Effect of Using Different Levels of Spirulina Algae (Spirulina Platensis) in The Diet on Concentration, Types of Fatty Acids, Oxidation Indicators, and Sensory Characteristics of Broiler Carcasses

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Abstract

This study was conducted at the Poultry Research Station of the Agricultural Research Department / Ministry of Agriculture in Abu Ghraib for the period from 25/2/2019 to 7/4/2019 (42 days) with the aim of using several levels of Spirulina (SP) Spirulina platensis in broiler diets. And their effect in the concentration and types of fatty acids, oxidation indices and sensory characteristics of the broiler carcass, 400 birds were used in this experiment One day old broiler birds of the Ross 308 strain are un sexed, with an average starting weight of 40 g / bird, and the birds were randomly distributed into five treatments with four replications per treatment (20 birds / duplicate). The following treatments included: the first (T1) control treatment (the basic diet without additives), the second (T2), third (T3), fourth (T4) and fifth treatments (T5) were used in the basic ration algae SP by 1%, 2% and 3% And 4%, respectively. The two treatments T4 and T5 showed significant superiority (P≤0.05) compared to the control group in the concentration of oleic acid, palmitic acid, and the concentration of docosahexaenoic acid and linoleic acid for the treatments T3, T4 and T5 compared to the control treatment. The value of peroxide (PV) was significantly decreased (P <0.05) in the 30-day storage period for treatment T5 birds compared with the two treatments T1 and T2 and the value of thiobarbituric acid (TBA) and total volatile nitrogen (TVN) for all treatments compared to the control treatment, and for the storage period of 60 One day, all oxidation indexes (PV, TBA, TVN) were significantly decreased (P <0.05) for all treatments using Spirulina. No significant effect of spirulina was shown on sensory evaluation scores for the chest and thigh cuts compared to the control treatment.

Keywords: Spirulina, Fatty acids, Oxidation indicators, Organoleptic traits, Broiler.

1. Introduction

Numerous studies have proven the possibility of including different types of edible algae without side effects for their positive effect on the human and animal diet, as the blue-green algae called Spirulina platensis is gaining global attention as it is characterized by its rapid growth ease of production and the nutritional value of these algae as food for humans [1]. Spirulina algae (Spirulina platensis) nowadays leads the world global markets in sales as a feed material in poultry diets [2,3]. Spirulina algae is added to poultry diets as a rich source of protein (55-70%) and unsaturated fatty acids. In addition to being a source of vitamins and antioxidants (phenols, -linoleic acid, phycoerycin, tocopherol, β carotene) as well as it contains several types of natural pigments (chlorophyll, carotenoids, xanthophyll) that improve the skin color of broilers [4]. Algae contains anti-bacterial and anti-fungal agents that have shown high inhibitory activity for many microbes [5].

Spirulina is a source of long-chain polyunsaturated fatty acids, especially Omega-6 acids (cama-linolenic acid and arcidonic acid) as well as Omega-3 acids (EPA acid and DHA acid), and these two groups of fatty acids (Omega 6 and 3) they are essential fatty acids that must be included in the diet of humans and poultry and are important for health and disease prevention [6]. Sotiroudis and Sotiroudis [7] showed that every 10 g of spirulina contains more than 100 mg GLNA (ka-linolenic acid). Agriculture conditions can affect the lipid content of microalgae and that some of them have the ability to store fats (triglycerides) up to 70% of dry weight under conditions of nitrogen deficiency [8].
It has been observed that many types of microalgae have a content of phenols that are similar in composition and higher than many fruits and vegetables [9]. Smerilli et al. [10] indicated that the microalgae contain marine which is one of the types of phenols that have distinct bioactivity as an antioxidant, antibacterial, antiviral, and inhibitor of the growth of cancer cells.

Spirulina is considered an ideal food and a high-quality pharmaceutical source due to its high content of protein, fats, vitamins, minerals, chlorophyll, beta-carotene and sugars, as it is characterized by the presence of the two natural colors represented by carotenoids and phycocyanin [11] and that the level of the two pigments carotenoids and phycocyanin has a clear effect as antioxidants [12]. They are used as effective antioxidants due to the presence of many active substances due to their positive effect on the health and performance of birds, the quality of meat and eggs and their preservation in different storage conditions, and this effect is important in the poultry industry [13] and can be used to produce functional foods (meat and eggs). of high nutritional value in human nutrition. [14,15].

