

## Effect of dietary supplementation of brown seaweed on performance of broiler chicken

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### ABSTRACT

A bio-assay was conducted to evaluate the effect of dietary supplementation of brown seaweed (*Sargassum wightii*) on the performance of broilers. Broilers (400) were divided into 5 treatment groups. Each treatment had 8 replicates with 10 birds per replicate. The chicks of control (Group A) were fed a basal diet. Group B was fed a basal diet with bacitracin methylene disalicylate (BMD) at 0.005%. Treatment Groups C, D, and E received the basal diet with supplementation of 0.07, 0.1, and 0.13% brown seaweed, respectively. All the diets were made isocaloric and isonitrogenous. Standard management practices were followed in the rearing of birds. Parameters, viz. growth performance, immune response, total viable count (TVC) and carcass traits were studied for a period of six weeks. Group E exhibited higher weight gain and better feed conversion ratio compared to Groups D, C, and B. The feed consumption was similar for Groups C, D, and E. Mortality was lower (2.5%) in Groups B, C, D, and E compared to Group A (3.75%). The eviscerated, ready to cook, breast, thigh, and drumstick yields were greater in Group E whereas higher giblet weights were recorded in Groups D and E. The cell-mediated immune response was significantly better in Group E compared to Groups D, C, B, and A with higher weight of lymphoid organs (thymus and spleen). Groups D and E were associated with a lower TVC, followed by Group C compared to positive control (Group B) and negative control (Group A). It was concluded that supplementation of 0.13% brown seaweed in the diet of broilers improved growth performance, cell mediated immunity, total viable count and carcass traits.

**Keywords:** Brown seaweed, Carcass traits, Immune response, Performance

India has the world's largest livestock population and it is a major producer of milk, meat, broiler chickens, eggs, and fish. Protein-rich diets are becoming more popular due to increased awareness regarding health and wellness (India Poultry Market Report and Forecast 2021-2026). The poultry industry utilizes a variety of synthetic feed additives in order to maximize production efficiency, product quality, and disease control (Bedford 2000, Whitehead 2002). Increase in the bacterial resistance to antibiotics has led to the use of alternative antibiotic growth promoters (Yadav *et al.* 2016). This has prompted the use of bioactive feed additives such as enzymes, probiotics, prebiotics, synbiotics, organic acids, and extracts of plants (phytobiotics), in place of antibiotics in diets of monogastric animals (Wenk 2003). Seaweed, which is one of the most diverse group of marine organisms, provides a range of bioactive components (Pomponi 1999, Wijesekara *et al.* 2011). There are three types of algae, viz. brown algae (Phaeophyta), green algae (Chlorophyta), and red algae (Rhodophyta). *Sargassum wightii* is a

marine brown algal species commonly found in India with numerous biological applications and a high content of sulphated polysaccharides. Fucoxanthin, a carotenoid, is the primary pigment in brown seaweeds, and the main polysaccharides present are alginates, laminarins, fucans, and cellulose. Despite their low caloric value, seaweed is packed with dietary fibres, proteins, minerals, vitamins, antioxidants, phytochemicals, and polyunsaturated fatty acids (Khotimchenko and Yakovleva 2005). They are full of vitamins and well balanced with essential amino acids which are needed for life and health (Dhargalkar and Pereira 2005). Marine macro algae also contain bioactive compounds that have various biological activities such as antioxidants (Yuan and Walsh 2006, Chandini *et al.* 2008), antiviral (Artan *et al.* 2008), anti-inflammatory (Kim *et al.* 2009), anticancer (Kong *et al.* 2009), and anticoagulants (Pushpamali *et al.* 2008).

Approximately 400 species belong to *Sargassum*, a genus of brown seaweed commonly known as gulfweed or sea holly. It belongs to the family Sargassaceae, order Fucales, subclass Cyclosporeae, and class Phaeophyceae (Mattio and Payri 2011). There are several *Sargassum* species found throughout tropical and subtropical areas of the world and they produce compounds with different properties,

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including terpenoids, polysaccharides, polyphenols, sargaquinoic acids, sargachromenol, plastoquinones, and steroids. The evaluation of phytobiotics in comparison with other in-feed antibiotic alternatives is still in its infancy and their potential uses need to be explored with greater emphasis. Therefore, the present study was undertaken to know the beneficial effects of brown seaweed (*Sargassum wiggertii*) as an alternative to antibiotic growth promoter on performance of broilers.

