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Growth performance, serum biochemistry, and carcass traits of growing rabbits fed supplemental levels of *Spirulina platensis*

Farag B. F.[a]*, Khalifa A. M. A.[b], Soliman A. S. H. [b]

[a]*Animal Production Department, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt*
[b]*Department of Animal production, Faculty of Agriculture, New Valley University, New Valley, Egypt*

Abstract

This study investigated the effects of fodder supplemented with various levels of *Spirulina platensis* (SP) on the growth, serum biochemical parameters, antioxidant, and carcass performance of New Zealand White (NZW) rabbits. 45 healthy growing rabbits at 35 d of age were selected for this study. Rabbits were divided into 3 treatments containing 5 replicates per group, and each replicate had 3 rabbits. The 1st treatment was control. The 2nd to 3rd treatments were received a basal diet with supplements with SP at doses of 1.5 and 2.5 gm SP/kg diet, respectively. The whole experiment lasted 55 days, Results showed that that feed intake and growth rates increased (P≤0.05) by using 1.5 and 2.5 gm SP/kg diet, with significantly improved FCR. There were no changes on albumin, globulin, and urea-N, creatinine, among groups. While Adding SP led to significantly (P≤0.05) increase TP, TAC, T3, and T4 compared with control. However, total cholesterol, ALT and AST were significantly decreased (P≤0.05) with SP compared with control group. Additionally, significant increases were observed for all carcass performances, including the weight of hot carcass, carcass yield, organs weights, and carcass parts. The presented results concluded that SP supplementation improves feed intake, blood biochemistry, antioxidant status, growth performance, and carcass performance in rabbits under New Valley conditions, Egypt.

Keywords: *Spirulina platensis*, productive performance, antioxidant, rabbits.

*Corresponding author: Farag B. F.,
E-mail address: belalmohammed.4419@azhar.edu.eg

1. Introduction

Developing countries suffer from a shortage of animal protein supply. Ruminant production, such as cows, buffalo, goats and sheep were unable to fill the gaps due to long gestation intervals, lack of feed, poor genetic for production performance and high disease rates (FAO, 2017). Nowadays, there is great interest in the benefits of rabbit farming in Egypt as a developing country as a means of alleviating the protein deficiency. Rabbits' benefits are mostly attributable to their greater rates of reproduction, development and maturation, low competition for human diets and meat quality (Badawi *et al*., 2016). When animals in New Valley, Egypt are exposed to heat stress (HS), for instance under summer heat waves, it can incur unfavorable effect on animal welfare and efficiency. New Valley is a desert governorate located in the western Egypt. This area is dry and arid (Soliman *et al*., 2024). The ambient temperature (AT) ranges between 43- 48°C in summer to 8°C during winter (Kassab *et al*., 2021). Regardless of the adaptation shown by some breeds, with the beginning of summer, a decline in production is observed, leading to a shortage of meat production and necessitating the import of meat, which requires huge foreign exchange. Rabbits are a relatively small industry, but they are gaining popularity all over the world. It is very sensitive to HS (Marai *et al*., 2002) because they cannot regulate their body temperature under HS conditions (Liu *et al*., 2022). Prolonged subjected to HS increase the body temperature (Ebeid *et al*., 2023). Rabbits are more likely to develop HS than other animals (Liu *et al*., 2022), due to their limited ability to sweat and cool themselves (Marai *et al*., 2002). To mitigate the deleterious effects of HS on rabbits, a number of nutritional techniques have been executed for this purpose (Abdel-Wareth *et al*., 2022; Bashar *et al*., 2024). *Spirulina platensis* (SP) is a type of blue-green microalga recognized as feed supplement due to its higher content of protein, fatty acids, vitamins and minerals (Abd El-Hamid, 2024 and Bashar *et al*., 2024). This cyanobacterium has gained popularity for its potential anti-inflammatory, immune-stimulating, and antioxidant activity (Maddiboyina *et al*., 2023). SP is rich in biologically active compounds such as tocopherols, phenolic acids, and γ-linolenic acids, which contribute to its therapeutic effects (Sharma *et al*., 2019). Microalga also contains valuable pigments like phycobiliproteins and β-carotene, as well as polyunsaturated fatty acids (Zhou *et al*., 2024). Bioactive peptides derived from SP have shown promise in various medicinal applications, including antihypertensive, antimicrobial, and anti-diabetes activities (Lafarga *et al*., 2020). Despite its widespread use and potential benefits, more research is urgently needed to elucidate the molecular and cellular mechanisms underlying Spirulina's effects. Thus, this study investigated the effectiveness of supplementing high and low SP levels on feed intake, production, and blood criteria of growing rabbits.