Among the studies dealing with the effect of spirulina on the concentration and type of fatty acids, the two nutritional additives of spirulina 5 and 10 g / kg of feed for broiler diets affected the composition of fatty acids in the carcass without any negative effect on the performance parameters and indicators of meat oxidation as it increased the concentration of some vital fatty acids. And unsaturated acids such as EPA (eicosapentaenoic acid), DPA (docosapentaenoic acid) and DHA (docosahexaenoic acid) in thigh meat [16]. Spirulina improved the palatability and quality of meat due to reduced fluid loss when cooking, which increased its frequency [12] in the same context, the addition of spirulina in drinking water showed a relatively low weight of belly fat in Japanese quail [17].

This is important for consumers who avoid fat consumption. The effectiveness of spirulina in fat reduction is due to its high content of GLA (cama-linolenic acid) or Omega. [18] and that GLA is a precursor to prostaclandin hormone (PG). Prostacladin PGEI is known to be essential for blood pressure regulation, cholesterol synthesis, and anti-inflammatory [19,20]. Since the nature of the substances consumed by animals, including poultry, can affect the composition of the product, whether meat or eggs, and as a result of the positive characteristics of spirulina algae, the aim of this study is to find out the effect of using different levels of spirulina algae in broiler diets in the concentration, types of fatty acids and oxidation indicators. And sensual qualities.

### 2. Materials and Methods

This study was conducted at the Poultry Research Station of the Agricultural Research Department / Ministry of Agriculture in Abu Ghraib for the period from 25/2/2019 to 7/4/2019 (42 days), 400 birds were used in this experiment One day old broiler birds of the Ross 308 strain are unsexed, with an average starting weight of 40 g / bird, birds were distributed randomly over the two places, and the dimensions of each were 2.6 mx 2.10 m. The experiment included five treatments with four replications, each treatment contained (80 birds) and distributed into (4) replicates at a rate of (20 birds) for each replicate. The experiment extended 42 days (up to the age of 6 weeks), and the transactions were distributed as follows:

- The first treatment T1: Basic diet without any additives (control).
- The second treatment T2: The algae *Spirulina platensis* was used in the base diet at 1%.
- The third treatment T3: The algae *Spirulina platensis* was used in the base diet at 2%.
- The fourth treatment T4: The algae *Spirulina platensis* was used in the base diet at 3%.
- The Fifth treatment T5: The algae *Spirulina platensis* was used in the base diet at 4%.

Raising chicks rearing a ground on a bed of sawdust. The hall was equipped with adequate and homogeneous lighting, as it provided 23 hours of light and one hour of darkness (according to the recommendation of the company producing the breed) after the third day, for the purpose of customizing the chicks to darkness to prevent their disturbance and accumulation when the power is suddenly cut off. Gas incubators were used to warm the chicks, as the temperature and relative humidity were appropriate for breeding, and for ventilation, the hall was provided with air vacuums, and the ventilation system used was the negative pressure system that provides an adequate exchange of the room air whenever necessary and to moderate the temperatures.

The *Spirulina* algae used in the study was in the form of a fine powder with a bluish green color table (1) shows the chemical composition of *Spirulina* used in the experiment.
Table 1. The chemical composition per 100 grams of Spirulina algae.

