Nutritional value of green seaweed (Ulva lactuca) for broiler chickens

Alaeldein M. Abudabos,1 Aly B. Okab,1,2 Riyadh S. Aljuumah,1 Emad M. Samara,1 Kalid A. Abdoun,1 Ahmad A. Al-Haidary1
1Department of Animal Production, King Saud University, Riyadh, Saudi Arabia
2Department of Environmental Studies, Alexandria University, Egypt

Abstract
The current work aimed to assess the potential of the green seaweed Ulva lactuca (U. lactuca) as an alternative ingredient in broiler chicken diets. The effect of substituting 1.0 or 3.0% of corn with U. lactuca on performance, carcass characteristics and serum constituents of broilers from 12 to 33 d of age was evaluated. Three treatments were distributed in a RCBD design: T1, control diet (0% U. lactuca); T2, 1.0 % U. lactuca; T3, 3.0% U. lactuca. A total of 45 chicks were assigned to three treatments (5 replicates per treatment) used in this experiment. Cumulative feed intake (FI), body weight gain (BWG), feed conversion ratio (FCR) and nutrients retention from 12 to 33 d of age were not affected by treatment (P>0.05). Birds which had received T3 had a higher dressing percentage. El-Deek et al. (1987) found that inclusion of seaweeds in finisher broiler diets had no significant effects on growth, feed intake (FI) and FCR. Gu et al. (1988) concluded that 2.0% of marine algae meal improved broiler performance and dressing percentage. Ross and Dominy (1990) found that the growth of the broilers fed diets containing up to 6.0% of Spirulina was not different from that of the chicks receiving the control diet. Ernest and Warren (1990) observed that performance of male broiler chickens was not significantly affected by incorporation of blue-green algae up to 6.0% in the diet. Other reports indicated negative effects for seaweeds on broiler performance. Ventura et al. (1994) studied the effect of inclusion of U. rigida at 0.0, 10.0, 20.0 and 30.0% on chicken performance, it was reported that U. rigida decreased FI and body weight gain (BWG) and they concluded that it is harmful to be included in the diet at level higher than 10.0%. The objective of this study was to evaluate the effect of substituting 1.0 and 3.0% of corn with seaweed (U. lactuca) on performance, carcass characteristics, serum constituents and nutrients retention of broilers from 12 to 33 d.

Materials and methods
The study was carried out at the Department of Animal Production, Faculty of Food and Agriculture Sciences, King Saud University; Riyadh, Saudi Arabia under a protocol approved by King Saud University and complies with the current laws of Saudi Arabia.

Seaweed preparation
Seaweed was handpicked and collected in April (2009) using scalpel from Mediterranean Sea shore of Alexandria, Egypt. The collected seaweed was from the species U. lactuca, green algae in the division of Chlorophyta. Collected seaweed was adequately washed with fresh water for 3 times to remove the salt, sun-dried for three days, and then oven-dried at 60°C for 72 h. Seaweed was ground to pass a 1.0 mm screen using Wiley mill grinder. Samples of U. lactuca were analyzed for gross energy (AOAC, 1990), crude protein (N x 6.25) (AOAC, 1968), crude fibre (AOAC, 1982b) and ether extract (AOAC, 1982a). Minerals content were determined by inductively coupled plasma emission spectrometry (ICP) (method 990.08 AOAC). Chemical analysis and mineral composition of U. lactuca are presented in Table 1.

Animals and husbandry
One-day-old male chicks (Ross) were obtained from a commercial hatchery and randomly distributed among cages in electrically heated battery brooders with raised wire floors. The chicks had been vaccinated for Marek’s disease, Newcastle and infectious
bronchitis. For the first 11 days, the chicks were fed a common starter mash diet that met the nutrient requirement suggested by NRC (1994). At 12 d, the chicks were grouped by weight in such a way as to reduce variation in mean chick weight and received the experimental diets. Five birds were randomly allotted to each of 15 cages; total number of birds used in this trial was 45. The temperature during the trial period was set at 22.0°C (actual temperature average during the trial period was 26.1°C). Feed and water were provided ad libitum and birds were maintained a 24-h light schedule.

**Diets and treatments**

Chemical composition of corn, SBM, and *U. lactuca* were determined and the adjusted values were used to formulate the experimental diets (Table 1). Corn was reduced at the expense of *U. lactuca*, chicks were fed a standard corn-SBM starter from 1 to 11 d of age and on d 12 chicks were received 1 of 3 dietary treatments: T1, control diet and was formulated to meet a minimum of 100% of NRC (1994) requirements; T2, 1.0% *U. lactuca*; T3, 3.0% *U. lactuca*. Diets 2 and 3 were formulated by substituting 1.0 and 3.0% of corn with *U. lactuca*, respectively. There was no attempt to make the diets isocaloric or isonitrogenous, the levels of other ingredients remained constant.