## MATERIALS AND METHODS

The research work was approved by the Institutional Animal Ethics Committee (Resolution No. I/2021- Ref. No. VCU/IAEC/CPCSEA/57/2021; Dated: 27 July 2021) and the Board of Studies. The study was conducted on 400 day-old commercial broiler chicks of the *VenCobb* 430Y strain at the Experimental Broiler Shed, College of Veterinary and Animal Sciences, Udgir (MAFSU, Nagpur) for a period of 6 weeks. Randomly, 400 day-old chicks were divided into 5 treatment groups equally. There were 8 replicates per treatment group and each replicate had 10 chicks. Each treatment therefore contained 80 broiler chicks. A basal diet was fed to the Control (Group A) as per BIS (2007). Treatment Group B was fed basal diet supplemented with 0.005% of the antibiotic growth promoter of the bacitracin methylene di-salicylate (BMD). Treatment Group C received a basal diet + 0.07% of brown seaweed. Brown seaweed was added at a level of 0.1% and 0.13% to the basal diet for treatment Groups D and E respectively (Table 1). All the diets were made Isocaloric and Isonitrogenous. The parameters like body weight gain, feed intake, FCR, mortality, carcass traits and immunity were studied.

The body weights of birds were recorded individually on a weekly basis. Based on the data of weekly live weights replicate wise, the weight gain in each treatment group was calculated. The broilers were fed pre-starter feed (0-7 days), starter feed (8-21 days), and finisher feed (22-42 days). The amount of feed consumed under each treatment group was recorded replicate-wise. Under each treatment group, the cumulative weekly feed consumption was calculated. The feed conversion ratio was calculated by dividing the total feed consumed by the body weight gain during the same period. Any mortality during the experimental period was recorded. A total of 30 broiler chicks were selected for determination of cell-mediated immunity (foot web index to phytohaemagglutinin-P, a lectin from *Phaseolus vulgaris* PHA-P) and humoral immune responses (against RD titres of broilers). As per Corrier and Deloach (1990), cutaneous basophilic hypersensitivity (CBH) was assessed *in vivo* using PHA-P for assessing cell mediated immunity (CMI). The toe thickness of 6 birds from each treatment was measured on the 22<sup>nd</sup> post-hatch day using a digital micrometer at the 3<sup>rd</sup> and 4<sup>th</sup> interdigital spaces of both feet. Immediately after measurements, 0.1 ml PHA-P (1 mg per ml) was intradermally injected in right foot web while 0.1 ml of phosphate buffer saline (PBS) was injected into the left foot

Table 1. Composition (%) of experimental broiler diets for different growth phases

| Ingredient (kg)                      | Pre-starter<br>(0-7 d) | Starter<br>(8-21d) | Finisher<br>(22-42 d) |
|--------------------------------------|------------------------|--------------------|-----------------------|
| Maize                                | 54.63                  | 55.62              | 59.6                  |
| Soybean meal                         | 39.20                  | 36.90              | 31.83                 |
| Vegetable oil                        | 2.49                   | 3.90               | 4.97                  |
| Dicalcium phosphate<br>(DCP)         | 1.78                   | 1.83               | 1.9                   |
| Limestone powder (LSP)               | 0.89                   | 0.87               | 0.85                  |
| Salt                                 | 0.30                   | 0.30               | 0.30                  |
| Trace min. premix*                   | 0.11                   | 0.10               | 0.10                  |
| Vitamin premix**                     | 0.15                   | 0.15               | 0.15                  |
| DL-Methionine                        | 0.15                   | 0.13               | 0.11                  |
| L-Lysine                             | 0.13                   | 0.036              | 0.03                  |
| Choline chloride                     | 0.05                   | 0.05               | 0.05                  |
| Toxin binder                         | 0.05                   | 0.05               | 0.05                  |
| Coccidiostat                         | 0.05                   | 0.05               | 0.05                  |
| B-Complex***                         | 0.015                  | 0.015              | 0.015                 |
| Total                                | 100.00                 | 100.00             | 100.00                |
| Nutrient composition (%), Calculated |                        |                    |                       |
| Crude protein                        | 23.00                  | 22.00              | 20.00                 |
| Calcium                              | 1.00                   | 1.00               | 1.00                  |
| Available phosphorus                 | 0.45                   | 0.45               | 0.45                  |
| L-Lysine                             | 1.34                   | 1.20               | 1.06                  |
| DL-Methionine                        | 0.53                   | 0.50               | 0.45                  |
| ME (kcal/kg)                         | 3000.91                | 3099.17            | 3200.67               |

\*Trace mineral premix supplied per kg diet: Mg, 300; Mn, 55; I, 0.4; Fe, 56; Zn, 30 and Cu, 4 mg. \*\*The vitamin premixes supplied per kg diet: 2475 mcg, Retinol; 30 mcg, Cholecalciferol; 1 mg, Menaquinone; 26.8 mg, Tocopherol as d-alpha tocopherol. \*\*\*B-complex supplied per kg diet: 2 mg, Thiamine; 4 mg, Riboflavin; 10 mcg, Cyanocobalamin; 60 mg, Niacin and 10 mg, Pantothenic acid.

web as placebo. A digital micrometer was used to measure the swelling of both foot webs 24 h after injection. The *in vivo* response to PHA-P was expressed as a web index.