2. Materials and methods

Our study conducted at commercial farm

(Al-Tahan rabbits farm) located in Elkharga city, New Valley governorate, Egypt (25°27'36.0"N 30°32'49.8"E) during April and May 2024.

2.1 Animals, housing and experimental design

Healthy 45 NZW-rabbits aged 35 days (average BW 606.39 ± 3.23 g) were used in this trial. Rabbits were distributed into 3 treatments (n = 15/ group). The 1st treatment (control), the 2nd to 3ed treatments were received a basal diet with supplements with SP at doses of 1.5 and 2.5 gm SP/kg diet, respectively. The basal diet was formulated according to NRC (1977). The ingredients of the basal diets and composition are shown in Table (1).

Table (1): Feed ingredients and chemical determined composition of the basal diet.

Ingredients	(kg/ton)	Chemical composition (%)	Basal diet
Yellow corn	120.0	Crude protein	17.2
Barley	140.0	Crude fiber	13.6
Molasses	30.0	Ether extract	2.8
Alfalfa hay	350.0	Nitrogen-free extract	56.8
Wheat bran	150.0	Ash	9.6
Soybean meal 44%	190.0		
Dicalcium phosphate	6.0		
Limestone	6.0		
Sodium chloride	4.0		
Vitamin and minerals premix*	4.0		

2.2 Growth performance

Rabbits were weighed at the beginning of the experiment and four weeks later (35 to 90 days of age). Daily feed intake (FI) was estimated, and the FCR was computed as the ratio of FI to weight gain.

$$\text{The RGR} = \frac{(wf - wi)}{\frac{1}{2}(wi + wf)} \times 100$$

where W i and Wf denote the rabbit weights at the beginning and completion of the trial.

2.3 Blood sampling, biochemistry, and antioxidant status

In the last week of the experiment, 5 rabbits / group were selected for blood samples for biochemical and hormonal evaluation. Blood samples were collected from the marginal ear vein without adding any anti-coagulant to collect serum for biochemical and hormonal profile. Samples were left under room temperature for 3 hours to clot and centrifuge at 3000 × for10min at 5 ºC. Serum samples were then placed into epindorf tubes and refrigerated until use. Serum was analyzed for TP and albumin, total cholesterol, urea-N, creatinine, ALT, AST and TAC. While concentration of globulin was determined by subtracting the TP from Alb. All biochemical analyses were assay using spectrophotometer commercial kits (*Bio* di- agnostics, Cairo, Egypt). Direct radioimmunoassay (RIA) technique was performed for determination of thyroid hormones. The concentrations of thyroxine (T_4, µg/dl) and triiodothyronine (T_3, ng/ml) were measured according to Barker and Silverto (1982).

2.4 Carcass characteristics

At the end of the experiment, 12 rabbits (4 rabbits / group) were selected for slaughter. The rabbits fasted for 12 hours. The next day, rabbits were weighed individually and were sacrificed immediately at the farm's abattoir. Skin, feet, genitals, urinary bladder, and digestive tract were removed. The hot carcass (HC) and internal organs (liver, heart, spleen, kidneys, and lungs) were weighed. Carcass cuts (shoulders, thorax, legs, loin and head) were also weighed. Carcass yield is calculated as follows:

$$\text{Carcass yield} = \frac{HC}{PSW} \times 100$$

2.5 Statistical analysis

Data was analyzed by SAS software (SAS, 2004). Duncan's Multiple Range Test (Duncan, 1955) were used for testing for significance for difference among treatment means the model used is $Y_{ij} = \mu + A_j + £_{ij}$.