**Measurements**

Feed intake and body weight (BW) were recorded weekly by pen and FCR computed at 19, 26 and 33 d. Mortality was checked daily and weights of dead birds were used to adjust FCR. At the conclusion of the trial at 33 d, two birds per cage were selected and kept without food for 12 h then were bled from cutaneous ulnar vein. Blood samples were collected in a 10 mL tubes (Iheukwumere and Herbert, 2003); blood samples were centrifuged using plain tubes at 5ºC (Iheukwumere and Herbert, 2003); blood samples were centrifuged using plain tubes. From the 10 mL tubes, serum was harvested and then transferred into eppendorf tubes and stored at -20ºC until further analysis, unless fresh sample is required for the analysis. The following analysis were conducted using enzymatic colorimetric kits (M, Europa GmbH, Hannover, Germany): total protein (Biuret method), albumin (Bromoresol green method), globulin concentration was calculated, as the difference between total protein (TP) and albumin concentrations, total lipid (sulfo-phosphate vanillin method), cholesterol (Trinders color method), glucose (Modified trinder/GOD method), uric acid (end point method), sodium (Na+) (sodium dependent β-galactosidase activity), potassium (K+) (turbidimetric method), chloride (Cl-) (thiocyanate method); calcium (Ca++) (color/end point method) and zinc (Zn++) (colometric method). In addition, the following serum enzymes were determined by using UV/Kinetic method: alanine transaminase (ALT), aspartateaminotransferase (AST), alkaline phosphatase (ALP), gamma-glutamyltransferase (GGT), lactate dehydrogenase (LDH), and creatine kinase (CK). All analyses were carried out in duplicate. The birds were processed using manual evisceration to determine dressing and parts yield. After euthanasia, feather, heads, necks, and shanks were removed, and the remaining carcasses were dissected to breast, thigh, drumstick, and abdominal fat and weighed. The percentage of yield of each part was calculated on the basis of dressed weight.

Breast muscle color was measured by using color values for (L*) lightness, (a*) redness and (b*) yellowness, by Chromo meter CR-400 (Konica Minolta sensing Inc., Japan, B 8207175).

**Statistical analysis**

All statistical analysis was performed using

**Table 1. Dietary ingredients and chemical composition of the experimental diets and *Ulva lactuca***

| Ingredients, g/kg | T1   | T2   | T3   | *Ulva lactuca* |
|------------------|------|------|------|-----------------|
| Corn             | 556.0| 556.0| 536.0|                 |
| Soybean meal     | 334.0| 334.0| 334.0|                 |
| Seaweed          | 0.0  | 10.0 | 30.0 |                 |
| Palm oil         | 63.0 | 63.0 | 63.0 |                 |
| Dicalcium phosphate | 23.0 | 23.0 | 23.0 |                 |
| Ground limestone | 5.0  | 5.0  | 5.0  |                 |
| DL-methionine (%9%) | 1.0 | 1.0 | 1.0  |                 |
| Salt             | 3.0  | 3.0  | 3.0  |                 |
| Vitamin premixa  | 2.5  | 2.5  | 2.5  |                 |
| Trace mineral mix | 0.5 | 0.5 | 0.5  |                 |
| Choline Cl 60    | 0.5  | 0.5  | 0.5  |                 |
| Sodium Bicarbonate | 1.5 | 1.5 | 1.5  |                 |
| Calculated analysis |   |      |      |                 |
| ME, kcal/kg      | 3160 | 3150 | 3120 |                 |
| Crude protein, % | 20.7 | 20.9 | 21.3 |                 |
| Lysine, %        | 1.11 | 1.11 | 1.12 |                 |
| Methionine, %    | 0.41 | 0.42 | 0.45 |                 |
| Threonine, %     | 0.79 | 0.82 | 0.88 |                 |
| TSSA, %          | 0.75 | 0.80 | 0.83 |                 |
| Calcium, %       | 0.90 | 0.96 | 1.08 |                 |
| Non-phyt P, %    | 0.45 | 0.45 | 0.46 |                 |
| Moisture, %      | 6.90 | 7.10 | 7.10 | 10.65           |
| ME, kcal/kg      | 3139 | 3127 | 3113 | 1878           |
| Crude protein, % | 20.8 | 21.1 | 21.5 | 23.1            |
| Ether extract, % | 7.53 | 7.77 | 6.87 | 0.25            |
| Crude fibre, %   | 2.57 | 3.18 | 3.24 | 12.31           |
| Ash, %           | 5.60 | 5.85 | 5.97 | 29.86           |
| Calcium, %       | 6.15 |      |      |                 |
| Phosphorus, %    | 0.20 |      |      |                 |
| Sodium, %        | 2.93 |      |      |                 |
| Potassium, %     | 1.51 |      |      |                 |
| Magnesium, %     | 1.90 |      |      |                 |
| Copper, ppm      | 7.07 |      |      |                 |
| Iron, ppm        | 1052 |      |      |                 |
| Manganese, ppm   | 101  |      |      |                 |
| Zinc, ppm        | 28.0 |      |      |                 |
Results

