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EFFECT OF DIETARY ALGA ON BROILER CHICK'S GROWTH PERFORMANCE, MEAT COMPOSITION AND THEIR FATTY ACIDS CONTENT, BLOOD BIOCHEMISTRY AND SOME INTESTINAL HISTOMORPHOLOGICAL MEASUREMENTS

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ABSTRACT: A total of 420, 1 d old unsexed, Ross (308) broiler chicks were randomly distributed and divided equally into 7 dietary treatment groups with 3 replicates of 20 chicks each and kept under similar management conditions. Control group (T_1) was fed with basal diet (without supplementation). Experimental groups; T_2, T_3, T_4 and T_5 were given basal diet supplemented with 1 and 2 g/ kg diet of single of Spirulina (SP) or Chlorella (CV). Experimental groups; T6 and T7 were fed basal diet supplemented with (0.5g SP + 0.5g CV)/ kg diet and (1g SP + 1g CV)/ kg diet, respectively. Results obtained that: all birds fed diets added to algae (Spirulina and Chlorella) individually or mixed were significantly highest in average live body weight, best rate of feed conversion and a significant decrease in feed intake compared to the birds of the control group. It was noted that adding algae alone or mixed to the diet led to a significant improvement in the characteristics of the carcass and immune organs compared to the control at the age of 35 days. Adding Spirulina, Chlorella or their mixture to the diet led to an increase in the percentage of protein and some percentage fatty acids (lenolenic, linoleic, arachidonic and docosahexaenoic) and a decrease in the percentage of fat in the meat of the breasts and thighs of bird carcasses compared to the control group. Adding algae alone or mixed to the diet led to a significant increase in some blood serum components (total protein, albumin, and globulin, high-density lipoprotein (HDL) and glutathione peroxidase (GPx) and a decrease in the level of total lipids, cholesterol, low-density lipoprotein (LDL) and malondialdehyde (MDA) in the blood serum of birds compared to the control group. Histological, measurements in the intestines of treated birds feed diets singly or mixed Spirulina and Chlorella showed an increase in height, width, depth and thickness of villi compared to the control group birds. Economic efficiency and relative economic efficiency were improved by adding algae (Spirulina and Chlorella) singly or mixed into the diet. The highest values were for T_7: (1.18 and 140.48%, respectively), which were fed a diet supplemented with 1g Spirulina + 1g Chlorella/ kg compared to the control group (0.84 and 100, respectively). In conclusion, based on the results obtained from the experiment and the economic efficiency study, it became clear that it is possible to use algae (Spirulina and Chlorella) alone or mixed as feed additives to improve productive performance, carcass traits, oxidative status and economic efficiency in broiler chicks, without any negative effects on the general health of the birds under experimental conditions.

Keywords: Algae, broiler chicks, histomorphological measurements, meat fatty acids, performance and serum biochemical traits.

INTRODUCTION

Algae products are good sources of protein, vitamins, enzymes, trace elements, antioxidants, pigments, carbohydrates, fatty acids, but most importantly, they contain high amounts of the beneficial polyunsaturated fatty acids, that is, omega-3 fatty acids, particularly

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eicosapertaenoic acid and docosahexaenoic acid (EL-Sheekh *et al.,* 2023).

Algae are added to poultry diets primarily as a source of long-chain n-3 polyunsaturated fatty acids. Most studies indicate that microalgae, namely spirulina and chlorella derived from defatted biomass from biofuel production, can be successfully used as feed elements in poultry nutrition (Saadaoui *et al.,* 2021), The beneficial impact of poly unsaturated fatty acids on human health inspired interest in supplementing chicken diets with defatted microalgae to boost nutritional value, especially that of n-3 fatty acids, (Chaves *et al.,* 2021).

Spirulina is quickly becoming one of the most widely used natural feed additives in broiler diet across the globe, particularly in the organic and natural poultry industries. This is because of a variety of characteristics, including its high nutritional value, ability to increase broiler performance, feed utilization, antioxidant status, immunity and gastrointestinal health (Alghamdi *et al.,* 2024).

Chlorella vulgaris (CV) is a commercially important unicellular green microalgawhich is one of the most attractive algae due to its rich source of nutrients as well as rapid growth and easy cultivation (Coudert *et al.,* 2020). Aside from major nutritional components (proteins, lipids, fiber, carbohydrates, vitamins and minerals), chlorella contain bioactive compounds such as phenolics, terpenoids, steroids, polysaccharides and chlorellin with potential antibiotic and antioxidant activities (Anthony *et al.,* 2018). There are several reports investigating the supplementation of Chlorella spp in animal diets which indicated numerous profitable biochemical and physiological functions and immunomodulation (El-Abd and Hamouda, 2017). Chlorella considered being an effective alternative to antibiotic growth promoter (AGP) in the diets to maintain optimum health and productivity of the poultry and animal.

Studies have been conducted to examine the potential use of Chlorella poultry diets (Halle *et al.,* 2009). Kang *et al.* (2013) evaluated the nutritional value of Chlorella as apigment, protein and energy source for replacing common feeds. More research wasconducted to study the potential health benefits of Chlorella improve growth and productivity in birds by increasing gut microbial populations (Janczyk *et al.,* 2009).

In general, the effects of Spirulina and Chlorella supplementation on performance and product quality have recently been investigated of broilers Lee *et al.* (2023) and El-Sharnobey *et al.* (2023). Also, Alwaleed *et al.* (2021) found that Spirulina platensis boosted humeral and cellular immunological responses, as well as lymphoid organ development, in chicks.

The purpose of this study was to investigate effect of dietary supplementation of *Spirulina platensis, Chlorella vulgaris* or their mixture) on growth performance, carcass characteristic, meat composition and their fatty acids content, some serum biochemical parameters, some histomorphological intestinal measurements and economic efficiency under experimental conditions in broiler chickens.

MATERIALS AND METHODS

The present study carried out at a private farm in Nagiup Mahfous, Housh Issa, Al-Beheira, Egypt, throughout the experimental period from March to April, (2023).

1. Experimental birds and their management

Total number of 420 unsexed Ross (308) chicks, one-day-old purchased from Arab Poultry breeders Company ommat, Giza, Egypt and randomly distributed into seven equal, treatment groups, every treatment contains three replicates with 20 birds each. During the period of this experiment, chicks were housed in clean metal cages of (1.5 m width × 1 m length × 0.5 m height) provides with nipple drinkers and the trough feeders. Broiler chick's wing vaccinated and management Guide (Ross 308 broiler commercial) AA-Broiler-Hand book 2020 – EN.Pdf). All birds were kept under the same managerial and environmental conditions with A 23 h of light and 1 h of darkness lighting schedule was maintained for the duration of the experiment. The initial temperature was 33°C at the first day of age and decreased approximately 2°C/ week until 24°C, which was maintained at this temperature until the end of the experimental period. Feed was offered ad-libitum in mash form. The clean fresh water was an available for broiler chicks all over the experimental period.

2. Experimental diets

All birds were fed a starter diets from (1 - 10 days of age), grower diet from (11 - 24 days of age) and finisher diets from (25 days of age until marketing; 35 days of age) as shown in Table 1. Two corn-soybean based basal diets were formulated to be fed during starter, grower and finisher diets in this experimental period. The broiler diets were formulated the meet or exceed the nutritional requirements according to National Research Council's nutrient (NRC, 1994). The basal corn-soybean meal starter diet contained approximately, 23.28% CP and 3002 ME kcal/ kg diet, in grower diet 21.3% CP and 3119 ME kcal/ kg diet and finisher diet 19.23% CP and 3220 ME kcal/ kg diet and both were offered in mash form. Control group (T_1) was fed with basal diet (without supplementation). Experimental groups; T_2, T_3, T_4 and T_5 were given basal diet supplemented with 1 and 2 g/ kg diet of single of Spirulina (SP) or Chlorella (CV). Experimental groups; T_6 and T_7 were fed basal diet supplemented with (0.5g SP + 0.5g CV)/ kg diet and (1g SP + 1g CV)/ kg diet, respectively. A commercially available dried Spirulina and Chlorella powder were provided by the Algae Biotechnology unit, National Research centre (Giza, Egypt) and supplemented to basal diet, Table 2 shows the nutrient composition of dried Sp and CV powder. The chemical composition of Sp and CV were performed according to A. O. A. C. (2005).

3. Studied traits

3.1. Performance traits

Body weight: All chicks from each treatment were individually weighed in grams at weekly intervals throughout the experimental period from 0 to 35 days of age to determine body weight and body weight gain. Feed intake (FI) was recorded weekly for each replicate by subtracting the residual from the offered feed according to the following equation:

$$FI = \frac{\text{feed intake (g)/ week/ pen}}{\text{Number of/ pen}}$$

The calculations were done during the intervals (0 - 21 days) of age and the total feed intake (TFI) g for each chick during whole experimental periods was also, calculated. Feed conversion values were obtained by divided the amount of feed intake/ chicks by the corresponding weight gain were calculated by the following formula (Singh and Panda, 1992) as follow:

Feed conversion ratio (FCR) =

$$\frac{\text{Amount of feed intake(g)/bird/ interval}}{\text{Body weight gain(g)/ bird/ the same interval}}$$

3.2. Slaughter traits and immune organs parameters

At the end of the experiment (35 days of age), 6 birds from each treatment around the average live body weight were randomly chosen, fasted for about 12 hours, weighed and slaughtered to complete bleeding, followed by plucking the feathers. Empty carcass without giblets and some slaughtering weight and dressing % calculated as following:

$$\text{Dressing \%} = \frac{\text{Empty carcass weight, g}}{\text{pre−slaughtering weight, g}} \times 100$$

Also, immune organs, bursa of fabricius, thymus (all lobes from left side of the neck) and spleen were cut and weighted separately to determine the immune organs weight/ body weight ratio by using the following formula (Giamborne and Closser, 1990):

Immune organ, % =

$$\frac{\text{Immune organ weight (g)}}{\text{Pre−slaughtering weight (g)}} \times 100$$

3. 3. Meat muscles analysis and fatty acid composition

At 35 days, carcasses were dissected to obtain samples from the breast and thigh muscles which used in triplicate for measuring the proximate chemical analysis. Including moisture (Method 950:46) crude protein (CP, Method 981.10), ether extract EE; (Method 960-39), and ash % (Method 920.153) following the procedures of A. O. A. C. (2005). Samples of breast and thigh were preserved in the refrigerator at a temperature of 4°C for 7 days before measuring the meat which were extracted according to Folch *et al.* (1957). The assessments of FA in the breast and thigh meat were done via the transformation of EE to FA methyl esters (Yang *et al.,* 2003) using a gas Chromatograph (Model GC-14A, Shimadzu Corporations, Kyoto, Japan) with a flame-Lionization detector and a Polar Capillary Column (BPX70, 10. 25, SGE Incorporated CA, USA).