3. Results and Discussion

3.1 Feed intake and growth performance

The growth performance was presented in Table (2). Results show that rabbit's growth (DWG, BWG, FBW, FI and RGR) increased ($P \leq 0.05$) by feeding 1.5 and 2.5 gm SP/kg diet, as well as significantly improved FCR by adding SP. According to many studies, SP supplementation increased growth rates of rabbits (Alazab *et al*., 2020; El-Desoky *et al*., 2013); does rabbit (El-Ratel, 2017); broiler chicks (Zeweil *et al*., 2016). Furthermore, Jin *et al*. (2020) reported that SP as a feed supplement had a positive effect on growth rate. In addition, El-Sabagh *et al*. (2014) observed that SP has a significant impact on FBW, and FCR of lambs. The results of improved growth performance of SP supplements in diets of growing rabbits may be attributed to the synergistic impact of the chemical components of SP supplements which have a good nutritional profile (Abundant in carotenoids, abundant in proteins including amino acids, minerals and vitamins) (Koli *et al*., 2022). SP has been found to enhance immune function, growth, and reproduction as shown by Khan *et al*. (2005). The effect of SP on the average of FI, FCR and RGR improved ($P \leq 0.05$) significantly because of improved ADG (Table 2) and found the same pattern which showed in body weight gain.

3.2 Blood biochemistry and antioxidant status

Table (3) noted the biochemical parameters and total antioxidant capacity. Adding different levels of SP not affected

($P > 0.05$) the albumin, globulin, and urea-N, creatinine. While the levels of cholesterol, ALT and AST were significantly lower with SP. While rabbits fed SP had significantly ($P \leq 0.05$) increase the total protein. Serum concentration of TAC in both SP groups was significantly increased. Meanwhile, significantly increase in concentrations of T3 and T4 were found with both SP groups.

Table (2): Growth rates of NZW rabbits as affected by SP supplementation.

Parameter	*Spirulina platensis* (gm/kg diet)			± SEM	*P*-values
	Control	1.5	2.5		
Growth performance					
Initial BW/ g	604.17	605.83	609.17	3.234	0.8402
Final body weight / g	1823.50^{b}	1887.58^{a}	1889.25^{a}	10.367	0.0070
Total weight gain / g	1219.33^{b}	1281.75^{a}	1280.08^{a}	10.731	0.0199
Average daily gain / g	24.38^{b}	25.63^{a}	25.60^{a}	0.215	0.0199
Total feed intake / g / h	4575.83^{b}	4587.50^{a}	4585.00^{a}	1.933	0.0299
Daily feed intake / g / h	91.51^{b}	91.75^{a}	91.70^{a}	0.039	0.0299
FCR	3.75^{a}	3.58^{b}	3.58^{b}	0.030	0.0202
RGR	100.45	102.78	102.47	0.554	0.1977

$^{a\ and\ b}$ indicate the differences among groups within each row at ($P \leq 0.05$).

Table (3): Blood biochemistry of NZW rabbits affected by SP supplementations.

Parameter	*Spirulina platensis* (gm/kg diet)			± SEM	*P*-values
	Control	1.5	2.5		
Total protein (g/dl)	5.90^{b}	6.20^{a}	6.27^{a}	0.066	0.0484
Albu min (g/dl)	3.46	3.66	3.55	0.070	0.6134
Globulin (g/dl)	2.44	2.54	2.71	0.084	0.5341
ALT (U/I)	42.63^{a}	39.57^{ab}	38.93^{b}	0.722	0.0874
AST (U/I)	34.20^{a}	30.16^{ab}	27.27^{b}	1.154	0.0346
Urea (mg/dl)	34.60	32.37	32.30	0.631	0.3166
Creatinine (mg/dl)	1.79	1.64	1.63	0.038	0.1907
Total cholesterol (mg/dl)	108.00^{a}	98.12^{b}	96.18^{b}	2.089	0.0307
TAC	0.495^{b}	0.866^{a}	0.878^{a}	0.062	8.0015

$^{a\ and\ b}$ indicate the differences among groups within each row at ($P \leq 0.05$).

