**Morphometric Responses of Ross 308 Male Broilers to Yeast β-Glucan Supplementation during Feed Stress**

**Abstract**

Broiler chicken have been subjected to intensive genetic selection, making them the fastest growing farmed avians. The primary determining factor is the feed which is the success behind the rearing of broilers. Some growth-promoting substances and antibiotics have been used in the broiler industry, which can negatively impact the overall health. In this study, Yeast β-glucans are carbohydrates made up of complex glucose polymers which is known for immunomodulating capabilities and potential use in poultry diets. This study involved total of 54-day-old birds (3 replicates x 6 N x 3 diets) that were divided into three treatment pens based on the diet given for 7 weeks. Morphometric measurements were employed to analyse the body orientation and dimensions of organisms, which can be used for growth prediction. Results revealed significant changes in body weight in broiler chicks that were exposed to feed stress, which the broilers in pen-1 and pen-3 showed good morphometric changes compared to pen-2 showed decrease in changes after the fifth week. The positive correlation coefficient between body weight and morphometric traits supports previous research, with body weight being reliably predicted with other morphometric traits like head length and back length. The present study suggested that supplementing yeast β-glucan in broiler chicken diets can positively influence various morphometric characteristics, particularly when combined with other feed additives.

**Keywords:** Yeast β-glucan, morphometric, broilers, poultry

**Introduction**

Broiler chickens have been raised for generations, because of their fast and large muscle growth and they are produced for meat consumption and this makes them the main sourceof animal protein for human consumption from the poultry industry. There are a wide range of broiler chicken breeds ranging from slow growing to fast growing breeds that attains a maximum weight in 70-80 days. Conventionally, fast growing broiler chickens are selected for their increased pectoral muscle massand heavy body weight (**Paxton *et al.*, 2010**). Broiler chickens are geneticallypredisposed to health and welfare issues due to the selection process. **(Wilcox *et al.,* 2024**).Due to the rapid development of broiler chickens, their nutrient needs change continuously throughouttheir production **(Moss *et al.,* 2021**). All the avian members possessmorphological traits that are used to understand the body orientation and growth.The quantitative study of employing morphometric data are used to investigate the external differences between the group of individuals(**Islam and Dutta, 2010**). Morphometrics dealwith shape analysis and shape variation between specimens of a single population and between distinct populations (**iLubabalo and Tyasi, 2022**). A morphometric study has been performed using the variables of body weight, leg length, and head length and other traits performances that highly dependon strain, nutrition, age, management and sex of the birds. (**Sam *etal.,* 2019; Akintunde *etal.,* 2020; Sophian *et al.,* 2021; Adeniyi*et al.,* 2022; Yunana *et al.,* 2024**). Understanding growth and development requires knowledge of the many factors and body morphometric structure in chicken and other birds. (**Isaac *et al.,* 2024**). Quantitative characteristics are useful for predicting the market value and growth and can be used in selection index for improvement of body weight in broilers. (**Olawumi *etal.,* 2012; Yahaya *etal.,* 2012**).

On the other hand, the feed used is the primary determining factor behind the success of broiler rearing. The calculation of the degree of feed restriction is a useful exercise in the charting of change in the broiler chicken industry(**Griffin*etal.,* 2005**). The use of unconventional feedssuch as agro-industrial wastes in the formulation of chicken diets have received a considerable attention to attain an appropriate utilisation efficiency and economic production efficiency (**El-Hack *et al*., 2019**). The concept of crude protein was implemented in the poultry feed formulation resulting in higher amino acid levels required by the birds (**Araújo *et al.,* 2006**). For promoting better growth in broilers,growth promoting substances and antibiotics were used in broiler industries, but they negativelyimpactthe overall health and this in turn stirred the need for alternative searches. Yeast β-glucans are carbohydrates made up of complex glucose polymers and they form a major structure in the cell wall of yeast, fungi and algae(**Schwartz and Vetvicka, 2021**). Yeast β-glucans have received great attention because of their immunomodulating capabilities and better acceptance by consumers (**Cox *et al.,* 2010**) and can be included in the poultry diet to aid in the reduction and replacement of antibiotics(**Ding *et al.,* 2019**). One of the most extensively commercialised types of yeast is *Saccharomyces cerevisiae*, whose cell wall components have recently been utilised in animal feed. Yeast cell walls provide protection against diseases attributing to the stimulation of the immune system through yeast β-glucans and mannans. β-glucan supplemented broilers exhibited an amplified humoral and cell mediated immune response (**Zhang *et al.,* 2012**). Gao *et al.,* (**2008**) observed that broiler diets containing 50 and 75 mg/kg of β-glucan improved the growth of the broilers. Nevertheless, Cox *et al.,*(**2010**) reported that there were no differences in broiler growth performance when dietwas supplemented with β-glucan. These contradictory findings demonstrated that more investigation is required to ascertain the efficient way to use β-glucan in broiler chicken (**Abd-Elsamee *et al.,* 2021**).Therefore the objective of this study was to elucidat0e the effectiveness of Yeast β-Glucan on morphometric characteristics in male broiler chicken in a feed stress condition.