| The nutritional content of 100 grams of Spirulina |   |
|--------------------------------------------------|---|
| Protein                                          | 62 g |
| Carbohydrate                                     | 15 g |
| Crude fat                                        | 6 g  |
| Fiber                                            | 2 g  |
| Moisture content                                 | 4 g  |
| Chlorophyll II                                   | 500 mg |
| Carotenoid                                       | 100 mg |
| Phycocyanobilin                                  | 3000 mg |
| Calcium                                          | 600 mg |
| Magnesium                                        | 200 mg |
| Zinc                                             | 200 mg |
| Fe                                               | 200 mg |
| Vitamin B1                                       | 2 mg  |
| Vitamin B2                                       | 3 mg  |
| Vitamin B6                                       | 0.1 mg |
| Vitamin B12                                      | 0.05 mg |
| Vitamin E                                        | 5 mg  |
| Vitamin PP                                       | 200 mg |
| Folic acid                                       | 0.05 mg |
| Linolenic acid                                   | 100 mg |
| Spirulina polysaccharide                         | 3000 mg |
| Calories                                         | 1234 KJ |

During the breeding period (6 weeks), three types of diets were used and in the form of crushed feed, the birds were fed diet balanced with protein and energy for three stages (initiation, growth and final) as shown in Table (2,3,4) respectively, and according to the needs of birds as indicated The mechanism of Breeding Guide for Roos 308. Note that the ratios of addition to experimental diets represent a partial substitution of soybean meal used in the diet.
### Table 2. Components and chemical analysis (%) of experimental diets for initiator diet (1-14) days.

| Feed material and food ingredients | Treatments |
|-----------------------------------|------------|
|                                   | T1 control | T2  | T3  | T4  | T5  |
| yellow corn                       | 47.5       | 47.5| 47.5| 47.5| 47.5|
| Wheat                             | 10         | 10  | 10  | 10  | 10  |
| Soybean meal (48% crude protein)  | 32         | 31  | 30  | 29  | 28  |
| Concentrated Protein *            | 5          | 5   | 5   | 5   | 5   |
| Spirulina **                      | 0          | 1   | 2   | 3   | 4   |
| Lipid                             | 3          | 3   | 3   | 3   | 3   |
| Dicalcium phosphate               | 0.7        | 0.7 | 0.7 | 0.7 | 0.7 |
| Food salt                         | 0.1        | 0.1 | 0.1 | 0.1 | 0.1 |
| Limestone                         | 1.2        | 1.2 | 1.2 | 1.2 | 1.2 |
| DL- Mthunine                      | 0.25       | 0.25| 0.25| 0.25| 0.25|
| L-lysine                          | 0.25       | 0.25| 0.25| 0.25| 0.25|
| Total                             | 100        | 100 | 100 | 100 | 100 |

**Calculated chemical composition ***

| Calculated representative energy (kcal / kg feed) | 3059 | 3064 | 3070 | 3075 | 3080 |
|--------------------------------------------------|------|------|------|------|------|
| Crude protein (%)                                | 22.5 | 22.7 | 22.8 | 23   | 23.1 |
| Crude fiber                                      | 2.7  | 5.7  | 5.7  | 5.8  | 5.8  |
| crude lipid                                      | 5.6  | 2.7  | 2.7  | 2.6  | 2.6  |
| Lysine                                           | 1.49 | 1.51 | 1.54 | 1.56 | 1.58 |
| Cysteine + methionine                            | 1.12 | 1.14 | 1.15 | 1.17 | 1.19 |
| Calcium                                          | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| Available phosphorous                            | 0.78 | 0.78 | 0.78 | 0.77 | 0.77 |

* The protein concentrate produced by the Dutch company Wafi and contains 40% crude protein and 2107 kilocalories of energy represented / kilogram of feed, 5% calcium, 3.7% methionine, 4.12% methionine and cysteine, 3.85% lysine, 4.68% available phosphorus and 5.6% Calcium, 0.42% Tryptophan, 1.70 Threonine, 2.50% Sodium, 4.20% Chloride. ** Spirulina platensis, a bluish-green algae, the amount of energy represented (M.E) is 2948.63 kcal / kg, and protein is 62%, according to what was indicated by the company producing Spirulina XI'an Ceres Biotech. *** According to the chemical analysis of the forage materials included in the composition of the feed according to what was stated in [21].
Table 3. components and chemical analysis (%) of experimental diets for growth diet (15-28) days.