Our results of the current study are supported by those findings by Bashar *et al*. (2022) who reported higher TP in rabbits fed 1 g SP/kg. Moreover, Abd Elzaher *et al*. (2023) found higher TP in quail chicks supplied with 0.5 g SP/kg diet. Also, albumin and globulin had no significance. Meanwhile, Khalifa *et al.* (2016) found that urea levels decreased in goat fed diets containing SP microalga. Moreover, the urea concentrations were reduced significantly in goats fed microalgae SP (Abd El-Hamid, 2024). El-Deeb *et al*. (2022) found that supplementing ewe's diets with SP algae reduced ALT enzyme activity. This decrease in our results supports the protective role of SP against liver dysfunction (Azab *et al*., 2013). As a result of SP containing bioactive components, including fatty acids, vitamins, phenolic, and minerals, in the mass-spectrometry chemical analyses (Garcia-Martinez *et al*., 2007). Total cholesterol was significantly lower with SP. The presented data are supported by Sugiharto *et al*. (2018), and Zaghari and Hajati, (2018) who found that SP supplements to broiler diets reduced total cholesterol. Moreover, Mahmoud *et al*. (2016) found that adding SP to broiler's diets led to significantly decrease cholesterol and triglyceride. In this regard, SP can decrease total cholesterol due to its antioxidant activity (Liang *et al*., 2020). Endogenous free radical formation in animals increases under HS and reduces the animal's antioxidant activity (Soliman *et al.*, 2023). On this regard, TAC of SP-supplemented rabbits were higher than that of control, indicating that SP enhances antioxidant activity and reduces homocysteine to prevent oxidative stress. In rats, SP treatment improved liver function markers, and enhanced antioxidant enzyme activities, demonstrating hepato-protective effects (Aissaoui *et al*., 2017). The impact of dietary SP supplementation on thyroid hormone T3 and T4 of rabbits is shown in Figure (1). Results showed that SP supplementation significantly increased the T_3 and T_4 hormones. Studies have demonstrated the ability of SP to alleviate radiation-induced thyroid dysfunction by reducing oxidative stress, improving antioxidant enzyme activity, and normalizing thyroid hormone levels in rats (Abd Allah, 2021; Ebrahim, 2020).

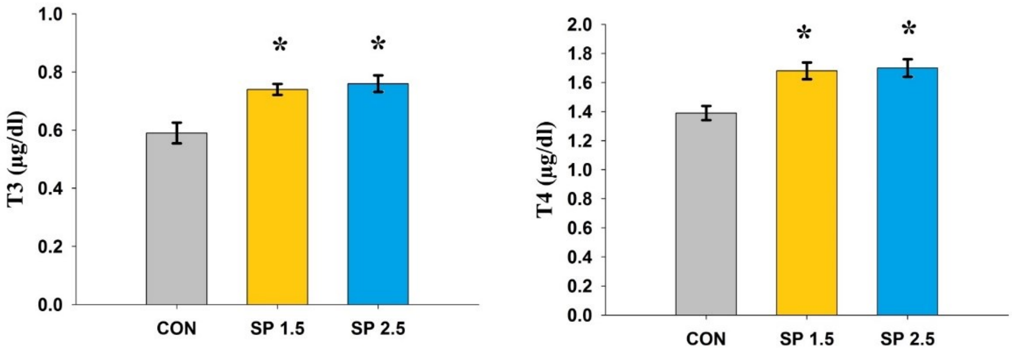

Figure (1): Thyroid hormones in growing rabbits after treated with SP. Data are presented as means ± stander error.

In our study, the increased T_3 and T_4 concentrations in SP treated rabbits; however, it is necessary to clarify the mechanism behind the influence of SP in modifying thyroid hormone concentrations. There is a binding site of glycine in the hypothalamic N-methyl-d-aspartate (NMDA) receptor (Johnson and Ascher, 1987), and it is generally believed that glycine is needed for the receptor of NMDA activation (Kleckner and Dingledine, 1988). SP contains a variable amount of glycine (Bashir *et al*., 2016; Bortolini *et al*., 2022), thus, increases the secretion of thyroid-stimulating hormone from pituitary gland, leading to increased serum T_3 and T_4 concentrations.