Feed intake, BWG, and FCR of male broiler chickens at different ages are shown in Table 2. At 26 and 33 d, no significant differences in BWG, FI and FCR were found due to treatment; similarly, cumulative FI and BWG and FCR from 12 to 33 d were not affected by treatment. However, a numeric improvement in BWG for birds which had received T3 was noticed (P=0.7). The mean percentage of carcass parts is documented in Table 3. Treatment had a significant effect on dressing percentage (P<0.004); birds which had received T3 had a higher dressing percentage compared to those which had received T1 or T2. While, there was no significant difference in dressing percentage between birds which had received T2 and T3. Breast muscle yield followed the same trend; heavier breasts were obtained from birds which had received T2 or T3 (P<0.001). No difference in breast muscle yield was noticed between birds which had received T2 and T3. Thigh and drumstick (leg quarter) yield percentage was not significantly affected by treatment (P>0.05). Abdominal fat was reduced significantly (P<0.001) in birds which had received T3 compared to those which had received T1 or T2, a significant differences in abdominal fat percentage between T2 and T3 (P<0.05) was found. On the other hand, breast muscle color was not affected by any dietary treatments. The data related to serum biochemistry are shown in Table 4. Serum total lipid concentrations were significantly affected by treatment (P<0.05), serum from birds which had received T3 had the lowest concentration, while there was no difference between those fed T2 and T3 or T1 and T2. Serum cholesterol was reduced for T2 and T3 as compared to T1 (P<0.05). Serum total protein, albumin, globulin, and glucose were similar in all groups. Serum mineral contents were found to be similar among birds that had received the dietary treatments, Na+, K+, Na: K ratio, Cl, Ca++, and Zn++ concentrations were not affected by any treatment (P>0.05). On the other hand, serum Ca++, and Zn++ concentrations were not affected by any treatment (P>0.05). Serum total protein, cholesterol were reduced for T2 and T3 as compared to T1 (P<0.05). Serum total protein, cholesterol were reduced for T2 and T3 as compared to T1 (P<0.05). Cumulative performance for the period from 19 to 33 day of age, ns, not significant.

Table 2. Body weight gain, feed intake and feed conversion ratio of broiler chickens given the experimental diets at different ages.

| Treatments | Performance 12-19 d | Performance 20-26 d | Performance 27-33 d | Cumulative performance |
|------------|---------------------|---------------------|---------------------|------------------------|
|            | BWG, g              | Fl, g               | PC, g               | BWG, g                |
| T1         | 342.7               | 440.4               | 1.291               | 534.3                 |
| T2         | 348.9               | 436.7               | 1.239               | 511.7                 |
| T3         | 3691.4              | 462.8               | 1.259               | 514.4                 |
|            | ±16.2               | ±1102               | ±0.03               | ±23.5                 |
|            | ns                   | ns                   | ns                   | ns                     |
| T1         | 354.3               | 735.4               | 1.381               | 596.1                 |
| T2         | 511.7               | 709.7               | 1.394               | 607.4                 |
| T3         | 514.4               | 718.1               | 1.408               | 623.2                 |
|            | ±22.3               | ±0.06               | ±0.04               | ±22.1                 |
|            | ns                   | ns                   | ns                   | ns                     |
| T1         | 380.7               | 2055.7              | 1.490               | 1473.2                |
| T2         | 2036.2              | 1.470               | 1.499               | 1506.8                |
| T3         | 2111.8              | 1.406               | 1.460               | 37.5                  |
|            | ±0.14               | ±0.04               | ±0.04               | ns                     |
| T1, control diet (0% U. lactuca); T2, 1.0% U. lactuca; T3, 3.0% U. lactuca. Treatments 2 and 3 were formulated by substituting 1.0 and 3.0% of corn with U. lactuca, respectively. BWG, body weight gain; Fl, feed intake; PC, feed conversion. Cumulative performance for the period from 19 to 33 day of age, ns, not significant.