**Materials and Methods**

**Experimental Site**

The experiments were carried out at the Research Farm in the Department of Zoology, The American College, Madurai (9°55'43.0"N 78°07'49.6"E) for a period of 7 weeks. Environmental parameters such as monthly temperature of 34±3⁰C and relative humidity were recorded. The site was equipped with aerated house facility with adequate light settings, water inlet and outlet and power supply to support the experimental setup.

**Bird Sampling and management**

54-day-old Ross 308 male chicks (N=54) were selected by the Vent sexing and Feather sexing methods and were purchased from a commercial retail farm and was transported during the cool hours of the night to minimize stress on the birds. The chicks were managed intensively in a dwarf walled house that had a deep litter and was well aerated. The lighting was adequate to cover the entire house, fitted in subaerial manner to provide enough lumination and heat generated by Standard Incandescent 60 W Bulbs for the 7 weeks.

**Feed formulation**

The birds were divided into three treatment groups according to the feed and each group was randomly assigned with 18 birds per pen.A total of 3 pens were made and labelled as Pen -1 (P-1), Pen -2 (P-2) and Pen -3 (P-3) respectively (Table 1). Each pen represented a feed type and was raised for seven weeks (**Sam *etal*., 2019**). Three different types of experimental feeds – Commercial feed (CF) for P-1, Formulated feed (FF)for P-2 (**El-Deek *etal.,* 2020**) and Formulated feed with Yeast β-Glucan (FFY) for P-3 were used for this study (Figure1; Table 2,3,4). To generate the feed stress condition, the average amount of feed per chick was limited and the feed was given in the morning – evening routine for 7 weeks and each pen received 738±12 g of the concern experimental feed (41g/chick) and fresh drinking water was offered *ad libitum* to maintain the feed stress throughout the study period.

**Morphometric character analysis**

Eighteen Morphometric measurements starting with Body Weight (GC-1) was doneusing a digital weighing balance and other linear measurements such as Ornithological Measurement (GC-2), Wingspan (GC-3),Skull length (H-1), Skull width (H-2), Comb length(H-3), Comb Width (H-4), Ocular length (H-5), Ocular width (H-6), Beak length(H-7), Beak width(H-8), Earlobe length (H-9), Earlobe width (H-10), Back length(B-1), Tail length (B-2), Thigh length(Ext-1), Tarsus length (Ext-2) and Tarsus diameter (Ext-3)was done using a measuring tape and Digital Vernier caliper (Ojo et al., 2020) for randomly sampled individuals (n=7) at weekly intervals for 7 weeks.

Table.1 Composition of Control and experimental diets

|  |  |  |  |
| --- | --- | --- | --- |
|  | Pen-1 | Pen-2 | Pen-3 |
| Ingredients | Feed-1 | Feed-2  (Experimental -1)  g/kg | Feed-3  (Experimental -2)  g/kg |
| Yellow Maize | Commercial feed\* | 551.2 | 549 |
| Groundnut cake | 200 | 200 |
| Dry fish meal | 100 | 100 |
| Wheat bran | 70.8 | 70.8 |
| Soybean meal | 50 | 50 |
| Mineral premix | 10 | 10 |
| Rice bran | 9 | 9 |
| Eggshell powder | 5 | 5 |
| Common salt | 4 | 4 |
| Yeast Beta Glucan | - | 2.2 |
| Energy |  | 2600±200 kcal/kg | 2600±200 kcal/kg |
|  |  | 1000.0 g | 1000.0g |

\*No other specific information about the composition available

**Statistical Analysis**

All descriptive and inferential statistics were made by using Microsoft office Excel and word. (Microsoft® Excel® 2021 MSO (Version 2409 Build 16.0.18025.20160) 64-bit)