To study humoral immune response, the chicks were vaccinated with LaSota vaccine on the 5<sup>th</sup> day and booster dose on the 21<sup>st</sup> day. The humoral immune response was assessed by estimating serum antibody titres against NDV. The blood was collected from 6 birds per treatment group and the serum was separated. A haemagglutination inhibition (HI) test was performed by means of U bottom microtitre plate by using 4 HA unit ND antigen. The reciprocal of the highest dilution showing 50% haemagglutination inhibition (button formation) was taken as the HI titre (log 2). The weights of immune organs such as bursa of fabricius, thymus, and spleen were recorded using digital weighing balance at 42<sup>nd</sup> day of age by slaughtering 6 birds from each treatment group and expressed as percentage of live weight.

The total viable count in all the treatment groups was studied on the 42<sup>nd</sup> day. Six birds per treatment group were sacrificed. The caecal content (1 g) was taken in a sterile glass tube in an aseptic condition. The content was serially

diluted in sterile normal saline to get  $10^{-5}$ ,  $10^{-6}$ , and  $10^{-7}$  dilutions and was used to get the total viable count (TVC). One ml content from each dilution was mixed with 9 ml of molten brain heart infusion agar ( $50^{\circ}\text{C}$ ) in a petri plate. After solidification, the petri plates were incubated at  $37^{\circ}\text{C}$  in a bacteriological incubator for 24 h. All the bacterial colonies were counted as colony forming units (CFU). The total viable count (CFU/g) was determined as a product of the mean of colonies at particular dilution and dilution factor.

Data pertaining to various treatment groups were analysed statistically using a completely randomized design (CRD) ensuing standard methods (Snedecor and Cochran 1994). Total viable counts were expressed as  $\log_{10}$ -transformed data for total colony forming units

(CFU). The analysis of data was done by means of SPSS software package version 20.0. Variables having unequal observations were analysed using the least square design method and Duncan's multiple range test (Duncan 1955).

## RESULTS AND DISCUSSION

*Body weight gain, feed consumption, feed conversion ratio and mortality:* The body weight gains were 584.2, 601.1, 634.6, 630.3 and 649.4 g for Groups A, B, C, D, and E, respectively at 6<sup>th</sup> week (Table 2). A significant ( $P<0.039$ ) increase in body weight gain was recorded in broilers fed diets supplemented with brown seaweed. Body weight gains by the end of the 6<sup>th</sup> week were 2617.2, 2683.9, 2751.7, 2777.7, and 2809.6 g in Groups A, B, C, D and E, respectively. As compared to both positive and

Table 2. Effect of dietary addition of brown seaweed on body weight gain, feed intake and feed conversion ratio of broiler chickens