3.4. Serum blood parameters and antioxidant activity

Blood samples were taken at slaughter time from each bird individually blood samples were collected in tubes without heparin and serum was separated by centrifugation at 3500 rpm for 15 minutes and frozen at -20C° until analysis. Serum total protein (TP) and albumin (A) were determined using chemical test. The globulin values obtained by subtracting the values of albumin from the corresponding values of total protein. Also albumin/ globulin (A/ G ratio) values were obtained by dividing the values of albumin on the values of globulins according to Coles, 1974. Total serum lipids (TL), serum high-density lipoprotein (HDL) and low density lipoprotein (LDL) were determined according to methods described by Stein and Myers 1995. The serum samples were used to determine the concentrations of malondialdehyde (MDA, cell Biolabes, San Diego, CA, USA) and glutathione peroxidase (GPx, Bio Assay systems, Hayward CA, USA) according to the manufacture's instructions.

Table 1: Composition and calculated analysis of the experimental diets fed during starter (1-10), grower (11-24) and Finisher Periods (25-35) days of age.

Ingredients	Starter diet (1-10 d)	grower diet (11-24 d)	Finisher diet (25-35 d)
Ground yellow corn (8.5%)	53.145	51.53	55.92
Soybean meal (44%)	33	36	32
Corn glutein (60 %)	5.8	2.65	1.5
Vegtable oil	2.9	5.47	6.5
Limestone	1.52	1.4	1.3
Mono–calcium phosphate	1.85	1.6	1.45
Vitamins and mineral mixture,(permix)[1]	0.2	0.2	0.2
DL-Metheonine	0.29	0.23	0.23
L-Lysine	0.5	0.25	0.2
Threonine	0.18	0.08	0.11
Sodium bicarbonate	0.22	0.257	0.257
Choline chloride (60%)	0.095	0.063	0.063
Salt (Sodium chloride)	0.3	0.27	0.27
Total	**100**	**100**	**100**
Calculated analysis[2]:			
Crude protein, CP %	23.28	21.30	19.23
ME, Kcal/ kg diet	3002	3119	3220
C/P ratio	128.95	146.43	167.44
Calcium, Ca %	0.960	0.882	0.811
Available phosphorous , av.P %	0.484	0.439	0.403
Lysine, Ly%	1.404	1.248	1.105
Methionine, Meth.%	0.643	0.552	0.519

[1]Vitamin and Mineral mixture at 0.30% of the diet supplies the following per kilogram of the diet: Vitamin A; 12,000 IU, vitamin D_3; 3,000 IU, vitamin E; 40 mg, vitamin K_3; 3 mg, vitamin B_1; 2 mg, vitamin B_2; 6 mg, vitamin B_6; 5 mg, vitamin B_{12}; 0.02 mg, niacin; 45 mg, biotin; 0.075 mg, folic acid; 2 mg, pantothenic acid; 12 mg, manganese; 100 mg, zinc; 600 mg, iron, 30 mg, copper; 10 mg, iodine; 1 mg, selenium; 0.2 mg and cobalt; 0.1mg.
[2]Calculate according to NRC (1994).

Table 2: Nutrient composition of dried *Spirulina platensis* (Sp) and *Chlorella vulgaris* powder.

Items, %	Sp	CV
Dry matter	94.78	94.02
Crude protein	56.01	50.13
Ether extract	7.89	11.78
Crude fiber	6.02	12.63
Ash	8.90	7.32

3.5. Histomorphological parameters

For histological studies of intestinal villi,duodenal, jejunal, and ileal specimens were taken from slaughtered birds at 35 days of age.Specimenswere removed from the centra l2cm of the duodenum, jejunum,and ileumand fixed in 4% buffered formalin.The duodenum and jejunum. Certain segments were gently washed of physiological saline andf ixed in 4% neutral buffered formalin solution. These samples were fixed in Bouinesolution for 24 hours for histological analysis according to Uni *et al.* (1999). Morphometric measurements were made on selected villi from each sample. Intestinal villus height was measured from the tip to the base of the villiin theorificepubis, and villus width was measured at its midpoint. The depth of the intestinal villi was measured from the base of the villi to the submucosa, and the muscle thickness was measured from the submucosa to the outer layer of the intestine (Ebrahimi *et al.,* 2017).

3. 6. Economic efficiency

The economic efficiency was calculated from the input-output analysis (Heady and Jensen, 1954) assuming that other head costs were constant, as follows: (Price of kg weight gain - feed cost/kg gain)/ Feedcost/kg gain) under local condition.

3. 7. Statistical analysis

Data were statistically analyzed by the completely randomized design using SPSS (2011) program and the differences among means were determined using Duncans multiple range test (Duncan, 1955). Percentages were trans formed to the corresponding arcsine values before performing statical analysis (Snedecor and Cochran, 1982). The following statical model was applied:

$$Y_{ij} = \mu + \alpha i + E_{ij}$$

Where: Y_{ij} = Observed traits,
μ = Overall mean,
αi = Effect of treatment (i = 1, 2, 3….and 7) and
E_{ij} = Experimental random error.

RESULTS AND DISCUSSION

Effect of dietary supplementation of algae on growth performance of broiler chicks

Results showed high significantly ($P \leq 0.05$) increase of body weight gain (g/ chick/ d) to birds fed single or mixture algae compared to the control group at 21 days of age (Table 3). In general with the progress in age and feeding dietary treatment, at 35 days of age; chicks fed the addition of Spirulina, Chlorella and/ or their mixture had high significantly ($P \leq 0.05$) increased body weight gain from (T2, T3, T4, T5, T6 and T7), respectively. The heaviest body weight gain had shown in group fed (1 g SP + 1 g CV, T7 was 66.63 (g/ chick/ d) in comparison (58.85 g/ chick/ d) with the control diet (T1). Body weight gain was progressively improved by mixture dietary levels of Spirulina and Chlorella. At 1 g SP +1 g CV (T7) daily body weight gain was 66.63 g at (T6; 0.5 g SP + 0.5 g CV/ kg diet) was 63.98 g whereas at levels of Spirulina (SP), T2 and T3, BW values were 61.64 and 62.73 g and Chlorella (CV), T4 and T5, daily BWG values were 63.78 and 63.84 g, respectively. Improvements in weight gain in birds may be due to the feeding of amixture of spirulina and chlorella with a particularly excellent nutritional profile and high levels of SP and CV whose high carotenoid and protein contentisint he range of 50 to 56 percent, including all of the essential amino acids required for growth performance (Alwaleed *et al.,* 2021). Physiologically active compounds in spirulina include polyunsaturated fatty acids, β-carotene, phenols, phycocyanin, water-and fat-soluble vitamins, and minerals such as phosphorus and copper, which have potent antimicrobial, antioxidant, andimmuno enhancing effects (Shokri *et al.*, 2014).

In addition, chlorellais an important uni cellular green containing more than 60% protein including most of the essential amino acids and bioactive compounds such as chlorella growth factor in humans and animals (Schubert, 1988). It also contains several micronutrients, fiber, polyunsaturated fatty acids, and many natural pigments. The potential nutritional value of chlorella has been shown to affects everal biochemical and physiological functions, including enhancing immune function (Singh *et al.,* 1998). The present results are consistent with those of Khan *et al.* (2020) and Alwaleed *et al.* (2021), who showed that the addition of spirulina algae improved the live weight of broilers.El-Bahr *et al.* (2020) showed that the addition of spirulina and chlorella algae to broiler diets improved broiler chicken toimprove nutrient digestibility, gutmorphology, body weight, and certain meat quality parameters. In general, these results are consistent with those found by El-Sharnobey *et al.* (2023) and Alghamdi *et al.* (2024).

Data showing the effect of Spirulina platensis, Chlorella vulgaris and/or their mixtures on feed intake (FI, g/bird/day) of broiler chicks are presented in Table 3. Feed intake was significantly ($P \leq 0.05$) reduced by the addition of microalgae (Spirulina, Chlorella and their mixtures) compared to the base diet (control) during 0 - 21 days of age. In general, chicks (T_7) fed the basic diet of 1 g SP + 1 g CV/ kg during the entire experimental period of 0 - 35 days of age had significantly reduced feed intake of 84.62 g/ chick/day compared to the control group (92.98 g). Feed intake of the other experimental groups was 91.84, 87.82, 87.38, 86.19, and 85.09 g/ chick/ day for T_2, T_3, T_4, T_5, and T_6, respectively. The above result is similar to the findings with Hassan *et al.* (2022) and Lee *et al.* (2023).

Results in the experiment was disagreement with the results of Coelho *et al.* (2021) and Alghamdi *et al.* (2024) observed no significant difference in feed intake of broiler chickens with the addition ofalgae (SP or CV).

Data revealed that FCR was significantly improved by supplementation during the experimental period 1 - 35 days of age. Chicks consuming the basic control diet (T_1) had an FCR 1.58 between 1 - 35 days of age, but feed conversion was gradually improved by the addition of Spirulina and Chlorella. The best values of FCR were obtained at 1 - 35 days of age compared to the other treatments and the control groupwith the Spirulina and Chlorella. The significant improvement in FCRwith the addition of SP and CV may be due to the lowest feed intake and superior weight gain rate.