Table 3. Effect of different treatments on parts yield as percentages of broiler dressed weight and breast color.

| Treatments | Dressed yield, % | Breast meat, % | Leg quarter, % | Abdominal fat, % | Breast color |
|------------|------------------|----------------|----------------|------------------|--------------|
| T1         | 70.3±            | 23.2±          | 35.9±          | 2.2±             | 65.2±        |
| T2         | 70.7±            | 25.2±          | 35.2±          | 1.9±             | 66.9±        |
| T3         | 71.3±            | 25.5±          | 35.6±          | 1.3±             | 67.0±        |
|            | ±0.14            | ±0.26          | ±0.48          | ±0.09            | ±1.91        |
|            | **               | ***            | ns             | **               | ns           |
| T1, control diet (0% U. lactuca); T2, 1.0% U. lactuca; T3, 3.0% U. lactuca. Treatments 2 and 3 were formulated by substituting 1.0 and 3.0% of corn with U. lactuca, respectively. Breast muscle color was measured by using color values for (L*) lightness, (a*) redness and (b*) yellowness, by Chromo meter CR-400 (Konica Minolta sensing Inc., Japan, B 8207175). Breast meat yield (Pectoralis major and Pectoralis minor), expressed as percentage of the chilled carcass weight. *P<0.01; **P<0.001; ns, not significant. Means in the row with different superscripts differ significantly.

Table 4. Serum chemistry concentrations of broiler chickens fed the experimental diets.

| Treatments | AST, U/L | CK, U/L | ALT, U/L | ALP, U/L | GGT, U/L | LDH, U/L |
|------------|----------|---------|----------|----------|----------|----------|
| T1         | 67.5     | 1.86    | 1.98     | 161.5    | 3.97     | 4.02     |
| T2         | 61.0     | 1.49    | 1.14     | 155.9    | 4.88     | 3.99     |
| T3         | 66.3     | 1.37    | 1.32     | 159.4    | 5.51     | 3.98     |
|            | ±4.9     | ±0.15   | ±0.17    | ±21.0    | ±0.59    | ±0.38    |
|            | ns       | ns      | *        | ns       | ns       | ns       |
| T1, control diet (0% U. lactuca); T2, 1.0% U. lactuca; T3, 3.0% U. lactuca. Treatments 2 and 3 were formulated by substituting 1.0 and 3.0% of corn with U. lactuca, respectively. AST, aspartate aminotransferase; CK, creatine kinase; ALT, alanine transaminase; ALP, alkaline phosphatase; GGT, gamma-glutamyltransferase; LDH, lactate dehydrogenase; *P<0.05; ns, not significant. Means in the row with different superscripts differ significantly.
hand, serum uric acid concentration was influenced by treatment (P<0.05), it was significantly higher for birds which had received the control diet compared to the other 2 treatments, no significant difference was found between those which had received T2 and T3. No significant difference in AST, ALT, ALP, GGT, LDH, and CK were found (P>0.05). The only enzyme that showed response to treatment was ALT, it was significantly higher for birds which had received T1 as compared to the other treatments (P<0.05) while it was similar between those fed T2 and T3.

## Discussion

During the trial period, there were no significant differences in BWG between birds fed the dietary treatments. Moreover, treatment did not affect FI or FCR. This may be indicative that there were no toxic or anti-nutritional effects caused by *U. lactuca*. These results agree with previous investigators who utilized the same or other species from the same genus and demonstrated that broilers which had received seaweed performed equally well or even better than birds received the positive control diet (Maurice *et al.*, 1984; El-Deek *et al.*, 1987; Gu *et al.*, 1988; Ross and Dominy, 1990; Ernst and Warren, 1990; Venkataraman *et al.*, 1994). Conversely, Carrillo *et al.* (1990) reported that growth rate of broilers gradually decreased as the inclusion rate of seaweed increased in the diet to 15.0%. Similarly, Ventura *et al.* (1994) reported that *U. rigida* decreased FI and BWG and they concluded that it is harmful to be included in the diet at level higher than 10.0%. By comparing corn and *U. lactuca* based on the analysis conducted in this trial, *U. lactuca* contained 44.0% lower ME, 55.0% higher crude protein and 82.0 % higher crude fibre. As a result, the effect of substituting 0.0, 1.0 or 3.0% of corn with *U. lactuca* resulted in producing diets with slightly lower ME, higher crude protein and higher amino acids (AA). The numeric improvement (33 g) in BWG for birds fed T3 compared to T1 could be a result of the improvement in essential AAs especially sulfur-containing AAs. According to Ito and Hori (1989) *U. lactuca* contains high AAs especially sulfur-AAs. In practical feeds the total sulfur amino acids, lysine and threonine are usually considered as the most limiting amino acids in practical feeding for growing chickens fed corn-SBM meal diets (Kidd, 2000). Dietary protein and AAs are major elements affecting carcass characteristics; and quality of meat such as abdominal fat content and breast meat yield are greatly influenced by AAs level (Leclereq, 1998).

