Journal of Marine Science and Engineering, 8(8), 620.

[14] Nhlane, L. T., Mnisi, C. M., Mlambo, V., & Madibana, M. J. 2020. Nutrient digestibility, growth performance, and blood indices of Boschveld chickens fed seaweed-containing diets. Animals, 10(8), 1296.

[15] Matshogo, T. B., Mnisi, C. M., & Mlambo, V. 2020. Dietary green seaweed compromises overall feed conversion efficiency but not blood parameters and meat quality and stability in broiler chickens. Agriculture, 10(11), 547.

[16] Spínola, M. P., Costa, M. M., & Prates, J. A. 2022. Digestive constraints of Arthrospira platensis in poultry and swine feeding. Foods, 11(19), 2984.

[17] Bortolini, D. G., Maciel, G. M., Fernandes, I. D. A. A., Pedro, A. C., Rubio, F. T. V., Branco, I. G., & Haminiuk, C. W. I. 2022. Functional properties of bioactive compounds from Spirulina spp.: Current status and future trends. Food Chemistry: Molecular Sciences, 5, 100134.

[18] Tounsi, L., Hentati, F., Hlima, H. B., Barkallah, M., Smaoui, S., Fendri, I., ... & Abdelkafi, S. 2022. Microalgae as feedstock for bioactive polysaccharides. International Journal of Biological Macromolecules, 221, 1238-1250.

[19] Aviagen. 2023. Ross Broiler Management Handbook. Available online from:https://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross BroilerHandbook2018-EN.pdf.

[20] Duncan, C. B. 1955. Multiple rang and Multiple "F" test. Biometric, 11 (1):1-42.

[21] Al-Rawi, Khashi Mahmoud, Abdul Aziz Muhammad Khalaf Allah. 1980. Design and analysis of agricultural experiments. Dar Al-Kutub for Printing and Publishing. University of Al Mosul. The Republic of Iraq.

[22] SPSS Inc.2011. Statistical Package for social Sci version 20 for windows LEAD Technologies. Inc. USA .

[23] National Research Council. 1994. Nutrient requirements of poultry. 9th rev.ed. National Academies Press, Washington, Dc.

[24] Abed, H. A., Ahmed, A. M. H., Abdel-Azeem, F., & Shourrap, M. I. 2023. Effect of spirulina platensis algae supplementation on growth performance, physiological status of broilers during summer season. Egyptian Journal of Nutrition and Feeds, 26(1), 101-107.

[25] Mullenix, G. J., Greene, E. S., Emami, N. K., Tellez-Isaias, G., Bottje, W. G., Erf, G. F., ... & Dridi, S. 2021. Spirulina platensis inclusion reverses circulating pro-inflammatory (chemo) cytokine profiles in broilers fed low-protein diets. Frontiers in Veterinary Science, 8, 640968.

[26] Kalia S, Lei XG. 2022. Dietary microalgae on poultry meat and eggs: Explained versus unexplained effects. Curr Opin Biotechnol 75:102689.

ISSN 2072-3857

[27] Valente, L. M., Cabrita, A. R., Maia, M. R., Valente, I. M., Engrola, S., Fonseca, A. J., ... & Freire, J. P. B. 2021. Microalgae as feed ingredients for livestock production and aquaculture. In Microalgae (pp. 239-312). Academic Press.

[28] Atiyah, W. R., & Hamood, M. F. 2021. Enhancing the productive performance of broiler chickens by adding Spirulina platensis compared with probiotic, prebiotics, and oxytetracycline. The Iraqi Journal of Veterinary Medicine, 45(1), 31-36.

[29] Mnisi CM, Oyeagu CE, Akuru EA, Ruzvidzo O, Lewu FB. 2023. Sorghum, millet and cassava as alternative dietary energy sources for sustainable quail production: A review. Front Anim Sci 4:1066388.

[30] Gržinić G, Piotrowicz-Cieślak A, Klimkowicz-Pawlas A, Górny RL, Ławniczek- Wałczyk A, Piechowicz L, Olkowska E, Potrykus M, Tankiewicz M, Krupka M, Siebielec G, Wolska L. 2023. Intensive poultry farming: A review of the impact on the environment and human health. Sci Total Environ 858:160014.

[31] Lingala S, Freymond M, Tshering PP, Kumari P, Kraemer K, Beesabathuni K. 2024. The egg hub model: A sustainable and replicable approach to address food security and improve livelihoods. Curr Dev Nutr 8:103795.

[32] Abdelfatah, S. H., Yassin, A. M., Khattab, M. S., Abdel-Razek, A. S., and Saad, A. H. 2024. Spirulina platensis as a growth booster for broiler; Insights into their nutritional, molecular, immunohistopathological, and microbiota modulating effects. BMC Veterinary Research, 20(1), 11.

[33] Costa, M. M., Spínola, M. P., Tavares, B., Pestana, J. M., Tavares, J. C., Martins, C. F., ... & Prates, J. A. (2024). Effects of high dietary inclusion of Arthrospira platensis, either extruded or supplemented with a super-dosing multi-enzyme mixture, on broiler growth performance and major meat quality parameters. BMC Veterinary Research, 20(1), 176.

ISSN 2072-3857