These results were confirmed by Abou-Zeid *et al*. (2015), where they reported that feed conversion ratio was significantly improved by dietary Spirulina platensis compared tocontrol broilers. In general, our results also showed that SP supplementation significantly ($P \leq 0.05$) improved FCR in poultry diets at 1.5 and 2 g/kg diet. The present findings are also inagreement with previous reports in broiler chicks (El-Bahr *et al.* 2020). This improvement may be due to the balanced microbial population in the digestive tract and increased absorption of vitamins and minerals in the diet that play an important role in broiler performance and health (Alwaleed *et al.*, 2021). These results were also consistent with previous finding (Roques *et al.,* 2022), where improvements in feed requirement ratio were observed with higher single and mixed Spirulina and Chlorella applications.

Conversely, Kang *et al.* (2013) did not describe the effects of Chlorella supplementation and feedconversion rate in broiler chicken diets between 28 and 42 days of age.

Effect of dietary supplementation of algae on carcass characteristics and immune organs responses parameters of broiler chicks

Experimental results of the effects of Spirulina, Chlorella and their mixture supplementation on carcass characteristics and immune organ parameters at 35 days of age arepresentedin Table 4. At 35 days of age, preslaughter weight and dressing % was significantly ($P \leq 0.05$) increased in Spirulina and Chlorella mixture treatments. Preslaughter weights were 2080.86, 2163.22, 2230.39, 2265.85, 2275.00, 2277.38, and 2305.26 g for T_1, T_2, T_3, T_4, T_5, T_6, and T_7, respectively. Asimilar trend was observed for dressing ratio. The addition of broiler chick SP1 g+CV1 g mixed feed (T_7) significantly increased (83.29 %) the dressing percentage compared to the other treatments. (77.12, 78.03, 78.42, 79.55, and 80.70 %) for T_2 (1 g SP/kg feed), T_3 (2 SP), T_4 (1 g CV), T_5 (2 g CV/kg feed), and T_6 (0.5 gSP+ 0.5 g CV/kg feed) compared to (76.24 %) for the control treatment of T_1, respectively (70%). Previous results on carcass yield and dressing percentage (Abdel-Moneim *et al.,* 2022) are as follows; the positive effects of Spirulina and Chlorella supplementation were reported. This finding may beattributed to the improved growth performance of the supplemented birds. The improvement in carcass traits can be justified by the potential of Spirulina and Chlorella powder to provide metabolizable energy and nutrients and improve muscle growth and nutrient conversion to lean meat (Tavernari *et al.,* 2018). Further more, Khan *et al.* (2020) found that 0.2% dietary Spirulina pratensis documented to increase dressing percentage of broiler chicks compared with the control group.

Table 3: Effect of dietary (*Spirulina platensis, Chlorella vulgaris* or their mixture) supplementation on growth performance of broiler chicks during experimental periods (Means ± S.E.).

Dietary treatments[1]	Body weight gain, (g/ chick/ d)		Feed intake (g/ chick/ d)		Feed conversion ratio (g feed/ g gain)	
	21, days	35, days	1 – 21 days	1-35 days	1-21 days	1-35 days
T_1	$40.46^{f,2,3}$ ± 12.18	58.85^{e} ± 19.25	56.24^{a} ± 0.69	92.98^{a} ± 0.89	1.39^{a} ± 0.03	1.58^{a} ± 0.18
T_2	42.78^{e} ± 13.89	$61.64^{d\pm}$ 19.25	53.47^{b} ± 0.64	91.84^{b} ± 0.89	1.25^{b} ± 0.02	1.49^{b} ± 0..16
T_3	42.92^{d} ± 12.27	62.73^{c} ± 19.66	53 $.22^{b}$ ± 0.62	87.82^{c} ± 0.86	1.24^{b} ± 0.02	1.40^{c} ± 0.12
T_4	44.02^{c} ± 11.89	63.78^{b} ± 15.3	53.26^{b} ± 0.59	87.38^{c} ± 0.88	1.21^{b} ± 0.03	1.37^{cd}± 0.13
T_5	44.92^{b} ± 12.56	63.84^{ab} ± 19.26	53.10^{b}± 0.53	86.19^{d} ± 0.79	1.18^{c} ± 0.02	1.35^{cd}± 0.11
T_6	45.33^{ab} ± 12.03	63.98^{ab} ± 20.15	53.04^{b} ± 0.63	85.09^{e} ± 0.82	1.17^{c} ± 0.03	1.33^{d} ± 0.10
T_7	46.69^{a} ± 1.93	66.63^{a} ± 20.83	52.79^{b} ± 0.59	84.62^{e} ± 0.82	1.13^{d} ± 0.02	1.27^{e} ± 0.11

[1]T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6 ; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.

[2] means ± S.E. of 3 replicates/ treatment.

[3]a,b,c and………etc. Means within the same colum with different superscripts are significant ($P \leq 0.05$).

The addition of microalgae (Spirulina and Chlorella) single or mixed resulted in decreasing the level of abdominal fat percentage in carcass of broiler (1.04 and 1.06 % for groups T_7 and T_6, respectively) followed by 1.15, 1.11, 1.16, 1.22 and 1.45 % for 1 g Chlorella/ kg diet (T_5), 2 g Chlorella/ kg diet (T_4), 2 g Spirulina (T_3), 1 g Spirulina/ kg diet (T_2) and the control group (T_1), respectively at 35 day of age Table 4. Our results are similar to the results of Kaoud, 2015 and khan *et al*. (2020), in this study, the use of Sp in poultry diets reduced fat deposition in the carcass and promoted protein deposition.

Table 4: Effect of dietary (*Spirulina platensis, Chlorella vulgaris or their mixture*) supplementation on carcass characteristics and immune organs at 35 days of age of broiler chicks (Means ± S.E.).

Dietary treatments[1]	Carcass traits			Giblets traits (%)				Immune organs (%)		
	Pre-slaughtering weight (g)	Dressing (%)	Abdominal fat (%)	Liver	Heart	Gizzard	Giblets	Spleen	Bursa	Thyms
T_1	$2080^{f, 2, 3} \pm 29.73$	$76.24^{c} \pm 1.24$	$1.45^{a} \pm 0.03$	$2.04^{e} \pm 0.02$	$0.46^{b} \pm 0.02$	$2.42^{d} \pm 0.11$	$4.91^{d} \pm 0.12$	0.09 ± 0.003	$0.19^{d} \pm 0.01$	$0.45^{c} \pm 0.01$
T_2	$2163^{e} \pm 30.19$	$77.12^{c} \pm 1.56$	$1.22^{b} \pm 0.03$	$2.07^{e} \pm 0.02$	$0.47^{b} \pm 0.02$	$2.49^{c} \pm 0.13$	$5.03^{c} \pm 0.14$	0.10 ± 0.003	$0.19^{d} \pm 0.01$	$0.49^{b} \pm 0.02$
T_3	$2230^{d} \pm 30.75$	$78.03^{c} \pm 1.36$	$1.16^{c} \pm 0.03$	$2.37^{c} \pm 0.01$	$0.47^{b} \pm 0.02$	$2.686^{b} \pm 0.13$	$5.52^{b} \pm 0.14$	0.10 ± 0.002	$0.20^{d} \pm 0.01$	$0.48^{b} \pm 0.01$
T_4	$2265^{c} \pm 29.73$	$78.42^{c} \pm 1.24$	$1.11^{d} \pm 0.03$	$2.48^{b} \pm 0.02$	$0.47^{b} \pm 0.02$	$2.62^{b} \pm 0.15$	$5.58^{b} \pm 0.11$	0.11 ± 0.002	$0.21^{c} \pm 0.01$	$0.45^{c} \pm 0.01$
T_5	$2275^{b} \pm 27.35$	$79.55^{b} \pm 1.33$	$1.15^{c} \pm 0.03$	$2.11^{d} \pm 0.02$	$0.48^{b} \pm 0.02$	$2.67^{b} \pm 0.11$	$5.25^{c} \pm 0.08$	0.11 ± 0.002	$0.22^{c} \pm 0.02$	$0.51^{ab} \pm 0.02$
T_6	$2277^{b} \pm 33.19$	$80.70^{b} \pm 1.26$	$1.06^{e} \pm 0.03$	$2.49^{b} \pm 0.01$	$0.48^{b} \pm 0.02$	$2.73^{a} \pm 0.10$	$5.70^{b} \pm 0.12$	0.11 ± 0.002	$0.24^{b} \pm 0.01$	$0.51^{ab} \pm 0.02$
T_7	$2305^{a} \pm 32.25$	$83.29^{a} \pm 1.39$	$1.04^{e} \pm 0.03$	$2.63^{a} \pm 0.02$	$0.52^{a} \pm 0.02$	$2.86^{a} \pm 0.12$	$6.01^{a} \pm 0.18$	0.12 ± 0.002	$0.27^{a} \pm 0.01$	$0.63^{a} \pm 0.02$

[1] T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.
[2] means ± S.E. of 3 replicates/ treatment.
[3] a,b,c and……..etc. Means within the same colum with different superscripts are significant ($P \leq 0.05$).

Percentages of giblets as liver, gizzard and heart were significantly affected by dietary levels of microalgae single of Spirulina and Chlorella or their mixture at 35 days of age, addition of microalgae (SP + CV) mixture significantly increased the giblets percent (T_7, 1 g SP + 1 g Ch/ kg diet) being 6.01 %, compared to unsupplemented treatment (T_1) 4.91 %. Values of giblets % were recorded as the single Spirulina (T_2 1 g SP/ kg, 5.03 % and T_3 2 g Sp/ kg diet, 5.52 % and Chlorella (T_4 1 g CV/ kg diet, 5.58 % and T_5 2 g CV/ kg diet, 5.25 %) or their mixture of T_6 (0.5 g Sp + 0.5 g CV, 5.70 %), respectively. Abbass *et al.* (2020) fed 1, 2, and 3% SP to 35- day – old broilers, which increased the percentage of spleen. Also, El-Sharnobey *et al.* (2023) observed that the liver percentage of broiler chicks fed Spirulina was significantly ($P \leq 0.05$) higher (2.22%) than that of the control group (2.00%).