**Results**

**Analysis of morphometric variance**

In the three feeding groups, morphological differences were observed from the initial phase to the final phase. Broiler chickens in Pen-1 (P-1) and Pen-3 (P-3) showed changes in morphological characters from the first week to the final week, but minor changes were observed in Pen-2 (P-2) (Figure 1; Table 2,3,4). The following differences in morphological characters were observed in Pen-1 and are as follows, Body weight, Wingspan, Skull length, Skull width, Ocular width, Beak length, Beak width, Earlobe length, Earlobe width, Thigh length, Tarsus length and Tarsus diameter. In Pen-3 the changes were observed in Ornithological measurement, Comb length, Comb width, Ocular length, Back lengthand Tail length. Decrease in certain morphological parameters were observed in Pen-2 such as, Ocular width, Beak length, Earlobe length, Earlobe width, Tail lengthand Tarsus lengthand similar results were also observed in Ocular width, Beak lengthand Tarsus lengthin the Pen-3 after the 5thweek.ANOVA revealedsignificant differences between the experimental groups (P-2 and P-3) and the control group (P-1) for the morphometric characters over the entire study period (Table 5). Significant differences were observed in theWing span, Comb length and Tarsus length(p˂0.05) and this was followed by Body weight, Ornithological measurement, Skull length, Skull width, Comb width, Ocular width, Earlobe length, Tail length and Tarsus diameter. Other differences were also noted in characteristics like Ocular length, Beak width, Earlobe width, Back length, Beak Length and Thigh length (p˃0.05) over the study period (Table 5)



|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **GC-1** | **GC-2** | **GC-3** | **H-1** | **H-2** | **H-3** | **H-4** | **H-5** | **H-6** | **H-7** | **H-8** | **H-9** | **H-10** | **B-1** | **B-2** | **EXT-1** | **EXT-2** | **EXT-3** |
| **W-1** | 57±3.9 | 13±1.5 | 14.6±1.2 | 19.7±2.2 | 14.7±1.2 | 9.6±0.5 | 2.7±0.4 | 7.4±1.1 | 4.3±0.6 | 5.8±0.4 | 4.5±0.5 | 5.6±0.4 | 4.9±0.4 | 48.5±2.9 | 9.4±1.1 | 36±5.6 | 24.7±3.1 | 3.6±0.4 |
| **W-2** | 96.9±10 | 14.6±0.4 | 18±2.7 | 20.7±13 | 18.4±0.6 | 11.9±1 | 4.7±1.4 | 8.1±0.5 | 6±0.5 | 7.4±1 | 6±0.6 | 5.8±0.7 | 5.1±0.9 | 61.9±24.7 | 11±4.9 | 39.9±6.6 | 28.1±2.8 | 6.2±3.6 |
| **W-3** | 140.7±14.3 | 17.8±0.6 | 16.9±0.7 | 38.1±1.3 | 19.7±0.9 | 17.9±1.4 | 8.4±1.5 | 9.3±0.2 | 8±0.5 | 10.4±1.1 | 7.2±0.6 | 8.1±1.6 | 6.6±0.3 | 85.8±3.8 | 11.4±1.1 | 54.4±3.5 | 29.9±1.1 | 6.2±0.7 |
| **W-4** | 205.7±13.4 | 19.3±0.4 | 17.9±0.4 | 41.4±1.9 | 23±0.6 | 24.7±2.8 | 11.6±2.1 | 9.3±0.2 | 8.1±0.5 | 12.1±0.4 | 8±0.6 | 8.2±0.7 | 7.1±0.3 | 91.2±4 | 12.4±0.3 | 58.4±2.4 | 32±3.1 | 7.6±0.3 |
| **W-5** | 257±22.9 | 20.7±0.8 | 20.3±0.4 | 44.2±1.5 | 23.3±1.1 | 29.1±3.6 | 15.7±1.5 | 10.1±0.2 | 8.9±1.1 | 13.5±1.2 | 8±0.2 | 8.7±0.4 | 7.2±0.5 | 100.1±6.2 | 14.5±1.3 | 68.8±3.7 | 35.3±2.2 | 7.6±0.5 |
| **W-6** | 306.4±32.1 | 22.1±1.2 | 21.9±2 | 46.9±3.7 | 23.6±1.1 | 29.1±3.7 | 16.7±3.3 | 10.2±0.2 | 7.7±0.9 | 14±1.8 | 8.4±0.7 | 8.8±0.3 | 7.3±0.1 | 110±6.9 | 14.5±0.5 | 88.3±7.1 | 35.4±2.4 | 8±0.6 |
| **W-7** | 415.3±36.4 | 24.3±1.7 | 24.6±1.1 | 48.4±3.2 | 25.6±2.9 | 35.1±6.2 | 17.1±2.7 | 10.4±0.3 | 7.4±0.5 | 14.1±1 | 8.8±1.8 | 8.9±0.4 | 7.5±0.2 | 134.5±11.4 | 16.1±2.1 | 98.3±4.4 | 36.4±0.8 | 8.2±0.2 |