3.3 Carcass characteristics

Carcass traits are shown in Table (4). Pre slaughter weight, hot carcass, carcass yield, liver, carcass parts (Shoulders, Legs, Thorax, Loin and head) were significantly increased in SP groups. While there were non-significant differences in organs weight (heart, kidneys, lungs and spleen) among the treatments, as presented in Table (4). Regarding the impact of SP, our results agree with Hamza (2019) who found that, carcass traits were significantly higher in rabbits fed on diets contains 0.1 or 0.2% SP. In Addition, Mariey *et al*. (2014) reported that carcass traits of broiler chicks were increased significantly in SP treatment.

Table (4): Carcass traits of growing NZW rabbits affected by addition SP.

Parameter	Spirulina platensis (gm/kg diet)			±SEM	*P*-values
	Control	1.5	2.5		
Pre-slaughter weight (g)	1829^b	1857.5^a	1861.52^a	6.809	0.0004
Hot carcass weight (g)	925.09^c	975.32^b	1035.70^a	13.337	0.0008
Carcass yield (%)	50.58b	52.50^b	55.65^a	0.615	0.0042
Organs weight (g)					
Liver	56.87^b	59.05^b	75.82^a	2.112	0.0004
Heart	3.75	3.86	3.97	0.091	0.1596
Kidneys	10.84	10.54	10.53	0.153	0.6822
Lungs	11.83	10.77	12.26	0.301	0.1705
Spleen	1.59	1.88	1.90	0.066	0.2909
Carcass parts (g)					
Head	83.93^b	98.28^a	101.22^a	2.266	0.0001
Shoulders	170.55^b	181.87^a	186.13^a	2.515	0.0217
Legs	312.05^b	344.97^a	343.60^a	3.748	0.0046
Thorax	142.41^b	141.39^b	163.27^a	2.418	0.0249
Loin	216.15^b	208.80^b	241.48^a	7.633	0.0407

$^{a\ and\ b}$ indicate the differences among groups within each row at ($P\leq0.05$).

Shanmugapriya and Saravana (2014) found that the breast, liver and heart weights increased in chicks fed diets with 0.1% of SP. In contrast, no differences on carcass weight were detected in rabbits, as found by Mahmoud *et al*. (2017) when adding SP in the diet of rabbits.

5. Conclusion

Our results shows that SP microalgae improve feed intake, growth, blood parameters, antioxidant status, and carcass traits in growing rabbits. Although rabbits receiving a 2.5 gm SP/kg diets had the best performance. Lower dose of 1.5 gm/kg diet also improved growth, antioxidant status and carcass traits.

References

Abd Allah, A. L. (2021), "Prophylactic effect of *Spirulina versus* monosodium glutamate-induced thyroid disorders in experimental rats", *Egyptian Journal of Nutrition and Health*, Vol. 16, pp. 45–59.

Abd El-Hamid, I. S. (2024), "Influence of Spirulina platensis supplementation alone or mixed with live yeast on blood constituents and oxidative status of Damascus goats and their newborns", *Journal of Applied Veterinary Sciences*, Vol. 9, pp. 1–12.

Abd Elzaher, H. A., Ibrahim, Z. A., Ahmed, S. A., Salah, A. S., Osman, A., Swelum, A. A. and Abd El-Hack, M. E. (2023), "Growth, carcass criteria, and blood biochemical parameters of growing quails fed *Arthrospira platensis* as a feed additive", *Poultry Science*, Vol. 102, Article No. 103205.

Abdel-Wareth, A. A. A., Amer, S. A., Mobashar, M. and El-Sayed, H. G. M. (2022), "Use of zinc oxide nanoparticles in growing rabbit diets to mitigate hot environmental conditions for sustainable production and improved meat quality", *BMC Veterinary Research*, Vol. 18, Article No. 354.