| Age/ Phase                   | A (Negative control) | B (Positive control) | Brown seaweed (g/kg) |                      |                     | Pooled SEM | p value |
|------------------------------|----------------------|----------------------|----------------------|----------------------|---------------------|------------|---------|
|                              |                      |                      | C 0.7                | D 1.0                | E 1.3               |            |         |
| <i>Body weight gain</i>      |                      |                      |                      |                      |                     |            |         |
| I wk                         | 144.0 <sup>a</sup>   | 144.6 <sup>ab</sup>  | 146.9 <sup>bc</sup>  | 149.5 <sup>cd</sup>  | 151.4 <sup>d</sup>  | 0.43       | 0.000   |
| II wk                        | 364.2 <sup>a</sup>   | 365.4 <sup>ab</sup>  | 367.0 <sup>abc</sup> | 370.5 <sup>bc</sup>  | 371.3 <sup>c</sup>  | 0.82       | 0.019   |
| III wk                       | 372.7 <sup>a</sup>   | 388.6 <sup>b</sup>   | 391.6 <sup>b</sup>   | 406.1 <sup>c</sup>   | 404.0 <sup>c</sup>  | 1.68       | 0.000   |
| IV wk                        | 569.2 <sup>a</sup>   | 587.4 <sup>ab</sup>  | 598.4 <sup>bc</sup>  | 596.6 <sup>bc</sup>  | 611.5 <sup>c</sup>  | 3.15       | 0.001   |
| V wk                         | 582.6 <sup>a</sup>   | 597.0 <sup>ab</sup>  | 612.9 <sup>ab</sup>  | 624.4 <sup>b</sup>   | 622.0 <sup>b</sup>  | 4.71       | 0.023   |
| VI wk                        | 584.2 <sup>a</sup>   | 601.1 <sup>ab</sup>  | 634.6 <sup>b</sup>   | 630.3 <sup>ab</sup>  | 649.4 <sup>b</sup>  | 7.49       | 0.039   |
| 0-III wk                     | 881.0 <sup>a</sup>   | 898.4 <sup>b</sup>   | 905.6 <sup>b</sup>   | 926.1 <sup>c</sup>   | 926.7 <sup>c</sup>  | 1.69       | 0.000   |
| III-VI wk                    | 1736.1 <sup>a</sup>  | 1785.5 <sup>b</sup>  | 1845.9 <sup>c</sup>  | 1851.3 <sup>c</sup>  | 1883.0 <sup>c</sup> | 7.39       | 0.000   |
| 0-IV wk                      | 1450.3 <sup>a</sup>  | 1485.9 <sup>b</sup>  | 1504.2 <sup>c</sup>  | 1522.7 <sup>d</sup>  | 1538.1 <sup>d</sup> | 3.10       | 0.000   |
| 0-V wk                       | 2033.0 <sup>a</sup>  | 2082.8 <sup>b</sup>  | 2117.1 <sup>c</sup>  | 2147.1 <sup>d</sup>  | 2160.2 <sup>d</sup> | 4.39       | 0.000   |
| 0-VI wk                      | 2617.2 <sup>a</sup>  | 2683.9 <sup>b</sup>  | 2751.7 <sup>c</sup>  | 2777.4 <sup>cd</sup> | 2809.6 <sup>d</sup> | 7.55       | 0.000   |
| <i>Feed intake</i>           |                      |                      |                      |                      |                     |            |         |
| I wk                         | 153                  | 152                  | 154                  | 155                  | 156                 | 0.99       | 0.663   |
| II wk                        | 422                  | 417                  | 418                  | 419                  | 417                 | 3.15       | 0.988   |
| III wk                       | 489                  | 497                  | 489                  | 502                  | 497                 | 2.95       | 0.588   |
| IV wk                        | 853                  | 862                  | 875                  | 863                  | 872                 | 5.12       | 0.691   |
| V wk                         | 1008                 | 1015                 | 1023                 | 1032                 | 1020                | 8.13       | 0.928   |
| VI wk                        | 1214                 | 1220                 | 1268                 | 1253                 | 1277                | 15.86      | 0.662   |
| 0-III wk                     | 1064                 | 1066                 | 1061                 | 1076                 | 1070                | 5.63       | 0.932   |
| III-VI wk                    | 3076                 | 3097                 | 3166                 | 3148                 | 3168                | 15.76      | 0.220   |
| 0-IV wk                      | 1917                 | 1927                 | 1936                 | 1939                 | 1941                | 7.89       | 0.872   |
| 0-V wk                       | 2925                 | 2943                 | 2959                 | 2971                 | 2961                | 10.27      | 0.668   |
| 0-VI wk                      | 4139                 | 4162                 | 4227                 | 4224                 | 4238                | 17.35      | 0.273   |
| <i>Feed conversion ratio</i> |                      |                      |                      |                      |                     |            |         |
| I wk                         | 1.06                 | 1.05                 | 1.05                 | 1.04                 | 1.03                | 0.007      | 0.651   |
| II wk                        | 1.16                 | 1.14                 | 1.14                 | 1.13                 | 1.12                | 0.009      | 0.763   |
| III wk                       | 1.31 <sup>b</sup>    | 1.28 <sup>ab</sup>   | 1.25 <sup>a</sup>    | 1.24 <sup>a</sup>    | 1.23 <sup>a</sup>   | 0.009      | 0.024   |
| IV wk                        | 1.50 <sup>c</sup>    | 1.47 <sup>b</sup>    | 1.46 <sup>b</sup>    | 1.45 <sup>ab</sup>   | 1.43 <sup>a</sup>   | 0.005      | 0.000   |
| V wk                         | 1.73 <sup>d</sup>    | 1.70 <sup>c</sup>    | 1.67 <sup>b</sup>    | 1.65 <sup>ab</sup>   | 1.64 <sup>a</sup>   | 0.006      | 0.000   |
| VI wk                        | 2.08 <sup>d</sup>    | 2.03 <sup>c</sup>    | 2.00 <sup>bc</sup>   | 1.99 <sup>ab</sup>   | 1.97 <sup>a</sup>   | 0.008      | 0.000   |
| 0-III wk                     | 1.21                 | 1.19                 | 1.17                 | 1.16                 | 1.15                | 0.007      | 0.196   |
| III-VI wk                    | 1.77 <sup>d</sup>    | 1.73 <sup>c</sup>    | 1.72 <sup>bc</sup>   | 1.70 <sup>ab</sup>   | 1.68 <sup>a</sup>   | 0.006      | 0.000   |
| 0-IV wk                      | 1.32 <sup>b</sup>    | 1.30 <sup>ab</sup>   | 1.29 <sup>ab</sup>   | 1.27 <sup>a</sup>    | 1.26 <sup>a</sup>   | 0.007      | 0.012   |
| 0-V wk                       | 1.44 <sup>c</sup>    | 1.41 <sup>b</sup>    | 1.40 <sup>b</sup>    | 1.38 <sup>ab</sup>   | 1.37 <sup>a</sup>   | 0.006      | 0.000   |
| 0-VI wk                      | 1.58 <sup>d</sup>    | 1.55 <sup>c</sup>    | 1.54 <sup>bc</sup>   | 1.52 <sup>ab</sup>   | 1.51 <sup>a</sup>   | 0.006      | 0.000   |