| Feed material and food ingredients | T1 control | T2 | T3 | T4 | T5 |
|-----------------------------------|------------|----|----|----|----|
| yellow corn                       | 51.75      | 52.75 | 52.75 | 52.75 | 52.75 |
| Wheat                             | 10         | 10  | 10  | 10  | 10  |
| Soybean meal (48% crude protein)  | 27         | 25  | 24  | 23  | 22  |
| Concentrated Protein *            | 5          | 5   | 5   | 5   | 5   |
| Spirulina **                      | 0          | 1   | 2   | 3   | 4   |
| Lipid                             | 4.15       | 4.15 | 4.15 | 4.15 | 4.15 |
| Dicalcium phosphate               | 0.6        | 0.6  | 0.6  | 0.6  | 0.6  |
| Food salt                         | 0.1        | 0.1  | 0.1  | 0.1  | 0.1  |
| Limestone                         | 1.14       | 1.14 | 1.14 | 1.14 | 1.14 |
| DL- Mthunine                      | 0.13       | 0.13 | 0.13 | 0.13 | 0.13 |
| L –lysine                         | 0.13       | 0.13 | 0.13 | 0.13 | 0.13 |
| Total                             | 100        | 100  | 100  | 100  | 100  |

Calculated chemical composition ***

| Calculated representative energy (kcal / kg feed) | 3183 | 3197 | 3203 | 3208 | 3213 |
| Crude protein (%)                                | 20.5 | 20.3 | 20.4 | 20.5 | 20.7 |
| Crude fiber                                      | 2.6  | 7    | 7    | 7.1  | 7.1  |
| crude lipid                                      | 6.9  | 2.6  | 2.6  | 2.5  | 2.5  |
| Lysine                                           | 1.26 | 1.26 | 1.28 | 1.3  | 1.33 |
| Cysteine + methionine                            | 0.94 | 0.95 | 0.97 | 0.99 | 1.01 |
| Calcium                                          | 0.92 | 0.91 | 0.91 | 0.91 | 0.90 |
| Available phosphorus                             | 0.75 | 0.75 | 0.75 | 0.74 | 0.74 |

* The protein concentrate produced by the Dutch company Wafi and contains 40% crude protein and 2107 kilocalories of energy represented / kilogram of feed, 5% calcium, 3.7% methionine, 4.12% methionine and cysteine, 3.85% lysine, 4.68% available phosphorus and 5.6% Calcium, 0.42% Tryptophan, 1.70 Threonine, 2.50% Sodium, 4.20% Chloride. ** Spirulina platensis, a bluish-green algae, the amount of energy represented (M.E) is 2948.63 kcal / kg, and protein is 62% according to what was indicated by the company producing Spirulina XI'an Ceres Biotech. *** According to the chemical analysis of the forage materials included in the composition of the feed according to what was stated in [21].


| Feed material and food ingredients% | T1 control | T2 | T3 | T4 | T5 |
|-----------------------------------|-----------|----|----|----|----|
| yellow corn                       | 57.84     | 57.84 | 57.84 | 58.34 | 58.34 |
| Wheat                             | 10        | 10  | 10  | 10  | 10  |
| Soybean meal (48% crude protein)  | 21        | 20  | 19  | 17.5 | 16.5 |
| Concentrated Protein *            | 5         | 5   | 5   | 5   | 5   |
| Spirulina **                      | 0         | 1   | 2   | 3   | 4   |
| Lipid                             | 4.3       | 4.3 | 4.3 | 4.3 | 4.3 |
| Dicalcium phosphate               | 0.4       | 0.4 | 0.4 | 0.4 | 0.4 |
| Food salt                         | 0.1       | 0.1 | 0.1 | 0.1 | 0.1 |
| Limestone                         | 1.1       | 1.1 | 1.1 | 1.1 | 1.1 |
| DL- Mthunine                      | 0.13      | 0.13| 0.13| 0.13| 0.13|
| L -lysine                         | 0.13      | 0.13| 0.13| 0.13| 0.13|
| Total                             | 100       | 100 | 100 | 100 | 100 |