Aissaoui, O., Amiali, M., Bouzid, N., Belkacemi, K. and Bitam, A. (2017), "Effect of Spirulina platensis ingestion on abnormal biochemical and oxidative stress parameters in the pancreas and liver of alloxan-induced diabetic rats", *Pharmaceutical Biology*, Vol. 55, pp. 1304–1312.

Alazab, A. M., Ragab, M. A., Fahim, H. N., El Desoky, A. E. M. I., Azouz, H. M. M. and Shazly, S. A. (2020), "Effect of *Spirulina platensis* supplementation in growing rabbit diets on productive performance and economic efficiency", *Journal of Animal and Poultry Production*, Vol. 11, pp. 325–330.

Azab, S. S., Abdel-Daim, M. and Eldahshan, O. A. (2013), "Phytochemical, cytotoxic, hepatoprotective, and antioxidant properties of *Delonix regia* leaf extract", *Medicinal Chemistry Research*, Vol. 22, pp. 4269–4277.

Badawi, L., Bakr, E., Mousa, M. and Abdel Ghaffar, M. (2016), "Effect of feeding rosemary and marjoram on reproductive performance of rabbit does under Sinai conditions", *Journal of Animal, Poultry and Fish Production*, Vol. 5, pp. 9–16.

Barker, F. S. and Silverton, R. E. (1982), *Introduction to Medical Laboratory Technology*, 5th ed., Butterworth, London, pp. 481–494.

Bashar, A. M., Abdelnour, S. A., El-Darawany, A. A. and Sheiha, A. M. (2024), "Dietary supplementation of microalgae and/or nanominerals mitigates negative effects of heat stress in growing rabbits", *Biological Trace Element Research*, Vol. 202, pp. 3639–3652.

Bashar, A., El-Darawany, A. and Sheiha, A. (2022), "Effect of selenium nanoparticles and/or *Spirulina platensis* on growth, hematobio-chemical, antioxidant status, hormonal profile, immunity, and apoptosis of growing rabbits exposed to thermal stress", *Egyptian Journal of Rabbit Science*, Vol. 32, pp. 77–103.

Bashir, S., Sharif, M. K., Butt, M. S. and Shahid, M. (2016), "Functional properties and amino acid profile of Spirulina platensis protein isolates", *Pakistan Journal of Scientific and Industrial Research: Biological Sciences*, Vol. 59, pp. 12–19.

Bortolini, D. G., Maciel, G. M., Fernandes, I. D. A. A., Pedro, A. C., Rubio, F. T. V., Branco, I. G. and Haminiuk, C. W. I. (2022), "Functional properties of bioactive compounds from *Spirulina* spp.: Current status and future trends", *Food Chemistry: Molecular Sciences*, Vol. 5, Article No. 100134.

Duncan, D.B. (1955), "Multiple range and multiple F-test", *Biometrics*, Vol. 11, pp. 1–42.

Ebeid, T. A., Aljabeili, H. S., Al-Homidan, I. H., Volek, Z. and Barakat, H. (2023), "Ramifications of heat stress on rabbit production and role of nutraceuticals in alleviating its negative impacts: an updated review", *Antioxidants*, Vol. 12, Article No. 1407.

Ebrahim, R. M. (2020), "Prophylactic effect of *Spirulina platensis* on radiation-induced thyroid disorders and alteration of reproductive hormones in female albino rats", *International Journal of Radiation Research*, Vol. 18, pp. 83–90.

El-Deeb, M. M., Abdel-Gawad, M., Abdel-Hafez, M. A. M., Saba, F. E. and Ibrahim, E. M. M. (2022), "Effect of adding *Spirulina platensis* algae to small ruminant rations on productive, reproductive traits, and some blood components", *Acta Scientiarum: Animal Sciences*, Vol. 45, Article No. e57546.

El-Desoky, G. E., Bashandy, S. A., Alhazza, I. M., Al-Othman, Z. A., Aboul-Soud, M. A. and Yusuf, K. (2013), "Improvement of mercuric chloride-induced testis injuries and sperm quality deteriorations by *Spirulina platensis* in rats", *PloS One*, Vol. 8, Article No. e59177.