In contrast, our results areindirect contrast to those of Abed *et al. (*2023), who noted that feeding diets supplemented with spirulinaand/ or chlorella did not significantly differ ingutrate.

The percent of thymus and bursa increased by addition of single microalgae (Sp and CV) or there mixture. The highest values were reported for (1 g SP+ 1 g Ch/ kg diet, T_7) being 0.63 % of thymus and was 0.27 % for bursa, respectively in compared to other treatments. While, percentages of spleen did not significantly differ between all treatments at 35 days of age (Table 4). Regarding the positive effect of Spirulina and Chlorella supplementation on thymus relative weight, our results are consistent with the findings of other researcher (Hassan *et al.*, 2022) reported that the addition of less than 1% Spirulin at chicken diets significantly stimulates Tcell- mediated immune responses and increases microbial killing activity. Furthermore, the high content of Zn in Spirulina significantly promotes cellular immunity in broiler birds. They also noticed that the relative weights of the bursa and spleen were significantly ($P \leq 0.05$) improved with Spirulina and Chlorella supplementation. Kaoud, 2015 showed arelative improvement in weight relative to live weight in the Spirulina supplemented group compared to the control group. Lysine as one of the essential amino acids in Spirulina and Chlorella content has been shown to be involved in cytokine production and lymphocyte proliferation, resulting in best immune system performance in the face of disease (Nasr and Kheiri, 2012). The improvement inrelative weight of bursa may indicate that Spirulina enhances immune system function by strengthening immunecells and organs and their resistance to environmental or in fectiousagent stress (Khan *et al.*, 2005). Significant effects of algae were observed in lymphoid organs that are primarily responsible for immune responsesin chicks (El-Gogary *et al.*, 2023). This is in agreement with Bennett and Stephens, 2006, who stated that the bird's bursa plays half of therole of the immune system and that the size of the burs aisindicative of thebird's overall health.

Effect of dietary supplementation of algae on meat composition and their fatty acids content of broiler chicks

Both *Spirulina platensis* and *Chlorella vulgaris* supplementation showed a significant difference ($P \leq 0.05$) in broiler breast and thigh meat muscles composition Table 5. At the age of 35 days of age, it was observed that group fed (1 g SP + 1 g CV/ kg diet, T_7; had increased protein (30.25 and 32.62 % of breast and thigh muscles, respectively) followed by the group fed (0.5 g SP + 0.5 g CV, T_6), 30.02 and 31.56 % protein of breast and thigh muscles, respectively as compared to other treatment groups and the control group. In term of lipids % of breast and thigh muscles, decreased values were observed in treatments groups compared to the control. Lower % lipids were observed in broiler chickens at mixture microalgae (SP and CV). Broiler chicks had significant higher values of minerals % by addition Spirulina and Chlorella single or mixture than those un-supplemented group. (T_1 control). Spínola *et al.* (2024) showed that cumulative Spirulina intake levels of 3.46 to 5.21 g/bird were associated with changes in meat traits. They also mentioned protein content, and Altmann *et al.* (2018) showed that the effects of Spirulinaon protein and lipid levels may depend

Table 5: Effect of dietary (*Spirulina platensis, Chlorella vulgaris* or their mixture) supplementation on meat composition at 35 days of age of broiler chicks (Means ± S.E.).

Dietary treatments[1]	Breast muscles (%)				Thigh muscles (%)			
	Dry matter	Protein	Lipids	Minerals	Dry matter	Protein	Lipids	Minerals
T_1	$29.52^{a,2,3} \pm 1.15$	$24.29^{d} \pm 1.06$	$5.78^{a} \pm 0.48$	$1.35^{b} \pm 0.08$	29.75 ± 1.15	$23.75^{d} \pm 1.06$	$6.89^{a} \pm 0.98$	$1.29^{d} \pm 1.29$
T_2	$24.22^{d} \pm 1.33$	$28.92^{bc} \pm 1.38$	$5.39^{a} \pm 0.69$	$1.62^{b} \pm 0.11$	29.02 ± 1.20	$28.56^{b} \pm 1.46$	$5.57^{b} \pm 0.92$	$1.51^{c} \pm 1.10$
T_3	$25.30^{c} \pm 1.20$	$29.56^{b} \pm 1.72$	$4.86^{bc} \pm 0.65$	$1.64^{b} \pm 0.13$	28.65 ± 1.19	$28.98^{b} \pm 2.13$	$5.13^{c} \pm 1.02$	$1.58^{b} \pm 0.08$
T_4	$27.15^{b} \pm 1.20$	$27.83^{c} \pm 1.26$	$4.92^{b} \pm 0.65$	$1.56^{b} \pm 0.14$	28.39 ± 1.23	$27.25^{c} \pm 2.15$	$5.73^{b} \pm 1.12$	$1.57^{b} \pm 1.13$
T_5	$26.98b^{c} \pm 1.35$	$29.53^{b} \pm 1.0$	$4.62^{c} \pm 0.82$	$1.64^{b} \pm 0.13$	28.02 ± 1.20	$28.13^{b} \pm 1.38$	$4.85^{d} \pm 1.83$	$1.53^{b} \pm 1.22$
T_6	$24.22^{d} \pm 1.20$	$30.02^{ab} \pm 2.11$	$4.83^{bc} \pm 0.72$	$1.86^{a} \pm 0.16$	27.56 ± 1.22	$31.56^{a} \pm 2.16$	$5.02^{c} \pm 1.86$	$1.73^{a} \pm 1.17$
T7	$23.56^{a} \pm 1.27$	$30.25^{a} \pm 2.20$	$3.89^{d} \pm 0.77$	$1.88^{a} \pm 0.16$	27.83 ± 1.27	$32.62^{a} \pm 2.39$	$4.70^{c} \pm 1.42$	$1.76^{a} \pm 1.13$

[1] T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /kg diet.

[2] means ± S.E. of 3 replicates/ treatment.

[3] a,b,c and………etc. Means within the same column with different superscripts are significant ($P \leq 0.05$).

on factors such as the specific strain of Spirulina, age of the birds, and overall diet composition. Indeed, a study by Fries-Craft *et al.* (2023) showed that the effect of a 0.175% microalgae strain incorporated in to acorn-or wheat-based diet fed to broilers for 42 days was dependent on the composition of the base diet. For example, Toyomizu *et al.* (2001) usedcornand barley, corn, soybeans, and wheat as base diets. Furthermore, the differences observed in the nutritional composition of broiler meat, especially in terms of lipid and protein, were attributed to the biological accessibility and digestibility of Spirulina and Chlorella, and not solely to the composition of the base feed fed to broilers, which were similar among the diets (Ibrahim *et al.,* 2020). The bioavailability of Spirulina and Chlorella nutrients can be enhancedby the application of mechanical or enzymatic pretreatments,which break do wnthecell walls of the microalgae, thus allowing there lease and hydrolysis of the nutrient compounds (Spinnola *et al.*, 2024).

Contrary to this, El-Bahr *et al.* (2020) demonstrated that feeding broilers with different levels of microalgae, Chlorella, Spirulina, and amphora at 1 g/ day in the diet significantly ($P \leq 0.05$) increased breast meat and muscle lipid %.

Table 6 shows the effect of feeding single or mixture algae on the concentration and types of fatty acids in the breast and thigh segments, as the results showed thigh significant differences ($P \leq 0.05$), in the characteristic of fatty acid concentrations for the experimental treatments. In breast, birds fed with (1 g SP + 1 g CV/ kg diet T_7) presented higher contents of palmitic acid 16:0, linoleic C18: 2,w^6, ɣ- linoleic acid, C18:3, w^6, arachidonic acid, C20: 4 W^6. In this study, docosahexaenoic C22:4, W^3, were improved by feeding single or mixture of Spirulina and Chlorella.

Values of docosahexaenoic C22:6w^3 concentration of breast meat were being (0.478, 0.490, 0.488, 0.482, 0.496 and 0.498 for T_2, T_3, T_4, T_5, T_6 and T_7, respectively) compared to the control group, (T_1, 0.390). On the other hand, oleic C18: 1, w^9 was found lower in groups treated basal diet with single or mixture algae compared to the control group in the breast meat of broiler chickens. In the thigh, birds fed with Spirulina, and Chlorella or their mixture had increased ($P \leq 0.05$) contents of palmatic C16:0, oleic C18:1, w^9 linoleic C18:2, w^6, ɣ -linolinic C18:3 w^6, 46, arachidonic acid C20:4, w6, and docosahexaenoic C22:6, w^3 in relation to control birds. A high significant superiority ($P \leq 0.05$) was observed in favor of the two treatments T_6 and T_7 in which Spirulina + Chlorella algae were used atarate of 0.5 g SP + 0.5 g CV/ kg diet and 1 g SP + 1 g CV/ kg diet, respectively, in palmatic, oleic, linolinic, arachidonic acid, docosahexaenoic acids compared to T_1 (control). As for the concentration of docosahexaenoic acid (DHA) the results showed that there was a high significant difference ($P \leq 0.05$) for the experimental treatments compared to the control treatment (T_1), and the superiority of the experimental treatments T_6 and T_7 was found to be superior to the high significant ($P \leq 0.05$) over the control treatment T_1 and other treatments. Spirulina and Chlorella are part of the long-chain poly unsaturated fatty acids, especially omega-6 acids (camarinoic acid and arachidonic acid), as well as omega-3 acids (EPA acid and DHA acid), two groups of fatty acids that are essential fatty acids that must be included inhuman and poultry feed and are important for health and disease prevention (Omega 6 and 3), and improvement due to their being omega 6 and 3 (Andrade *et al.,* 2018). In astudy dealing with the effect of Spirulinaon the concentration and type of fatty acids, two nutritional additives of 5g and 10 g/ kg in broiler diets affected the composition of fatty acids. Incarcasses, they increased the concentration of some important fatty and unsaturated acids witho uthavinga negative impact on performance parameters and indicators of meat oxidation, such as EPA (eicosapentaenoic acid), DPA (docosapentaenoic acid) and DHA (docosahexaenoic acid) in thigh meat (Bonos *et al.*, 2016).