*Table. 3. Mean and SD of different morphometric variables of treated birds with Formulated feed (P-2)*

*Table. 2. Mean and SD of different morphometric variables of treated birds with Commercial Feed (P-1)*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **GC-1** | **GC-2** | **GC-3** | **H-1** | **H-2** | **H-3** | **H-4** | **H-5** | **H-6** | **H-7** | **H-8** | **H-9** | **H-10** | **B-1** | **B-2** | **EXT-1** | **EXT-2** | **EXT-3** |
| **W-1** | 57.1±3.2 | 12.9±0.7 | 10.6±0.3 | 16.6±0.5 | 14.1±0.4 | 0.7±0.1 | 2.6±0.3 | 5.9±0.6 | 6±0.4 | 6.7±0.6 | 4.6±0.4 | 4.1±0.5 | 3±0.4 | 58.4±2.3 | 8.6±0.4 | 37.6±1.6 | 24.4±1.5 | 3.2±0.3 |
| **W-2** | 72.7±5.6 | 14.5±0.5 | 14.8±0.5 | 32.2±1.5 | 17.9±0.4 | 9.9±0.7 | 4.9±1.3 | 8±0.4 | 6.7±0.5 | 8.1±1 | 6.2±0.6 | 5.4±0.5 | 4.6±0.2 | 68.1±5.5 | 11.9±1.5 | 40±4.2 | 24.4±4.6 | 4.4±0.6 |
| **W-3** | 107.3±17.2 | 16.7±0.9 | 14.3±0.5 | 35.6±2.1 | 18.8±1 | 15.5±2 | 5.7±1.8 | 8.9±0.7 | 7.3±0.4 | 10±0.4 | 7±0.5 | 6.3±0.6 | 6.2±1.1 | 78.7±4.8 | 10.2±0.7 | 48±3.9 | 23±1.1 | 5.3±0.4 |
| **W-4** | 166.4±31.1 | 17.4±1.2 | 16±0.7 | 39±2.3 | 21.4±1 | 21.9±5.4 | 10.7±3.3 | 9.4±0.2 | 8±0.5 | 11.9±0.7 | 7.4±0.5 | 7.5±0.7 | 6.9±0.8 | 81.4±3.9 | 11.8±2.2 | 55.7±4.5 | 26.2±3.1 | 6.4±0.9 |
| **W-5** | 214.1±39.9 | 19.6±1.4 | 18.6±0.9 | 41.4±2.2 | 21.9±0.7 | 25.8±4.4 | 13.9±2.3 | 9.7±0.2 | 8.5±0.6 | 13.2±0.6 | 8.2±0.4 | 6.8±0.4 | 6.4±0.6 | 93.5±6.6 | 12.6±1 | 62.4±3.7 | 30.1±2.2 | 7.2±0.5 |
| **W-6** | 289.3±47.9 | 21.8±1.1 | 21.6±1 | 44.4±2 | 24.3±3.3 | 28.4±3.1 | 14.6±4.1 | 10.2±0.6 | 7.6±1 | 13.8±1.3 | 7.8±0.8 | 5.2±1 | 3.8±1.1 | 108.7±4.7 | 15.9±2 | 84.7±3 | 25.8±2.1 | 6.9±0.9 |
| **W-7** | 356.6±66.2 | 23.8±1.3 | 23.1±1.3 | 47.5±2.1 | 23.5±0.8 | 33.4±6 | 15.7±2.7 | 10.4±0.3 | 5.9±1 | 13.1±1.3 | 9.3±0.4 | 4.4±1.1 | 2.8±0.9 | 122.6±6.2 | 12.4±2.1 | 94.3±5.2 | 24.8±1.7 | 7±0.5 |