Values bearing different superscript differed significantly; NS, Non-significant ( $p>0.05$ ).

negative control groups, body weight gains (0-3, 4-6, 0-4, 0-5 and 0-6 weeks) were significantly ( $p < 0.000$ ) higher in treatment groups. Significantly higher body weight gain was recorded in broilers fed 0.13% of brown seaweed (Group E) compared to other dietary treatments at 6 week of age. Similar findings were reported by earlier workers (Mohammadigheisar *et al.* 2020) who found that birds fed seaweed had higher BWGs during the finishing phase compared to the control group. The results of present study are contradicted by the findings of Abudabos *et al.* (2013), Armin *et al.* (2015), Karu *et al.* (2018), Bai *et al.* (2019) and Reski *et al.* (2021) and who reported non-significant increase in body weight gain due to the feeding of brown seaweed or their blend. In this study, increase in body weight gain might be due to the presence of the secondary metabolites like alkaloids, phenols, flavonoids, saponins, steroids and other active metabolites in *Sargassum wiggertii*, causing a conducive environment in the gastrointestinal tract, resulting in an increase in the permeability of mucosal cells throughout the intestinal tract for maximum utilization of nutrients.

During the first week of the experiment, feed consumption among the different treatment groups was 153, 152, 154, 155, and 156 g, while during the sixth week, the feed consumption was 1214, 1220, 1268, 1253, and 1277 g for Groups A, B, C, D, and E, respectively (Table 2). There was no significant difference between the feed intake of various dietary treatment groups. Overall feed consumption (0-6 weeks) among the various treatment groups did not differ significantly. The present findings are similar to those reported by Choi *et al.* (2014), who reported that brown seaweed consumption had no significant effect on weekly and total feed consumption. Similarly reports by Deek and Brikaa (2009), Abudabos *et al.* (2013), Armin *et al.* (2015), Bonos *et al.* (2016), Gumus *et al.* (2018), Bai *et al.* (2019), Hafsa *et al.* (2019) and Andri *et al.* (2020) revealed that there was no significant difference among the various treatment groups due to inclusion of brown sea weed in the diet. The non-significant increase in feed intake by the birds in the treatment groups may be due to the antioxidant and hepatoprotective properties of the flavonoids present in brown seaweed.

Supplementation of brown seaweed to the diet at levels of 0.1 and 0.13% significantly improved FCR at 0-28, 0-35 and 0-42 d compared to the negative control group. Birds fed with 0.13% brown seaweed showed significantly better improvement in FCR during 0-35 and 0-42 d compared to both negative and positive control groups. This indicates a positive impact of brown seaweed on FCR. The FCR during the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> week was significantly improved when birds were fed with 0.13% brown seaweed, as compared to other dietary treatments containing 0.07 and 0.1% brown sea weed. This finding is in agreement with the earlier reports (Manal *et al.* 2018) who found a marked improvement in FCR ( $p < 0.05$ ) with the addition of liquid brown algae. Mohammadigheisar *et al.* (2000) and Hussein (2018) reported that seaweed blends improved

FCR linearly. Previous studies have also demonstrated that brown seaweed is advantageous for improving FCR (Kumar 2018, Bai *et al.* 2019, Canedo-Castro *et al.* 2019, Hafsa *et al.* 2019, Andri *et al.* 2020). Several minerals present in seaweed, including potassium, phosphorus, magnesium, calcium, sodium, chlorine, and sulphur, as well as trace elements (such as zinc, cobalt, chromium, iodine, etc.) have contributed to the better feed conversion capacity of the broilers in the present study. In Groups B, C, D, and E, mortality was lower (2.50%) than in Group A (3.75%). During the experimental trial, the overall mortality rate was 2.75%, which was within the normal range.