Breast muscle provides the greatest portion of edible meat in broilers and the contribution of breast muscle to total carcass meat is extensive (Acar *et al.*, 1993). In this trial and based on estimated values, T3 contained 11.1% and 10.2% higher methionine and threonine, respectively compared to T1 and the improvement in breast yield and dressing percentage could be explained by the improvement in essential AAs. Wong and Cheung (2001) evaluated the nutritional values of seaweed protein, they reported that seaweed protein concentrates were rich in leucine, valine and threonine but lacked cystine. In a subsequent study, Burtin (2003) reported that the protein levels of *Ulua* species are in the range of 15 to 20%. Ojano-Dirain and Waldroup (2002) reported that increasing Methionine from 0.38 to 0.44% in a broiler diet resulted in significant improvements in dressing percentage and breast yield and a numerical reduction in AF. Café and Waldroup (2006) reported that increasing the Met level to 130.0% of NRC (1994) improved dressing percentage and breast yield of broilers at 35 d of age as compared to a control group. A significant reduction of abdominal fat was associated with feeding *U. lactuca*. Based on determined analysis, crude protein level of the diet increased as the level of *U. lactuca* increased, the substituting of 3.0% corn with *U. lactuca* resulted in 2.8% increase in protein content compared to T1. The results of this trial agree with those obtained by Moran *et al.* (1992) they demonstrated that crude protein level had a major impact on abdominal fat deposition, increasing crude protein intake and decreasing abdominal fat deposition rather than single AA.

| Treatments | T1 | T2 | T3 | SEM | P |
|------------|----|----|----|-----|---|
| Total protein, g/dL | 3.23 | 3.08 | 3.10 | ±0.21 | ns |
| Albumin, g/dL | 1.81 | 1.57 | 1.59 | ±0.15 | ns |
| Globulin, g/dL | 1.42 | 1.52 | 1.51 | ±0.27 | ns |
| Total lipids, g/dL | 409.0* | 324.3* | 283.9* | ±28.9 | * |
| Cholesterol, g/dL | 145.2* | 116.1* | 115.7* | ±12.1 | * |
| Glucose, g/dL | 188.6 | 197.4 | 192.4 | ±12.3 | ns |
| Uric acid, g/dL | 7.25* | 5.20* | 4.57* | ±0.62 | * |
| Na, mmol/L | 178.5 | 193.7 | 156.3 | ±22.96 | ns |
| K, mmol/L | 3.68 | 3.74 | 3.74 | ±0.25 | ns |
| NaCl | 49.2 | 51.4 | 192.4 | ±5.32 | ns |
| Cl, mmol/L | 114.4 | 136.8 | 120.0 | ±8.85 | ns |
| Ca, mg/dL | 114.4 | 128.8 | 125.8 | ±0.69 | ns |
| Zn, µmol/L | 24.4 | 26.6 | 27.1 | ±2.00 | ns |

T1, control diet (% *U. lactuca*); T2, 1.0 % *U. lactuca*; T3, 3.0 % *U. lactuca*. Treatments 2 and 3 were formulated by substituting 1.0 and 3.0% of corn with *U. lactuca*, respectively. AST, aspartate aminotransferase; CK, creatine kinase; ALT, alanine transaminase; ALP, alkaline phosphatase; GGT, gamma-glutamyltransferase; LDH, lactate dehydrogenase; °P<0.05, ns, not significant. *Means in the row with different superscripts differ significantly.
improved carcass characteristics. However, it is important to keep in mind the crude fibre and soluble fibre percentages when using *U. lactuca* in broilers diet. It has been shown that *U. lactuca*, has 21.3% of soluble fibre (Lahaye, 1991). The viscosity associated with soluble dietary fibres has been shown to increase the thickness of the intestinal boundary layer and consequently impede nutrient uptake (Johnson and Gee, 1981; Flourie et al., 1984). The physiological importance of soluble dietary fibres lies in their ability to reduce the diffusion and absorption of nutrients in the small intestine (Furda, 1990).