El-Ratel, I. T. (2017), "Reproductive performance, oxidative status, and blood metabolites of doe rabbits administered with Spirulina algae", *Egyptian Poultry Science Journal*, Vol. 37, pp. 1153–1172.

El-Sabagh, M. R., Eldaim, M. A. A., Mahboub, D. H. and Abdel-Daim, M. (2014), "Effects of Spirulina platensis algae on growth performance, antioxidative status, and blood metabolites in fattening lambs", *Journal of Agricultural Science*, Vol. 6, pp. 92–98.

FAO (2017), *The Future of Food and Agriculture: Trends and Challenges*, Food and Agriculture Organization of the United Nations, Rome, Italy, p. 163.

García-Martínez, D., Rupérez, F. J., Ugarte, P. and Barbas, C. (2007), "Tocopherol fate in plasma and liver of streptozotocin-treated rats that orally received antioxidants and Spirulina extracts", *International Journal for Vitamin and Nutrition Research*, Vol. 77, pp. 263–271.

Hamza, S. S. (2019), "Effect of *Kemenzme spirulina* on growing rabbits' performance", *Current Science International*, Vol. 1, pp. 140–146.

Jin, S. E., Lee, S. J., Kim, Y. and Park, C. Y. (2020), "Spirulina powder as a feed supplement to enhance abalone growth", *Aquaculture Reports*, Vol. 17, Article No. 100318.

Johnson, J. W. and Ascher, P. (1987), "Glycine potentiates the NMDA response in cultured mouse brain neurons", *Nature*, Vol. 325, pp. 529–531.

Kassab, A., Hamdon, H., Daghash, H. and Soliman, A. (2021), "Impact of betaine supplementation as anti-stress on some hematological parameters and thermoregulatory responses of Aberdeen Angus cows in arid subtropical regions", *New Valley Journal of Agricultural Science*, Vol. 1, pp. 89–97.

Khalifa, E. I., Hassanien, H. A., Mohamed, A. H., Hussein, A. M. and Abd-Elaal, A. A. (2016), "Influence of addition of Spirulina platensis algae powder on reproductive and productive performance of dairy Zaraibi goats", *Egyptian Journal of Nutrition and Feeds*, Vol. 19, pp. 211–225.

Khan, Z., Bhadouria, P. and Bisen, P. S. (2005), "Nutritional and therapeutic potential of Spirulina", *Current Pharmaceutical Biotechnology*, Vol. 6, pp. 373–379.

Kleckner, N. W. and Dingledine, R. (1988), "Requirement for glycine in activation of NMDA-receptors expressed in *Xenopus oocytes*", *Science*, Vol. 241, pp. 835–837.

Koli, D. K., Rudra, S. G., Bhowmik, A. and Pabbi, S. (2022), "Nutritional, functional, textural, and sensory evaluation of Spirulina-enriched green pasta: A potential dietary and health supplement", *Foods*, Vol. 11, Article No. 979.

Lafarga, T., Fernández-Sevilla, J. M., González-López, C. and Acién-Fernández, F. G. (2020), "Spirulina for the food and functional food industries", *Food Research International*, Vol. 137, Article No. 109356.

Liang, Y., Bao, Y., Gao, X., Deng, K., An, S., Wang, Z. and Fan, Y. (2020), "Effects of Spirulina supplementation on lipid metabolism disorder, oxidative stress caused by high-energy diet in Hu sheep", *Meat Science*, Vol. 164, Article No. 108094.

Liu, H., Zhang, B., Li, F., Liu, L., Yang, T., Zhang, H. and Li, F. (2022), "Effects of heat stress on growth performance, carcass traits, serum metabolism, and intestinal microflora of meat rabbits", *Frontiers in Microbiology*, Vol. 13, Article No. 998095.