Calculated chemical composition ***

| Calculated representative energy (kcal / kg feed) | 3254 | 3259 | 3265 | 3274 | 3279 |
|--------------------------------------------------|------|------|------|------|------|
| Crude protein (%)                                | 18.1 | 18.3 | 18.4 | 18.4 | 18.5 |
| Crude fiber                                      | 2.5  | 7.3  | 7.3  | 7.4  | 7.4  |
| crude lipid                                      | 7.2  | 2.5  | 2.5  | 2.4  | 2.4  |
| Lysine                                           | 1.10 | 1.12 | 1.14 | 1.15 | 1.18 |
| Cysteine + methionine                            | 0.88 | 0.90 | 0.92 | 0.93 | 0.95 |
| Calcium                                          | 0.84 | 0.84 | 0.83 | 0.83 | 0.83 |
| Available phosphorous                            | 0.70 | 0.70 | 0.70 | 0.70 | 0.69 |

* The protein concentrate produced by the Dutch company Wafi and contains 40% crude protein and 2107 kilocalories of energy represented / kilogram of feed, 5% calcium 3.7% methionine 4.12% methionine and cysteine 3.85% lysine 4.68% available phosphorus and 5.6% Calcium 0.42% Tryptophan 1.70 Threonine 2.50% Sodium 4.20% Chloride. ** Spirulina platensis a bluish-green algae the amount of energy represented (M.E) is 2948.63 kcal / kg, and protein is 62% according to what was indicated by the company producing Spirulina XFan Ceres Biotech. *** According to the chemical analysis of the forage materials included in the composition of the feed according to what was stated in [21].
2.1. Estimation of fatty acids in meat:

The fatty acids in the meat of the thigh piece were assessed for all experimental treatments (T1, T2, T3, T4, T5) in the laboratory of the Ministry of Science and Technology / Department of Environment and Water. The fat of the thigh meat was extracted by taking samples from the thigh piece of chicken carcasses at the rate of 8 samples per treatment. The samples were placed in an organic solvent (hexane) and then placed in a succulite device (Soxholet) to extract the fat from the meat for the purpose of estimating the level and type of fatty acids and then extracting all the samples based on the AOAC [22] method (Association of Official Analytical Chemists referred to by Zhang [23]).

2.2. Oxidation indicators

2.2.1. Estimation of P.V (Peroxide Value) in Meat:

The estimation was based on the method of Egan [24].

2.2.2. Estimation of Thiobarbituric Acid (TBA) in Meat

The fat oxidation of the meat sample was measured by estimating thiobarbuty acid according to the method of Witte [25].

2.2.3. Estimation of the value of T.V.N (Total Volatile Nitrogen) in meat

Estimate total volatile nitrogen as indicated by Egan [24].

2.3. Sensory orthodontics of leg and breast parts for broiler

The degrees of the taste sensory evaluation of the meat determined the breast and thigh pieces for the following characteristics of flavor, juiciness and tenderness, according to the method of Baker and Darfler [26].

2.4. Statistical analysis

The completely randomized design was used to study the effect of different treatments on the studied traits, the significant differences between the averages were compared using Duncan's Multiple Range Test [27] and the SAS [28] was used to analyze the data. According to the following mathematical model:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

where:
- \( Y_{ij} \) represents the watching value of the studied trait (pertaining to the i treatment).
- \( \mu \) represents the overall mean of the trait.
- \( T_i \) represents the effect of addition factors (1%, 2%, 3%, 4%) of spirulina algae powder.
- \( e_{ij} \) represents the normally distributed random error by a mean of zero and a variance of \( 2\sigma \).