**Carcass traits:** The brown seaweed-fed birds had a lower shrinkage and feather loss ( $p < 0.000$ ), indicating that brown seaweed was effective in reducing shrinkage and feather loss (Table 3). Compared to the positive and negative control groups, the percentage blood loss in the treatment groups (C, D, and E) was significantly higher ( $p < 0.000$ ). Blood loss was the greatest when birds were fed with 0.13% brown seaweed. The eviscerated yields for Group D and E broilers were significantly higher than those recorded for Groups A, B, and C. The ready-to-cook yield of brown seaweed fed birds (Groups C, D and E) was significantly higher ( $p < 0.000$ ) compared to negative and positive control groups. A dietary addition of 0.13% brown seaweed (Group E) produced significantly higher ready-to-cook yields compared to those fed lower doses of brown sea weeds (0.07 and 0.10%).

The individual weight of heart and gizzard remained similar, but the relative weight of giblets was significantly ( $p < 0.001$ ) higher in the Groups C, D, and E when compared with negative and positive control groups (Group A and B). The back and wing weights were similar for all the treatments. The relative yields of the breast ( $p < 0.000$ ), drumstick ( $p < 0.017$ ) and thigh ( $p < 0.004$ ), were significantly higher for groups fed 1.3% brown seaweed compared to negative and positive control groups.

Dietary additions of 0.13% brown seaweed significantly reduced the fat pad thickness compared to all other groups. The results of this study are consistent with the reports of earlier researcher (Hussein 2018), who observed that supplementation with brown algae significantly increased dressing percentage, giblet weight, and reduced the abdominal fat content. A study conducted by Kumar (2018) revealed that dietary addition of 2% brown seaweed (*Sargassum wiggertii*) resulted in greater dressing yields as well as higher relative weights of giblet, breast, drumstick and thigh. Mohammadigheisar *et al.* (2020) reported a significant increase in breast yield when brown seaweed blend was supplemented in the diet of broilers. Furthermore, Hafsa *et al.* (2019) found that brown seaweed supplementation resulted in lower abdominal fat in broiler quails with higher dressing percentage. Supplementation of 3% of *Ulva lactuca* (green seaweed) produced higher dressing percentage and breast yield (Abudabos *et al.* 2013). Additionally, Abdel-Ghany *et al.* (2020) found that the addition of 2% of *Ascophyllum nodosum* (Brown

Table 3. Effect of dietary addition of brown seaweed on carcass (% of live wt.) trait