Table 6: Effect of dietary (*Spirulina platensis*, *Chlorella vulgaris* or their mixture) supplementation on fatty acids %(breast and thigh meat) of broiler chicks at 35 day of age (Means ± S.E.).

Items	Dietary Treatments[1]						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Breast meat							
Palmatic, C16:0	$20.56^{f,2,3} \pm 1.33$	$20.89^{e} \pm 1.49$	$21.23^{d} \pm 1.72$	$22.77^{c} \pm 1.56$	$22.86^{c} \pm 1.72$	$23.03^{b} \pm 1.89$	$23.91^{a} \pm 1.83$
Oleic, C18:1, w^9	$27.85^{a} \pm 1.18$	$25.83^{c} \pm 1.39$	$26.72^{b} \pm 1.98$	$26.98^{b} \pm 1.07$	$26.40^{b} \pm 1.17$	$24.84^{e} \pm 1.23$	$24.98^{e} \pm 1.09$
Linoleic, C18:2, w^6	$13.32^{e} \pm 0.97$	$15.56^{d} \pm 0.86$	$16.82^{c} \pm 1.98$	$17.77^{b} \pm 2.02$	$16.42^{c} \pm 1.78$	$19.56^{a} \pm 2.1$	$19.87^{a} \pm 2.22$
y- Linoleic, C18:3, w^6	$0.880^{c} \pm 0.03$	$0.986^{a} \pm 0.03$	$0.931^{a} \pm 0.04$	$0.889^{b} \pm 0.04$	$0.989^{a} \pm 0.04$	$0.889^{b} \pm 0.04$	$0.986^{a} \pm 0.04$
Arachidonic acid, C20:4, w^6	$5.83^{d} \pm 0.73$	$6.420^{c} \pm 0.89$	$7.13^{b} \pm 0.56$	$6.83^{c} \pm 0.76$	$6.93^{c} \pm 0.88$	$8.12^{a} \pm 0.92$	$8.32^{a} \pm 0.65$
Docosahexaenoic, C22:4, w^6	$0.390^{b} \pm 0.01$	$0.478^{a} \pm 0.03$	$0.490^{a} \pm 0.05$	$0.488^{a} \pm 0.01$	$0.482^{a} \pm 0.04$	$0.496^{a} \pm 0.05$	$0.498^{a} \pm 0.05$
Thigh meat							
Palmatic, C16:0	$22.53^{c} \pm 1.56$	$23.01^{b} \pm 1.77$	$23.32^{b} \pm 1.49$	$22.67^{c} \pm 1.63$	$23.42^{b} \pm 1.85$	$24.02^{a} \pm 1.11$	$24.13^{a} \pm 1.92$
Oleic, C18:1, w^9	$31.85^{b} \pm 1.32$	$32.46^{a} \pm 1.33$	$32.19^{ab} \pm 1.33$	$33.02^{a} \pm 1.99$	$30.65^{c} \pm 1.89$	$33.00^{a} \pm 1.99$	$33.21^{a} \pm 1.99$
Linoleic, C18:2, w^6	$20.56^{c} \pm 1.06$	$21.79^{b} \pm 1.75$	$22.11^{a} \pm 3.02$	$22.03^{a} \pm 1.92$	$21.73^{b} \pm 2.01$	$22.61^{a} \pm 2.98$	$22.85^{a} \pm 3.25$
y- Linoleic, C18:3, w^6	$0.092^{f} \pm 0.01$	$0.198^{e} \pm 0.02$	$0.429^{b} \pm 0.03$	$0.306^{c} \pm 0.03$	$0.250^{d} \pm 0.01$	$0.535^{a} \pm 0.03$	$0.589^{a} \pm 0.04$
Arachidonic acid, C20:4, w^6	$4.05^{a} \pm 0.01$	$4.36^{a} \pm 0.02$	$4.12^{a} \pm .012$	$4.15^{b} \pm 0.13$	$4.11^{a} \pm 0.09$	$4.26^{a} \pm 0.12$	$4.17^{a} \pm 0.11$
Docosahexaenoic, C22:4, w^6	$0.120^{e} \pm 0.01$	$0.144^{d} \pm 0.02$	$0.0133^{d} \pm 0.03$	$0.135^{c} \pm 0.1$	$0.140^{b} \pm 0.3$	$0.149^{a} \pm 0.03$	$0.149^{a} \pm 0.03$

[1] T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.
[2] means ± S.E. of 3 replicates/ treatment.
[3] a,b,c and……. etc. Means within the same row with different superscripts are significant ($P \leq 0.05$).

In addition, the various sources of fatused in broiler diets directly affect the total amount and percentage of monoun saturated fatty acids in meat and subcutaneous tissue, which leads to an increase in the percentage of poly unsaturated fatty acids, and fatty acid composition may differ between these different muscle tissues, possibly duetophospho lipid content (Zelenka *et al.,* 2008). This was confirmed by Oliveira *et al.* (2016), who found positive changes in the ratio of omega-3toomega-6 in the meat of algae-fed birds, leading to an improvement in the fatty acid composition of broilers, which can like wisebe considered as EPA and D14A dietary supplement. Also, Pestana *et al.* (2020) found that breast meat of birds fed Spirulina contained 17:0 ($P \leq 0.05$), 17:1C9 ($P \leq 0.05$), 18:3n-6 ($P \leq 0.05$), 20:3n6 ($P \leq 0.05$), saturated fatty acids (SfA) and n-6/n-3 polyunsaturated fatty acids (PCFA) increased in the birds. In addition, the thighs of birds fed Spirulina had increased 18:3n6, SFA, and n-6/n-3 PUFA in relation to control birds. The data reported here in dicate that the fatty acid profiles of breast and thigh meat arec onsistent with the diet, as reported ino this study (Coelho *et al.,* 2021).

Effect of dietary supplementation of algae on some serum biochemical parameters, lipid profile and antioxidant of broiler chickens

Data concering the effect of Spirulina, Chlorella or their mixture on blood serum constituents at 35 days are shown in Table 7. The data revealed that chicks fed diets contain mixture of Spirulina and Chlorella (0.5 g SP + 0.5 g CV/ kg; T_6 and 1 g SP + 1 g CV/ kg diet, T_7) significantly increased total protein, albumin, globulin and decreased A/ G ratio compared to the control group. Globulin is a source of antibody production, so its level in the serum is a good indicator of immune responses and consequently better disease resistance (Griminger and Scances 1986). Plasma biochemical parameters are useful tools for assessing metabolic changes inorgans and tissues. These results were noted by Fathi *et al.* (2018), who noted significant differences ($P \leq 0.05$) in globulin with the addition of 0.5, 0.7, and 0.9 g SP/kg diet in broiler chicks. Hassan *et al*. (2022) also showed that birds fed 0.5%or 1% SP (4.98 and 5.44 g/dl) had increased ($P \leq 0.05$) serum blood total proteincompared to birds fed 0.25% (3.24 g/dl) or the control diet (3.35 g/dl).

Also, the results of blood serum total lipids (TL), total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL) concentration, and GPx and MDA activities showed statistical different levels of Spirulina, Chlorella or their mixture in broiler chickens (Table 7). Total lipids, total cholesterol, and low density lipoprotein (LDL) were decreased by single or mixture of Spirulina and Chlorella supplementation at levels of 1 gSP + 1 g CV/ kg diet, T_7, compared to the control group. While, the high density lipoprotein (HDL) was higher, (94.25mg/ dl, T_7) than other treatments (88.26, 89.73, 88.95, 95.75 and 92.68 mg/ dl) for (T_2, T_3, T_4, T_5 and T_6, respectively) and the control group (T_1), 83.35 mg/ dl). In general; the results of glutathione peroxidase activities (GPx) showed significant increased by addition of single or mixture of Spirulina and Chlorella Table 7: Gp_x levels were increased the of addition Spirulina and Chlorella mixture (0.5 g SP + 0.5 g CV, T_6) and (1 g SP +1 g CV/ kg diet, T_7) in compared to other treatments on the other hands Spirulina, Chlorella or mixture had significantly ($P \leq 0.05$) decreased malondialdehyde (MDA) concentration in comparison with the control group. Similar results were reported by (Abed *et al.,* 2023) when they tasted Spirulina supplementation in broiler diets, serum levels of total lipids, total cholesterol and low density lipoprotein were significantly reduced compared to the control group. The decrease in serum in chickens fed dietary Spirulina may reflect the low gastric and intestinal tract due to Spirulina supplementation, which reflects the increased Spirulina lacto bacillus population in broilers (Mariey *et al.,* 2014).

Table 7: Effect of dietary (*Spirulina platensis, Chlorella vulgaris* or their mixture) supplementation on blood serum parameters, lipid profile and antioxidant status of broiler chicks at 35 days of age (Means ± S.E.).