3. Results and discussion

3.1. Fatty acid concentrations and types in thigh meat

Table (5) shows the effect of using different levels of spirulina algae in the concentration and types of fatty acids in the thigh segment, as the results showed high significant differences (P ≤0.01) in the characteristic of fatty acid concentrations for the experimental treatments. A high significant superiority was observed (P ≤0.01) in favor of The two treatments T4 and T5 in which spirulina algae were used at a rate of 3% and 4% respectively in the characteristic of the oleic acid concentration compared to the treatment T1 (control) and their superiority over the two treatments T2 and T3 (spirulina 1% and 2% respectively) as well as the case for a high significant superiority (P 0.01) for the two treatments T2 and T3 for the oleic fatty acid concentration compared to the control treatment T1 which recorded a significant decrease (P≤0.01) for oleic acid compared to all the spirulina treatments.
As for the concentration of docosahexaenoic acid (DHA) the results showed that there was a high significant difference (P≤0.01) for the experimental treatments compared to the control treatment (T1), and the superiority of the experimental treatments T3, T4 and T5 was found to be superior to the high significant (P ≤0.01) over the treatments T1, T2 and T3 for the characteristic of linolenic acid concentration. It was significantly different (P≤0.01) with treatment T4, as well as the superiority of the two treatments T3 and T4 was highly significant (P≤0.01) over the second and first treatments. As for the concentration of linoleic acid, it is noted that the superiority of the treatments for using Spirulina T3, T4 and T5 was highly significant (P ≤0.01) compared to the control treatment as well as on the second treatment, and the two treatments T4 and T5 were noted as highly significant (P≤0.01) in palmitic acid concentration over the control treatment (T1) and the third treatment (T3) followed in the effect by treatment T2.

**Table 5.** The effect of using different levels of spirulina algae in the concentration and types of fatty acids in the thigh (mean ± standard error) of broilers.

| Fatty acids          | T1       | T2       | T3       | T4       | T5       | Significant |
|----------------------|----------|----------|----------|----------|----------|-------------|
| Oleic% C18:1         | 0.05±15.55<sup>a</sup> | 0.05±16.25<sup>b</sup> | 0.10±16.30<sup>b</sup> | 0.05±18.35<sup>a</sup> | 0.10±20.30<sup>a</sup> | *           |
| Docosahexaenoic % C22:0 | 0.45±10.65<sup>c</sup> | 0.05±14.35<sup>b</sup> | 0.10±16.50<sup>a</sup> | 0.05±15.65<sup>a</sup> | 0.10±16.70<sup>a</sup> | *           |
| Linolinic C18:3      | 0.05±8.25<sup>c</sup> | 0.05±8.25<sup>c</sup> | 0.10±10.60<sup>b</sup> | 0.05±11.35<sup>ab</sup> | 0.50±12.50<sup>a</sup> | *           |
| Linoleic C18:2       | 0.45±9.45<sup>b</sup> | 0.00±9.61<sup>b</sup> | 0.10±13.60<sup>a</sup> | 0.05±13.55<sup>a</sup> | 0.10±14.80<sup>a</sup> | *           |
| Palmitic C16:0       | 0.05±10.15<sup>c</sup> | 0.05±13.65<sup>b</sup> | 0.10±10.30<sup>c</sup> | 0.05±16.85<sup>a</sup> | 0.10±20.10<sup>a</sup> | *           |

The averages that carry different letters within the same class differ significantly between them. * It means that there are significant differences between the parameters at the (P≤0.01) probability level. Experimental treatments T1: control, T2: use of 1% spirulina, T3: use of 2% spirulina, T4: use of 3% of spirulina, T5: use of 4% of spirulina.

The sources of different fats used in the broiler diet directly affect the total amount and the proportions of monounsaturated fatty acids in the meat and subcutaneous tissues, which leads to an increase in the proportion of polyunsaturated fatty acids, and the composition of fatty acids can be different between these different muscle tissues perhaps. Because of their phospholipids content [29], [30]. This was confirmed by [31], [32] found positive changes in the ratio of Omega-3 and Omega-6 in the meat of birds fed on seaweed, which led to an improvement in the fatty acid composition of broilers, which can be considered as dietary supplement to EPA and DHA as well.