Maddiboyina, B., Vanamamalai, H. K., Roy, H., Ramaiah, Gandhi, S., Kavisri, M. and Moovendhan, M. (2023), "Food and drug industry applications of microalgae *Spirulina platensis*: A review", *Journal of Basic Microbiology*, Vol. 63, pp. 573–583.

Mahmoud, A. E., Naguib, M. M., Higazy, A. M., Sultan, Y. Y. and Marrez, D. A. (2017), "Effect of substitution of soybean with blue-green algae *Spirulina platensis* on performance and meat quality of growing rabbits", *American Journal of Food Technology*, Vol. 12, pp. 51–59.

Mahmoud, R. M., El-Rayes, T. and Eldamrawy, S. Z. (2016), "Effect of stocking density and *Spirulina platensis* algae supplementation as a feed additive on performance and physiological status of broiler chicks", *Egyptian Journal of Nutrition and Feeds*, Vol. 19, pp. 535–547.

Marai, I., Habeeb, A. and Gad, A. (2002), "Rabbits' productive, reproductive, and physiological performance traits as affected by heat stress: A review", *Livestock Production Science*, Vol. 78, pp. 71–90.

Mariey, Y. A., Samak, H. R., Abou-Khashba, H. A., Sayed, M. A. M. and Abou-Zeid, A. E. (2014), "Effect of using *Spirulina platensis* algae as a feed additive for poultry diets: 2- Productive performance of broilers", *Egyptian Poultry Science Journal*, Vol. 34, pp. 245–258.

NRC (1977), *Nutrient Requirements of Rabbits*, National Research Council, Washington, DC, USA.

SAS Institute Inc. (2004), *SAS Procedures Guide for Personal Computers*, Statistical Analysis System Institute Inc., Cary, NC, USA.

Shanmugapriya, B. and Saravana, S. B. (2014), "Supplementary effect of Spirulina platensis on performance, hematology, and carcass yield of broiler chicken", *Indian Streams Research Journal*, Vol. 4 No. 3, pp. 1–7.

Sharma, A., Kaur, K., Manjari, D. M. and Marwaha, D. (2019), "*Spirulina platensis* an 'ultimate food': A review", *International Journal of Research and Analytical Reviews*, Vol. 6, pp. 428–437.

Soliman, A., Daghash, M. W. H., Hamdon, H. and Mohamed, A. A. A. (2024), "Influence of betaine and zinc supplementation on milk production and its components, thermoregulatory responses, blood characteristics, and reproductive performance of lactating cows in arid subtropical regions", *Egyptian Journal of Animal Production*, Vol. 61, pp. 73–81.

Soliman, A. S. H., Daghash, H. A.,

Hamdon, H. A. and Kassab, A. Y. (2023), "Assessment of betaine as a feed additive to improve the metabolic status and reproductive performance of Aberdeen Angus cows in arid subtropical regions", *Egyptian Journal of Animal Production*, Vol. 60, pp. 131–136.

Sugiharto, S., Yudiarti, T., Isroli, I. and Widiastuti, E. (2018), "Effect of feeding duration of *Spirulina platensis* on growth performance, haematological parameters, intestinal microbial population, and carcass traits of broiler chicks", *South African Journal of Animal Science*, Vol. 48, pp. 98–107.

Zaghari, M. and Hajati, H. (2018), "Influence of dietary *Spirulina platensis* supplementation on growth, carcass characteristics, egg traits, and immunity response of Japanese quails", *Banats Journal of Biotechnology*, Vol. 19, pp. 29–42.

Zeweil, H., Abaza, I. M., Zahran, S. M., Ahmed, M. H., AboulEla, H. M. and Asmaa, A. S. (2016), "Effect of *Spirulina platensis* as a dietary supplement on some biological traits of chickens under heat stress condition", *Asian Journal of Pharmaceutical Sciences*, Vol. 6, pp. 8–12.

Zhou, Y., Huang, Z., Liu, Y., Li, B., Wen, Z. and Cao, L. (2024), "Stability and bioactivities evaluation of analytical grade C-phycocyanin during the storage of *Spirulina platensis* powder", *Journal of Food Science*, Vol. 89, pp. 1442–1453.