Items	Dietary Treatments[1]						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Total protein, (g/ dl)	$4.26^{e,2,3}$ ± 0.007	4.83^{b} ± 0.006	4.87^{b} ± 0.006	4.29^{e} ± 0.012	4.90^{b} ± 0.012	5.019^{ab} ± 0.011	5.22^{a} ± 0.013
Albumen, (g/ dl)	2.06^{d} ± 0.006	2.27^{b} ± 0.011	2.29^{b} ± 0.006	2.25^{c} ± 0.006	2.24^{c} ± 0.006	2.28^{b} ± 0.01	2.37^{a} ± 0.006
Globulin, (g/ dl)	2.20^{e} ± 0.006	2.56^{d} ± 0.006	2.58^{d} ± 0.006	2.64^{c} ± 0.011	2.66^{c} ± 0.012	2.73^{b} ± 0.009	2.85^{a} ± 0.012
A/ G ratio	0.94^{a} ± 0.004	0.89^{b} ± 0.002	0.88^{b} ± 0.004	0.85^{c} ± 0.006	0.84^{c} ± 0.006	0.84^{c} ± 0.006	0.83^{c} ± 0.006
Total lipids, (mg/ dl)	418.62^{a} ± 2.23	402.02^{b} ± 2.16	366.43^{c} ± 1.83	389.56^{c} ± 1.29	386.90^{c} ± 1.26	342.55^{d} ± 1.18	326.57^{e} ± 1.20
Total cholesterol, (mg/ dl)	182.64^{a} ± 1.26	158.59^{b} ± 1.13	148.25^{b} ± 1.16	149.36^{b} ± 1.13	133.72^{c} ± 1.18	128.37^{d} ± 1.12	120.48^{e} ± 1.13
HDL, (mg/ dl)	83.35^{d}±0.62	88.26^{c} ±0.67	89.73^{c}±0.62	88.95^{c}±0.69	95.75^{a}±0.64	92.68^{b} ± 0.62	94.25^{a}±0.64
LDL, (mg/ dl)	62.03^{a} ± 0.35	55.16^{b} ± 0.65	50.93^{c} ± 0.17	49.26^{c} ± 0.54	44.53^{d} ± 0.65	42.73^{e} ± 0.58	39.73^{f} ± 0.16
GPx. Activity, (mg/ dl)	3.45^{d} ± 0.03	4.15^{c} ± 0.02	4.53^{b} ± 0.03	2.86^{e} ± 0.03	4.52^{b} ± 0.02	4.48^{b} ± 0.03	4.96^{a} ± 0.03
MDA, (mg/ dl)	29.38^{a} ± 1.23	26.55^{b} ± 1.19	24.29^{c} ± 1.21	27.13^{b} ± 1.26	26.56^{b} ± 0.98	23.98^{c} ± 1.16	23.02^{d} ± 1.12

[1] T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.

[2] means ± S.E. of 3 replicates/ treatment.

[3] a,b,c and……. etc. Means within the same row with different superscripts are significant ($P \leq 0.05$).

This reduction in cholesterol serum has been described as an effect of Spirulina on lipo protein metabolism and an increase in lipo protein enzyme activity levels, Spirulina's cholesterol effects on plasma and total cholesterol levels by increasing lipoprotein lipase andlivertriglyceride lipase activityincluding a decrease (Hassan *et al.*, 2024). This finding suggested that the inclusion of microalgae (Spirulina and Chlorella) in broiler chicken diets significantly increased glutathione activity GPx and reduced malondialdehyde activity (MDA), total lipids and total cholesterol in blood broiler chicken profiles Coelho *et al.* (2021) and supported with that of Alwaleed *et al.* (2021).

Effect of dietary supplementation algae of (Spirulina, Chlorella or their mixture) on intestinal morphological parameters of broiler chicks

The mean villi height (VH, µm), width (VW, µm), crypt depth (CD, µm), muscle coat thickness (MCT, µm) and goblet cellcount of the duodenum, jejunum and ileum of broiler chicks measured at 35 days of age are shown in Tables 8, 9, 10 and Figures 1, 2 and 3. The data show asignificant increase ($P \leq 0.05$) induodenal, jejunal and ileal height with the addition of Spirulina, Chlorella or their mixtures, especially in the T_7 (2947.31, 2406.18 and 2993.544um) diets, compared to the control (T_1) group (1612.79, 1730.43 and 1770.32µm) compared to the birds fed a combination containing 1 g SP + 1 g CV/ kg of feed, respectively. The increase in the height of different segments of the small intestinal epithelium plays an important role in the digestion, absorption and assimilation of nutrients (Wang and Pen, 2008). Asimilar trend was observed for the intestinal width, which was 328.40, 303.41, and 473.66 µ minth eduodenum, jejunum, and ileum, respectively, compared to 173.60, 253.85, 151.43, 265.38, and 369.69 µ minthe other treatments. 38 and 369.69 µm, 303.14, 265.36, 201.65, 294.72 and 313.65 µm for jejunum and 330.48, 366.30, 284.82, 257.66 and 383.14 µmforileum and control groups (202.09, 195.78, and 267.48 µm, respectively). Similar effects were also reported by Khalilnia *et al.* (2023).

Results from this study indicate that feeding Spirulina, Chlorella, or amixture of the two in broiler diets significantly reduced depth, which indicates increased epithelial cell turnover. Similarly, Khalilnia *et al.* (2023) reported that supplementation of algae to broiler diets resulted in responses related to the morphology of the constituted gut, when their effects were more evident in the duodenum and ileum when the gut was fully developed. Increased crypt depth (CD) correlated with increased epithelial cell turnover (Fan *et al.*, 1997). Increased villus height and pubicfoss adepth are associated with healthyepithelial cell turn over and active celldivision. Deepercrypt depth means faster villirene wal, suggestingth at intestinal respon semechanisms are at work to replace villi cells that have been shedo ratrophied by inflammation with new cells (Gao *et al.*, 2008).

Assessment of intestinal morphology mayr eflect the health of the animal's digestive tract. Because the gut is the primary site of enzymatic digestion and absorption of nutrients, absorption efficiency is highly dependent on gut morphology (Liu *et al.*, 2008) Positive morphology has been correlated with increased body weight. Various studies have shown that administration of algae improvesthe in tegrity of intestinal epithelial cells, resulting in efficient absorption of nutrients andu ltimate lyimproving growth performance (Wang *et al.*, 2021).This result is similar to that reported previously, which stated that the addition of Spirulina platensis and Chlorella vulgaris powder to poultry diets leads to homogeneous development of intestinal villi and epithelial cells (Shehata *et al.*, 2022).

Table 8: Effect of dietary (*Spirulina platensis, Chlorella vulgaris* or their mixture) supplementation on intestinal morphology (duodenum) of broiler chicks at 35 days of age (Means ± S.E.).

Histological parameters	Dietary Treatments[1]						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Villi height (µm)	$1612.79^{e,2,3} \pm 24.26$	$2010.00^{d} \pm 25.62$	$2434.62^{b} \pm 27.73$	$2205.41^{c} \pm 29.29$	$2221.51^{c} \pm 24.53$	$2481.40^{b} \pm 24.11$	$2947.31^{a} \pm 32.19$
Villi width (µm)	$202.09^{e} \pm 7.93$	$173.60^{f} \pm 11.72$	$253.85^{d} \pm 16.55$	$151.43^{g} \pm 10.32$	$265.38^{c} \pm 12.73$	$369.69^{b} \pm 15.83$	$328.40^{a} \pm 17.02$
Crypt depth (µm)	$294.77^{d} \pm 9.82$	$302.30^{c} \pm 11.26$	$334.62^{bc} \pm 13.92$	$345.75^{b} \pm 15.22$	$392.31^{a} \pm 16.89$	$296.87^{d} \pm 10.88$	$391.78^{a} \pm 16.2$
Muscle coat thickness (µm)	$378.93^{f} \pm 9.82$	$509.32^{c} \pm 11.26$	$686.02^{a} \pm 13.92$	$427.10\ ^{c} \pm 15.22$	$594^{b} \pm 16.89$	$414.50^{c} \pm 10.88$	$437.81^{d} +16.2$

[1]T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.

[2] means ± S.E. of 3 replicates/ treatment.

[3]a,b,c and………etc. Means within the same row with different superscripts are significant ($P \leq 0.05$).

Table 9: Effect of dietary (*Spirulina platensis, Chlorella vulgaris* or their mixture) supplementation on the intestinal morphology (jejunum) of broiler chicks at 35 days of age (Means ± S.E.).

Histological parameters	Dietary Treatments[1]						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Villi height (µm)	$1730.43^{e,2,3} \pm 19.75$	$1898.04^{d} \pm 16.98$	$2221.75^{b} \pm 21.73$	$1882.86^{d} \pm 19.22$	$2105.15^{c} \pm 20.11$	$2290.96^{b} \pm 27.23$	$2406.18^{a} \pm 29.22$
Villi width (µm)	$195.78^{d} \pm 9.55$	$303.14^{ab} \pm 11.26$	$265.36^{b} \pm 9.88$	$201.65^{c} \pm 11.26$	$294.72^{b} \pm 15.33$	$313.65^{a} \pm 10.98$	$303.41^{a} \pm 17.92$
Crypt depth (µm)	$322.09^{d} \pm 11.62$	$458.00^{a} \pm 14.96$	$392.31^{b} \pm 19.22$	$364.09^{c} \pm 15.33$	$290.51^{f} \pm 17.29$	$302.47^{e} \pm 15.63$	$347.35^{c} \pm 17.22$
Muscle coat thickness (µm)	$530.50^{c} \pm 9.82$	$467.00^{d} \pm 18.62$	$594.23^{b} \pm 19.33$	$593.74^{b} \pm 18.26$	$719.96^{a} \pm 22.02$	$486.49^{d} \pm 19.75$	$713.64^{a} + 22.73$
Goblet cell numbers	$20.63^{e} \pm 5.16$	$24.23^{d} \pm 11.62$	$26.80^{c} \pm 10.01$	$22.98^{e} \pm 8.76$	$24.32^{d} \pm 9.82$	$28.73^{b} \pm 11.73$	$29.78^{a} \pm 19.37$

[1]T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.

[2]means ± S.E. of 3 replicates/ treatment.

[3]a,b,c and… … … etc. Means within the same row with different superscripts are significant ($P \leq 0.05$).

Table 10: Effect of dietary (*Spirulina platensis, Chlorella vulgaris or their mixture*) supplementation on the intestinal morphology (ileum) of broiler chicks at 35 days of age (Means ± S.E.).