3.2. Oxidation indicators

Table (6) shows the effect of using different levels of Spirulina powder to broiler feed in estimating oxidation indicators in meat stored for 30 and 60 days, during storage period 30 days, the results indicate the presence of significant differences (P ≤0.05) in the value of peroxide. value (PV) for all treatments, as its value decreased significantly for T5 birds compared with the control treatments (T1) and T2, and it did not differ significantly (P ≤0.05) with T3 and T4, and that the treatments for Spirulina T2, T3, and T4 did not differ significantly (P ≤0.05) with treatment T1, as for the value of thiobarbituric acid (TBA) and total volatile nitrogen (TVN), as the results indicate that there are significant differences (P ≤0.05) in the value of (TBA) and (TVN) as their concentration decreased significantly. For birds of treatment T5 compared to control treatment T1, followed by treatment T4, then T3, then T2. The results may be similar in the 60-day storage period, as treatment T5 recorded the lowest values of the characteristics of peroxide, thiobarbituric acid and total volatile nitrogen compared to control treatment T1, followed by the effect in treatment T4, then T3 Then T2.
Table 6. The effect of using different levels of spirulina algae in the concentration of oxidation indicators for 30 and 60 days (mean ± standard error) of frozen broiler carcasses.

| Meat oxidation | Treatments | Significant |
|----------------|------------|-------------|
|                | T1         | T2          | T3           | T4          | T5          |
| Storage period of 30 days |  |  |  |  |  |
| PV             | 3.31 ±0.03 a | 1.87 ±0.06 a | 2.43±0.02 ab | 2.29±0.08 ab | 1.51±0.07 b |
| TBA            | 0.059±0.0003 a | 0.048±0.0005 b | 0.042±0.0005 c | 0.036±0.0005 d | 0.030±0.0005 e |
| TVN            | 11.14±0.05 a | 10.4±0.02 b | 9.04±0.02 c | 8.57±0.005 d | 8.02±0.05 e |
| PV             | 3.99±0.01 a | 3.01±0.08 b | 2.94±0.17 c | 2.77±0.01 d | 2.59±0.05 e |
| Storage period of 60 days |  |  |  |  |  |
| TBA            | 0.067±0.0005 a | 0.052±0.0005 b | 0.047±0.0005 c | 0.037±0.001 d | 0.034±0.0005 e |
| TVN            | 11.50±0.01 a | 10.83±0.02 b | 9.17±0.05 c | 9.01±0.01 d | 8.52±0.02 e |

The averages that carry different letters within the same class differ significantly between them. * It means that there are significant differences between the parameters at the (P≤0.05) probability level. Experimental treatments T1: control, T2: use of 1% spirulina, T3: use of 2% spirulina, T4: use of 3% of spirulina, T5: use of 4% of spirulina.

The reason for the significant decrease in the oxidation indicators (PV, TBA, TVN) of the meat stored by freezing for 30 and 60 days may be due to the role of spirulina used in the diets of broiler meat, which contributed to preventing the deterioration of the quality of the meat by inhibiting the process of oxidation, rancidity, and the decomposition of fats and fatty acids, considering Spirulina is a source of antioxidants [33] because of its higher content of phenolic compounds than other algae, especially tannic acid, as it constitutes more than 63% of the phenols that have the ability to fix roots by donating a hydroxyl group [34], and also containing phycocyanin, beta-carotene and phenols [12] that increase the formation and effectiveness of antioxidant enzymes such as catalase (CAT), peroxidase (PX), superoxidase (SOD) and ascorbate peroxidase (APX) that preserve cells and prevent the formation of free radicals and get rid of Hydrogen peroxide in animal tissues [35]. The unique dyes active in spirulina, such as phycobiliprotein, phycocyanin, and phycoerythrin, also play an important role as effective antioxidants [36]. This indicates the ability of spirulina to protect the body's physiological system from oxidative damage [37]. Due to its positive effect on the quality of meat and its preservation under different storage conditions, this effect is important in the poultry industry [13].

In addition, spirulina is a source of long-chain polyunsaturated fatty acids, especially Omega-6 acids (gama linolenic acid and Arachidonic acid) as well as Omega-3 acids (EPA acid and DHA acid), as shown in Table (5) of the current study, and these two groups of acids Fatty acids (Omega 6 and 3) are essential fatty acids and are one of the antioxidant systems in broilers [6]. Linoleic acid has an important role in preventing the formation of free radicals through its association with glutathione peroxidase in stored broiler meat, which prolongs the storage period Meat without deteriorating its properties and preserving it from oxidation and rancidity obtained as a result of storage [38] as well as its ability to prevent the formation of intermediate compounds that produce free radicals, including butyl hydroxy toluene [13].