| Trait                       | A (Negative control) | B (Positive control) | Brown seaweed (g/kg) |                     |                    | Pooled SEM | p value |
|-----------------------------|----------------------|----------------------|----------------------|---------------------|--------------------|------------|---------|
|                             |                      |                      | C 0.7                | D 1.0               | E 1.3              |            |         |
| Shrinkage                   | 5.56 <sup>d</sup>    | 5.46 <sup>cd</sup>   | 5.25 <sup>bc</sup>   | 5.14 <sup>b</sup>   | 4.72 <sup>a</sup>  | 0.063      | 0.000   |
| Blood loss                  | 2.95 <sup>a</sup>    | 3.06 <sup>b</sup>    | 3.13 <sup>c</sup>    | 3.18 <sup>d</sup>   | 3.31 <sup>c</sup>  | 0.023      | 0.000   |
| Feather loss                | 4.77 <sup>d</sup>    | 4.62 <sup>c</sup>    | 4.53 <sup>b</sup>    | 4.64 <sup>c</sup>   | 4.43 <sup>a</sup>  | 0.023      | 0.000   |
| Eviscerated yield           | 69.26 <sup>a</sup>   | 69.33 <sup>a</sup>   | 69.41 <sup>a</sup>   | 70.01 <sup>b</sup>  | 70.54 <sup>c</sup> | 0.114      | 0.000   |
| Ready to cook yield         | 74.38 <sup>a</sup>   | 74.50 <sup>a</sup>   | 74.71 <sup>a</sup>   | 75.32 <sup>b</sup>  | 75.92 <sup>c</sup> | 0.132      | 0.000   |
| Heart                       | 0.78                 | 0.79                 | 0.80                 | 0.81                | 0.82               | 0.005      | 0.169   |
| Liver                       | 2.25 <sup>a</sup>    | 2.31 <sup>ab</sup>   | 2.35 <sup>bc</sup>   | 2.37 <sup>bc</sup>  | 2.40 <sup>c</sup>  | 0.015      | 0.004   |
| Gizzard                     | 2.09                 | 2.07                 | 2.15                 | 2.12                | 2.15               | 0.011      | 0.083   |
| Giblet                      | 5.12 <sup>a</sup>    | 5.18 <sup>a</sup>    | 5.30 <sup>b</sup>    | 5.31 <sup>b</sup>   | 5.38 <sup>b</sup>  | 0.025      | 0.001   |
| Breast                      | 21.44 <sup>a</sup>   | 21.74 <sup>b</sup>   | 21.80 <sup>b</sup>   | 22.11 <sup>c</sup>  | 22.46 <sup>d</sup> | 0.070      | 0.000   |
| Back                        | 15.82                | 15.56                | 15.60                | 15.58               | 15.70              | 0.034      | 0.075   |
| Drumstick                   | 10.47 <sup>a</sup>   | 10.51 <sup>a</sup>   | 10.54 <sup>ab</sup>  | 10.65 <sup>b</sup>  | 10.66 <sup>b</sup> | 0.024      | 0.017   |
| Thigh                       | 10.55 <sup>a</sup>   | 10.59 <sup>ab</sup>  | 10.59 <sup>ab</sup>  | 10.69 <sup>bc</sup> | 10.77 <sup>c</sup> | 0.022      | 0.004   |
| Neck                        | 3.63 <sup>b</sup>    | 3.63 <sup>b</sup>    | 3.56 <sup>a</sup>    | 3.59 <sup>ab</sup>  | 3.64 <sup>b</sup>  | 0.008      | 0.018   |
| Wing                        | 7.36                 | 7.30                 | 7.32                 | 7.39                | 7.32               | 0.035      | 0.941   |
| Abdominal fat pad thickness | 0.68 <sup>b</sup>    | 0.65 <sup>ab</sup>   | 0.63 <sup>b</sup>    | 0.63 <sup>b</sup>   | 0.58 <sup>a</sup>  | 0.008      | 0.000   |

Values bearing different superscript differed significant ( $p < 0.05$ ); NS, Non-Significant

seaweed meal) improved eviscerated yield and decreased abdominal fat in turkeys.

On the contrary, Manal *et al.* (2018) and Reski *et al.* (2021) reported that brown seaweed supplementation did not influence carcass characteristics. However, Reski *et al.* (2021) reported a reduction in abdominal fat pad due to supplementation of brown seaweed. Based on the results of the present study, the increase in carcass traits might be attributed to the presence of secondary metabolites in *Sargassum wiggertii*, which might have resulted in an optimum environment in the gastrointestinal tract, increasing mucosal cell permeability for optimal nutrient utilization, thereby increasing the body weight and carcass traits. The diets of broiler chickens supplemented with 0.13% *Sargassum wiggertii* (Group E) reduced the abdominal fat percentage compared to those fed control diets (Group A and B) and other treatment diets (Group C and D). These findings could be due to optimum alginate compounds present in the treated rations, which can allow for a reduction in fat and cholesterol levels. Since alginates can bind with bile salts, these are not digestible by poultry, as birds lack the enzymes required to break down alginates. Consequently, alginates bind to bile salts will be excreted through faeces.

**Immunity:** Significant ( $p < 0.000$ ) increase in foot web index was recorded in broilers fed brown seaweed at a level of 0.13% compared to all other groups. Broilers fed with either, 0.07, 0.10 or 0.13% of brown seaweed had better foot web index compared to the birds of negative control group. Serum antibody titre values (HI titres) expressed as log 2 were similar among all the groups. There was no significant difference in bursa weight among all the treatment groups including the negative and positive control groups. On the contrary, there was a significant difference in the relative weight of spleen ( $p < 0.003$ )

and thymus ( $p < 0.000$ ) between the treatment groups. As compared to the birds of negative control group, birds fed with 0.1 and 0.13% of brown seaweed (Groups D and E) had a higher spleen weight. The relative weight of the thymus was significantly higher ( $p < 0.000$ ) in birds fed with 0.13% of brown seaweed (Group E), followed by 0.1% and 0.07% (Group D and C) compared to the birds of negative and positive control groups.