Histological parameters	Dietary Treatments1						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Villi height (µm)	$1770.32^{f,2,3} \pm 19.83$	$2363.78^{d} \pm 24.22$	$2431.40^{c} \pm 19.00$	$2248.00^{e} \pm 17.22$	$2380.88^{d} \pm 19.23$	$2749.32^{b} \pm 22.75$	$2993.54^{a} \pm 29.22$
Villi width (µm)	$267.48^{f} \pm 17.23$	$330.48^{d} \pm 20.00$	$366.30^{c} \pm 20.43$	$284.82^{e} \pm 11.63$	$257.66^{f} \pm 19.88$	$383.14^{b} \pm 20.65$	$473.66^{a} \pm 21.79$
Crypt depth (µm)	$236.77^{f} \pm 11.73$	$347.28^{c} \pm 16.98$	$227.36^{f} \pm 15.26$	$442.08^{a} \pm 20.02$	$341.38^{d} \pm 19.75$	$252.62^{e} \pm 19.55$	$372.61^{b} \pm 20.26$
Muscle coat thickness(µm)	$264.00^{d} \pm 12.03$	$397.70^{b} \pm 14.74$	$492.60^{a} \pm 16.02$	$435.71^{ab} \pm 19.55$	$397.70^{b} \pm 15.98$	$450.50^{ab} \pm 16.25$	$322.09^{c} + 18.26$
Goblet cell numbers	$51.29^{e} \pm 2.93$	$54.98^{d} \pm 2.79$	$56.92^{c} \pm 3.25$	$54.26^{d} \pm 4.89$	$55.98^{c} \pm 4.55$	$62.82^{b} \pm 7.82$	$67.45^{a} \pm 7.22$

[1] T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.

[2] means ± S.E. of 3 replicates/ treatment.

[3] a,b,c and……… etc. Means within the same row with different superscripts are significant ($P \leq 0.05$).

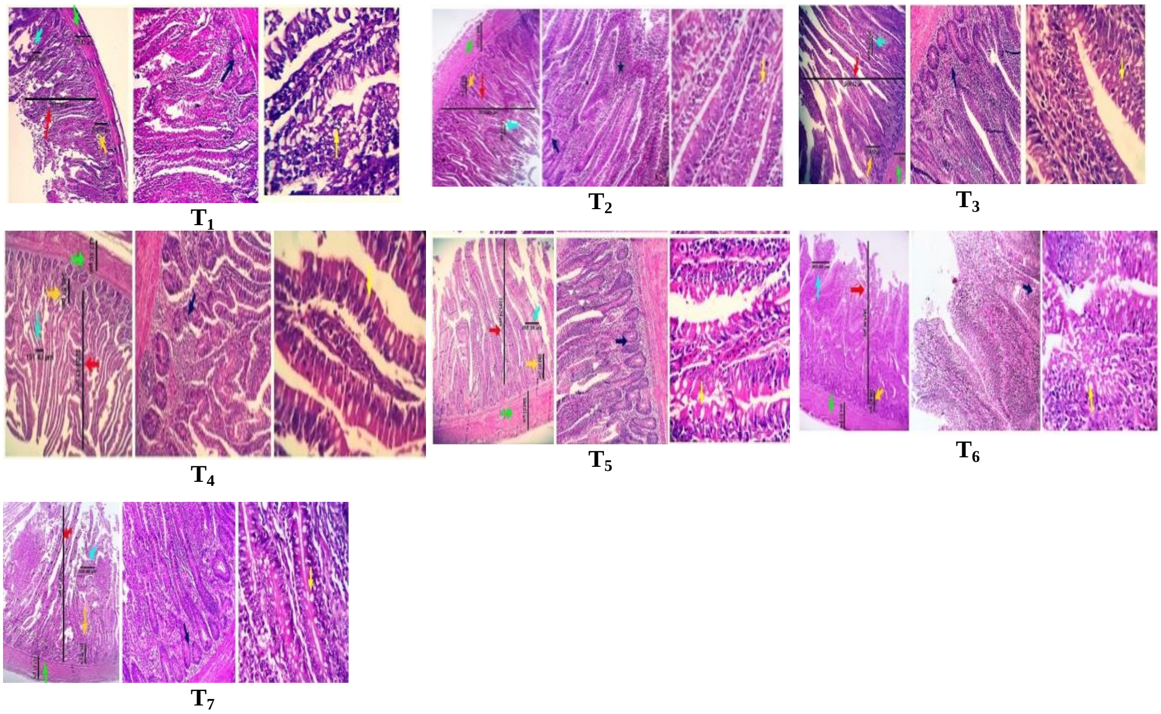

Figure 1: Photomicrographs of the villi from the duodenum of broiler chicks at 35 days of age in T_1, control, basal diet without supplementation; T_2; basal diet + 1 g SP; T_3; basal diet + 2 g SP,T_4; basal diet + 1 g CV, T_4; basal diet + 2 g CV, T_5; basal diet + 2 g CV T_6; basal diet + 0.5 g SP + 0.5 g CV, T_7; basal diet + 1 g SP + 1 g CV/ kg diet.

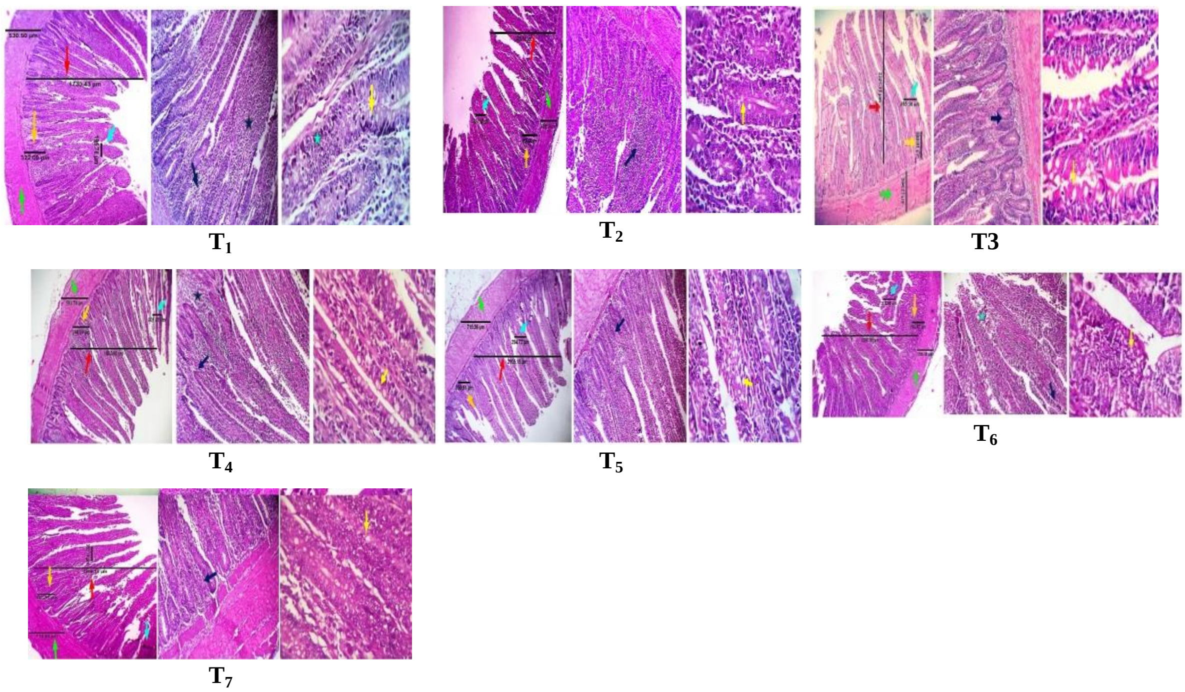

Figure 2: Photomicrographs of the villi from the jejunum of broiler chicks at 35 days of age in T_1, control, basal diet without supplementation; T_2; basal diet + 1 g SP; T_3; basal diet + 2 g SP,T_4; basal diet + 1 g CV, T_4; basal diet + 2 g CV, T_5; basal diet + 2 g CV T_6; basal diet + 0.5 g SP + 0.5 g CV, T_7; basal diet + 1 g SP + 1 g CV/ kg diet.