Or, the reason may be due to the role of vitamins in spirulina, the most important of which are vitamin C, vitamin E, and betacarotene, as vitamin C is an important water-soluble antioxidant in extracellular fluids and is able to neutralize ROS in the aqueous phase before it can attack and oxidize fats [39] Vitamin E is a fat-soluble antioxidant that breaks down the chain inside the cell membrane and plays an important role in protecting membrane fatty acids from lipid peroxidation [40]. Beta-carotene and other carotenoids also have antioxidant properties and may act. In Synergy with Vitamin E [41].

3.3. The Sensual traits of meat:

There was no significant effect of the use of spirulina algae on the degrees of sensory evaluation of the chest and thigh pieces that included testing the flavor, juiciness and mellowness in all the treatments of this study and shown in Table (7) and that the absence of significant differences (P≤0.05) in the flavor is very useful for the two chest pieces And the thigh of birds fed on spirulina, compared to birds fed on diets that do not contain spirulina algae, and from the foregoing inferred that the use of spirulina in broiler broiler diet had no effect on the palatability of the cooked meat and it did not show any desired distinct flavor while it prevented the emergence of an unpleasant flavor un desirable in taste.

| Meat sensory traits | Treatments | Significant |
|---------------------|------------|-------------|
| Flavor              | T1         | T2          | T3           | T4          | T5          |
| Juiciness           | T1         | T2          | T3           | T4          | T5          |
| Mellowness          | T1         | T2          | T3           | T4          | T5          |

The averages that carry different letters within the same class differ significantly between them. * It means that there are significant differences between the parameters at the (P≤0.05) probability level. Experimental treatments T1: control, T2: use of 1% spirulina, T3: use of 2% spirulina, T4: use of 3% of spirulina, T5: use of 4% of spirulina.
The reason may be due to the content of spirulina in a large number of substances such as essential fatty acids, as shown in Table (5) of the current study, or fat-soluble vitamins that can only be provided through the diet. Fats are responsible for many of the desired properties in meat. And its products [42] influence flavor and contribute to improving the tenderness and juiciness of meat [43]. Therefore, the content and composition of fats are of great importance to consumers due to their importance to meat quality and nutritional value [38]. As well as its content of antioxidant compounds that prevented the appearance of the rancid flavor of chicken meat with a high content of unsaturated fatty acids that are rapidly rancid, as shown in Table (5).

Table 7. The effect of using different levels of Spirulina algae on the degrees of gastronomic assessment (flavor, juiciness, mellowness) of the chest and thigh parts (mean ± standard error) of broilers.

| Sensory Calendar | Treatments | T1     | T2     | T3     | T4     | T5     | Significant |
|------------------|------------|--------|--------|--------|--------|--------|-------------|
| Flavor           | Chest piece| 0.26±5.40 | 0.18±5.50 | 0.23±5.91 | 0.31±5.83 | 0.37±6.00 | N.S         |
|                  | Thigh piece| 0.16±5.83 | 0.18±5.50 | 0.47±5.25 | 0.42±5.50 | 0.32±5.80 | N.S         |
| Juiciness        | Chest piece| 0.45±5.00 | 0.18±5.50 | 0.23±5.50 | 0.21±5.66 | 0.36±5.57 | N.S         |
|                  | Thigh piece| 0.22±5.50 | 0.25±5.75 | 0.25±5.75 | 0.21±5.66 | 0.22±5.60 | N.S         |
| Mellowness       | Chest piece| 0.41±5.10 | 0.18±5.50 | 0.22±5.75 | 0.22±5.50 | 0.47±5.28 | N.S         |
|                  | Thigh piece| 0.22±5.50 | 0.32±6.00 | 0.40±6.00 | 0.30±6.16 | 0.30±5.70 | N.S         |

N.S is not significant. Experimental treatments T1: control, T2: use of 1% spirulina, T3: use of 2% spirulina, T4: use of 3% of spirulina, T5: use of 4% of spirulina.

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