**Conclusions**

In this experiment, birds fed on the 3.0% seaweed diet performed better than birds fed on respective control diet. It was speculated that higher crude protein and AAs specially methionine which resulted in improvement in broiler diets. J. Agric. Sci. Mansoura Univ. Egypt 12:707-717. Ernest, R., Warren, D., 1990. The nutritional value of Blue-Green algae Spirulina Plantensis for poultry. Poultry Sci. 69:794-800. Flourie, B., Vidon, N., Florent, C.H., Bernier, J.J., 1984. Effect of peptin on jejunal glucose absorption and unstirred layer thickness in normal man. Gut 25:936-941. Furda, I., 1990. Interaction of dietary fiber with lipids - mechanistic theories and their limitations. In: I. Furda and C.J. Brine (eds.) New marine alga and algal products. Hydrobiology 260/261:15-21. Johnson, I.T., Gee, J.M., 1981. Effect of gel-forming gums on the intestinal unstirred layer and sugar transport in vitro. Gut 22:398-403. Kidd, M.T., 2000. Nutritional consideration concerning threonine in broilers. World. Poultry Sci. J. 56:139-151. Lahaye, M., 1991. Marine algae as source of fiber: determination of soluble and insoluble dietary contents in some “sea vegetables”. J. Sci. Food Agric. 54:587-594. Lahaye, M., Jegou, D., 1993. Chemical and physical-chemical characteristics of dietary fibres from Ulva lactuca (L.) Thuret and Enteromorpha compressa (L.) Grev. J. Appl. Physiol. 5:195-200. Leclercq, B., 1998. Specific effects of lysine on broiler production: comparison with threonine and valine. Poultry Sci. 77:118-123. Lumeej, J.T., 1994. Hepatology. In: B.W. Ritchie, G.J. Harrison and L.R. Harrison (eds.) Avian medicine: principles and application. Wingers Publ., Lake Worth, FL, USA, pp 522-537. Manivannan, K., Karthiak, Devi G., Thirumaran, G., Anantharaman, P., 2009. Mineral composition of marine macroalgae from Mandapam coastal regions; Southeast Coast of India. Amer. Eurasian J. Bot. 2:42-51. Maurice, D.V., Jones, J.E. Dillon, C.R., Weber, J.M., 1984. Chemical composition and nutritional value of Brazilian elodea (Egeria densa) for the chick. Poultry Sci. 63:317-323. Moran, E.T.Jr., Bushong, R.D., Bilgili, S.F., 1982. Reducing dietary crude protein for broilers while satisfying amino acid requirements by least-cost formulation: Live performance, litter composition and yield of fast food carcass cuts at six weeks. Poultry Sci. 71:1687-1694. National Research Council, 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC, USA. Ojano-Dirain, C.P., Waldroup, P.W., 2002. Evaluation of lysine, methionine and threonine needs for broilers three to six week of age under moderate heat temperature stress. Int. J. Poultry Sci. 1:16-21. Ross, E., Dominy,W., 1990. The nutritional value of dehydrated, blue-green algae (Spirulina platensis) for poultry. Poultry Sci. 69:794-800. SAS, 2003. SAS Users Guide: Statistics, ver. 7.0. SAS Inst. Inc., Cary, NC, USA. Venkataraman, L.V., Somasekaran, T., Becker, E.W., 1994. Replacement value of bluegreen alga (Spirulina platensis) for fishmeal and a vitamin mineral premix for broiler chicks. Brit. Poultry Sci. 35:373-381. Ventura, M.R., Castanon, J.I.R., McNab, J.M., 1994. Nutritional value of seaweed (Ulva rigida) for poultry. Anim. Feed Sci. Tech. 49:87-92. Wahbeh, M.I., 1997. Amino acid and fatty acid profiles of four species of macro algae from Aqaba and their suitability for use in fish diets. Aquaculture 159:101-109. Wong, K.H., Cheung, P.C.K., 2001. Nutritional evaluation of some subtropical red and green seaweeds: Part II. In vitro protein digestibility and amino acid profiles of protein concentrates. Food Chem. 72:11-17.

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