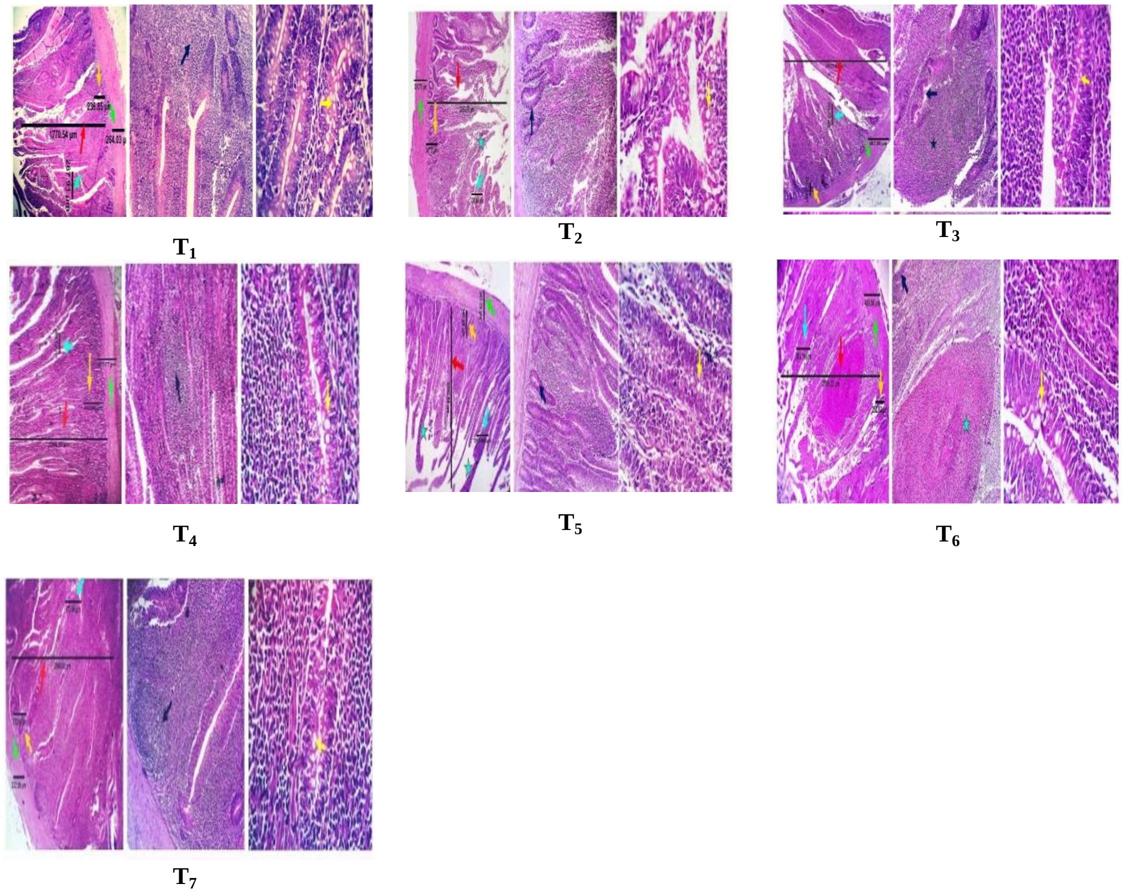

Figure 3: Photomicrographs of the villi from the ileum of broiler chicks at 35 days of age in T_1, control, basal diet without supplementation; T_2; basal diet + 1 g SP; T_3; basal diet + 2 g SP,T_4; basal diet + 1 g CV, T_4; basal diet + 2 g CV, T_5; basal diet + 2 g CV T_6; basal diet + 0.5 g SP + 0.5 g CV, T_7; basal diet + 1 g SP + 1 g CV/ kg diet.

Muscle thickness was increased in all segments of the small intestine by asingle or mixture of algae compared to controls. These results are in agreement with those reported by Roques *et al.* (2022), where thea ddition of SP and CVresulted inl onger and thicker villi than in the control group. It has been shown that intestinal morphology, particularly the structure of villi and crypts, as well asthe thickness of the mucosa, canbe altered by diet composition (Samanya Yamauchi, 2002).

Effect of dietary supplementation algae on economic efficiency and relative economic efficiency of broiler chicks

The economic efficiency of adding the supplement to the basal diet remains a major concern for small-scale and long-scale commercial poultry farming, opting for feed supplement which provides desired growth in poultry performance and profile as well are the ideal characteristic for such supplements. Data pertaining to dietary Spirulina, Chlorella or their mixture supplementation on the relative economical efficiency (REE) are presented in Table 11. In comparison with the control treatment (100 %), the supplementation of algae alone or mixture improved REE about 140.48 % for T7 which was supplemented with (1 g SP + 1 g CV)/ kg diet. This may be due to better feed conversion obtained in birds received the experimental diet. The lowest values of economical efficiency were obtaining for chicks fed basal diet (T_1, Control). Our findings agree with a previous finding of Fathi, 2018 who recorded that the levels of SP were cost-effective with regard to significant improvements in broiler diet health and growth performance. It was reported that SP supplementation in broiler diets has a positive effect on gross and net return values (Bellof and Alarco, 2013).

Table 11: Effect of dietary (*Spirulina platensis*, *Chlorella vulgaris* or their mixture) supplementation on economical and relative economic efficiency of broiler chicks during experimental periods (Means ± S.E.).

Items	Dietary Treatments[1]						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Initial body weight, g	42.79	42.83	42.68	42.69	42.80	42.76	43
Final body weight, kg	2.09	2.19	2.24	2.27	2.28	2.28	2.37
Total revenu[2], L.E	167.20	175.20	179.20	181.60	182.40	182.40	189.60
Feed intake, Kg	3.25	3.21	3.07	3.06	3.02	2.98	2.96
Price of one kg feed, L.E	28.00	28.60	29.20	28.80	29.60	28.70	29.40
Feed cost. L.E	91.00	91.80	89.64	88.13	89.39	85.53	87.02
Net revenu[3], L.E	76.20	83.40	89.56	93.47	93.01	96.87	102.58
Economical efficiency[4]	0.84	0.91	1.00	1.06	1.04	1.13	1.18
Relative economical efficiency[5]	100	108.33	119.05	126.19	123.81	134.52	140.48

[1]T_1; control; basal diet without supplements, T_2; basal diet + 1 g SP/ kg diet, T_3; basal diet + 2 g SP/ kg diet, T_4; basal diet + 1 g CV/ kg diet, T_5; basal diet + 2 g CV/ kg diet, T_6 ; basal diet +(0.5 g SP + 0.5 g CV) /Kg diet, T_7; basal diet +(1 g SP + 1 g CV) /Kg diet.
[2]Total revenue = live body weight × marketing price (80 L.E. according to prices in April, 2023).
[3]Net revenue = total revenue-feed cost.
[4]Economical efficiency= net revenue/ feed cost.
[5]Relative economical efficiency.

Conclusion

Based on the results obtained from the experiment and the economic efficiency study, it became clear that it is possible to use algae (Spirulina and Chlorella) alone or mixed as feed additives to improve productive performance, carcass traits, oxidative status and economic efficiency in broiler chicks, without any negative effects on the general health of the birds under experimental conditions.

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تأثير إضافة الطحالب على أداء نمو كتاكيت التسمين، مكونات اللحم ومحتواه من الأحماض الدهنية، بعض قياسات سيرم الدم وبعض القياسات الهيستولوجيه للأمعاء

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الملخص العربى

استخدم في هذه الدراسة عدد 420 كتكوت تسمين روص (308) Ross عمر يوم غير مجنس - قسمت الكتاكيت إلى سبع معاملات غذائية تجريبية متماثله تقريبا في وزن الجسم (42 جم) كل مجموعة قسمت عشوائيا إلى ثلاث مكررات بكل منها 20 كتكوت، تم إضافة طحلب الاسبيرولينا، الكلوريلا إلى عليقة البادئ والنامي والناهي كما يلي: غذيت كتاكيت المعاملة الأولي علي العليقة الأساسية بدون إضافة أي طحالب (الكنترول)، المعاملة الثانية والثالثة: العليقة الأساسية + ا جم، 2 جم اسبيرولينا/ كجم عليقة علي الترتيب، المعاملة الرابعة والخامسة: العليقة الأساسية + ا جم، 2 جم كلوريلا علي التوالي، أما العليقة السادسة والسابعة: العليقة الأساسية + (0.5 جم اسبيرولينا + 0.5 جم كلوريلا)، (1جم اسبيرولينا + 1 جم كلوريلا)/ كجم من العليقة علي التوالي. أوضحت النتائج أن طيور المعاملات المغذاه على العلائق المضاف إليها الطحالب (اسبيرولينا وكلوريلا) بشكل فردي أو مخلوطة كانت أعلى معنويا في متوسطات الزيادة فى وزن الجسم الحي، أفضل معدل تحويل غذائي وانخفاض معنوي في الغذاء المأكول مقارنة بطيور معامله الكنترول. لوحظ أن إضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة أدت إلى تحسن معنوي في صفات الذبيحة وبعض أعضاء المناعة مقارنة بمجموعة الكنترول عند عمر 35 يوم (نهاية التجربة). إضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة إلى العلائق أدت إلى زيادة نسبة البروتين وانخفاض نسبة الدهن في لحم صدور وأفخاذ ذبائح الطيور مقارنة بمجموعة الكنترول، وكان أفضلها طيور المعاملة السابعة التي غذيت على عليقة مضاف إليها 1 جم اسبيرولينا + 1 جم كلوريلا. اتضح أن إضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة إلى العلائق أدي إلى زيادة معنوية في نسبة الأحماض الدهنية (اللينولينك، اللينوليك، الأراكيدونيك والدوكوساهيكسانويك) في لحم صدور وأفخاذ ذبائح الطيور مقارنة بمجموعة الكنترول. أدت إضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة إلى العلائق إلى زيادة معنوية لبعض مكونات سيرم الدم (البروتين الكلي، الألبيومين، الجلوبيولين وإنزيمات الكبد) وانخفاض مستوى الليبيدات الكلية، الكولسترول والجلسريدات الثلاثية في سيرم دم الطيور مقارنة بمجموعة الكنترول. تبين أن إضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة إلى العلائق أدى إلى زيادة معنوية في مستوى الكولستيرول عالي الكثافة (HDL) وانخفاض مستوى الكولستيرول منخفض الكثافة (LDL) في سيرم دم الطيور مقارنة بمجموعة الكنترول. لوحظ تحسن نشاط إنزيم الجلوتاثيون بروكسيديز (GP_X) وانخفاض نشاط إنزيم المالون داي ألديهايد (MDA) في سيرم دم الطيور المغذاه على علائق مضاف إليها الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة مقارنة بمجموعة الكنترول. أوضحت القياسات الهستولوجية في أمعاء طيور المعاملات المغذاه على علائق مضاف إليها الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة زيادة ارتفاع، عرض، عمق وسمك الخملات مقارنة بطيور مجموعة الكنترول. تحسنت الكفاءة الاقتصادية والكفاءة الاقتصادية النسبية بإضافة الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة إلى العلائق وكانت أعلى قيم للمعاملة السابعة (1.18 و140.48 على الترتيب) التي أضيف إليها 1 جرام اسبيرولينا + 1 جرام كلوريلا مقارنة بمجموعة الكنترول (0.84 و100 على الترتيب). بصفة عامة وبناء على النتائج المتحصل عليها من التجربة ودراسة الكفاءة الاقتصادية اتضح إمكانيه استخدام الطحالب (اسبيرولينا وكلوريلا) منفردة أو مخلوطة كإضافات غذائية لتحسين الأداء الإنتاجي، صفات الذبيحة، الحالة التأكسدية، والكفاءة الاقتصادية في كتاكيت التسمين دون أي تأثيرات سلبية على الصحة العامة للطيور تحت ظروف التجربة.