A previous study conducted by Erum *et al.* (2017) confirmed that *Sargassum muticum* was beneficial when added to poultry diets to boost immune function. Using the brown seaweed *Laminaria japonica* powder (LJP), Bai *et al.* (2019) demonstrated that dietary supplementation did not significantly affect humoral immunity. In contrast to our results, Kereh *et al.* (2021) reported that supplementation of 10% brown seaweed (*Sargassum crassifolium*) resulted in the highest antibody titre. It seemed that the significant increase in growth performance was related to both the cell-mediated immune response and the relative weights of spleen and thymus. It appears that the broilers were in better health and responded positively to their environment throughout the experiment. With higher relative weights of the spleen and thymus, increased foot web indexes indicated that the addition of brown seaweed at 0.13% level had a better effect on immunity and disease resistance than the control birds.

Treatments containing 0.1 or 0.13% brown seaweed (Groups D and E) were associated with a lower TVC which was gradually, increased for Group C with 0.07% brown seaweed, positive control (Group B) and negative control (Group A) (Table 4). Bai *et al.* (2019) reported that the brown seaweed powder of *Laminaria japonica* (LJP) combined with cecropin in the diet significantly decreased *E. coli* growth while increasing *Lactobacillus* growth. Vijayabaskar and Shiyamala (2011) reported that

Table 4. Effect of dietary addition of brown seaweed on the immune-competence and total viable count

| Immune-competence                  | A (Negative control)   | B Positive control)    | Brown seaweed (g/kg)    |                        |                        | SEM   | p value |
|------------------------------------|------------------------|------------------------|-------------------------|------------------------|------------------------|-------|---------|
|                                    |                        |                        | C 0.7                   | D 1.0                  | E 1.3                  |       |         |
| CMI PHA-P foot web index (mm)      | 0.232 <sup>a</sup>     | 0.272 <sup>b</sup>     | 0.272 <sup>b</sup>      | 0.298 <sup>bc</sup>    | 0.307 <sup>c</sup>     | 0.007 | 0.000   |
| Humoral-HI titer against ND (log2) | 4.833                  | 4.833                  | 5.00                    | 5.167                  | 5.167                  | 0.117 | 0.829   |
| Lymphoid Organ Weight              |                        |                        |                         |                        |                        |       |         |
| Bursa (% of live wt.)              | 0.150                  | 0.157                  | 0.149                   | 0.160                  | 0.172                  | 0.003 | 0.083   |
| Spleen (% of live wt.)             | 0.215 <sup>a</sup>     | 0.221 <sup>ab</sup>    | 0.226 <sup>ab</sup>     | 0.232 <sup>b</sup>     | 0.228 <sup>b</sup>     | 0.002 | 0.030   |
| Thymus (% of live wt.)             | 0.401 <sup>a</sup>     | 0.406 <sup>a</sup>     | 0.426 <sup>b</sup>      | 0.432 <sup>bc</sup>    | 0.442 <sup>c</sup>     | 0.003 | 0.000   |
| Total Viable Count                 |                        |                        |                         |                        |                        |       |         |
| TVC (CFU/gm)                       | 2.416×10 <sup>9d</sup> | 1.952×10 <sup>9c</sup> | 1.617 ×10 <sup>9b</sup> | 1.501×10 <sup>9a</sup> | 1.430×10 <sup>9a</sup> | 0.069 | 0.000   |

Values bearing different superscript differed significantly; NS, Non-significant (p>0.05).

*Sargassum wightii* strongly inhibited the growth of *E. coli* and *Aeromonas hydrophila*. According to Erum *et al.* (2017), *Sargassum muticum* is added to poultry diets to reduce the microbial load in the digestive tract of the birds. Further, Yan *et al.* (2011) reported that supplementation of alginate oligosaccharides (AOS) at 0.2% led to significant reductions in *Salmonella* colonization and an increase in the number of lactic acid bacteria in chicken caecum. Addition of 0.1 or 0.13% of brown seaweed to the diet decreased the caecal bacterial load significantly (p<0.05). The reduction in bacterial load may be attributed to lowering the number of bacteria entering the crop and gizzard. It is indicated that optimum bactericidal activity can be achieved by adding 0.1% or 0.13% of brown seaweed. A decrease in the total viable count may be attributed to the antibacterial activity of the brown seaweed. It was inferred from the present study that seaweed polyphenols (*S. wightii*) possess exceptional antimicrobial properties that can inhibit the growth of most pathogenic bacteria. Possibly, this is due to the presence of inhibitory compounds in the crude extracts responsible for the antibacterial activity. A diet containing brown seaweed can substantially reduce bacterial colonization in chickens' intestines, and improve performance and health.

It is concluded that brown seaweed (*Sargassum wightii*) at a dietary level of 0.13% significantly improved growth performance, carcass traits, cellular immunity and total viable count.

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