*Table. 4. Mean and SD of different morphometric variables of treated animals with Formulated feed with Yβ-g (P-3)*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **GC-1** | **GC-2** | **GC-3** | **H-1** | **H-2** | **H-3** | **H-4** | **H-5** | **H-6** | **H-7** | **H-8** | **H-9** | **H-10** | **B-1** | **B-2** | **EXT-1** | **EXT-2** | **EXT-3** |
| **W-1** | 61.9±4.7 | 14.5±0.5 | 13.2±0.4 | 27.1±1.3 | 16.5±0.5 | 9.6±0.4 | 2.6±1 | 6.6±0.4 | 5.1±0.3 | 7.3±0.2 | 5.6±0.4 | 4.5±0.4 | 4.1±0.3 | 66.6±1.4 | 10±1.4 | 35.4±1.9 | 17.1±0.4 | 4.2±0.2 |
| **W-2** | 87.6±12.5 | 15.1±0.3 | 14.5±0.9 | 32.5±3.7 | 19.3±1.7 | 12.8±2.9 | 5.4±1.3 | 8.6±0.9 | 6.3±0.5 | 8.7±0.9 | 6.3±0.5 | 5.5±1.4 | 5.4±1 | 75.9±6.2 | 11.3±1.8 | 43±5.2 | 25±4.6 | 4.8±0.5 |
| **W-3** | 147.7±16.8 | 17.8±0.4 | 16.2±1 | 39.1±1.7 | 20.8±0.8 | 20.8±2.4 | 9.7±1.1 | 9.8±0.8 | 8±0.6 | 11±0.7 | 7.9±0.6 | 8.3±1.1 | 7.6±0.8 | 81.8±4.3 | 11.3±0.8 | 50.3±3.3 | 26.7±2.8 | 6±0.4 |
| **W-4** | 205.3±28.7 | 19.3±0.5 | 18.2±1.1 | 42.1±1.8 | 22.3±0.6 | 27.7±3.2 | 15.6±3.5 | 9.9±0.7 | 7.9±0.2 | 12.3±0.6 | 8.2±0.5 | 7.9±1 | 8.1±0.5 | 91.7±7.4 | 13.9±1.3 | 62.1±4.3 | 28.7±2.3 | 7.1±0.7 |
| **W-5** | 285.4±14.5 | 21.7±0.7 | 20.4±0.3 | 45.3±2.2 | 22.5±1.1 | 33.1±6.6 | 18.9±4.2 | 10±0.2 | 8.6±0.6 | 13.6±0.5 | 8.7±0.3 | 6.9±0.6 | 6.9±0.8 | 103.8±1.9 | 15.6±1.6 | 70.2±3.3 | 35.6±4.7 | 8.4±0.4 |
| **W-6** | 321.4±24.4 | 22.1±0.9 | 22.8±1.4 | 46.2±3.5 | 25.1±1.9 | 36.2±3.6 | 19.6±2.4 | 10.5±0.3 | 7.3±0.8 | 12.9±1.3 | 8±1.1 | 5±1 | 3.2±0.6 | 116.9±11.3 | 14.8±3.5 | 89.1±3.8 | 28.4±2.7 | 7.5±1.6 |
| **W-7** | 414±27.8 | 24.3±1.4 | 23.8±1.3 | 47.3±4.1 | 25.5±1 | 38.8±5.3 | 21.6±3.7 | 11±0.3 | 6.3±0.9 | 12.5±0.6 | 8.8±1.5 | 5.8±1.2 | 3.6±0.8 | 134.5±14 | 16.2±3.1 | 95.3±6.2 | 26.1±2 | 7.7±0.9 |

*Table 5. p-values observed in morphometric characteristics among all experimental groups from initial to final weeks*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Week -1** | **Week -2** | **Week -3** | **Week -4** | **Week -5** | **Week -6** | **Week -7** |
| Body Weight | 0.055218445b | 0.000813746a | 0.00038887a | 0.014215334a | 0.000570078a | 0.274912347b | 0.046781847a |
| Orni.length | 0.011216017a | 0.012041282a | 0.005102437a | 0.000249949a | 0.00480735a | 0.833539151b | 0.442763897b |
| Wingspan | 8.7687E-08a | 0.003895555a | 9.75183E-05a | 0.000460281a | 9.88298E-05a | 0.30350433b | 0.013232123a |
| Skull length | 3.42667E-08a | 0.020002241a | 0.005281909a | 0.009493224a | 0.011608298a | 0.492902988b | 0.873744738b |
| Skull width | 0.000219196a | 0.071995578b | 0.001732441a | 0.002206583a | 0.10526948b | 0.751079061b | 0.125534137b |
| Comb length | 1.4711E-20a | 0.022155478a | 0.000445858a | 0.040591402a | 0.043034369a | 0.000816201a | 0.231051653b |
| Comb Width | 0.910806627b | 0.604595263b | 0.000327451a | 0.017178718a | 0.015250786a | 0.038108462a | 0.005653916a |
| Ocular length | 0.005273306a | 0.198201964b | 0.03140812a | 0.051095953b | 0.020452657a | 0.326571935b | 0.005497966a |
| Ocular Width | 5.42155E-06a | 0.037884072a | 0.027511365a | 0.672383631b | 0.661387537b | 1.20817E-09a | 0.009111007a |
| Beak Length | 1.02423E-05a | 0.067978682b | 0.083049338b | 0.430298692b | 0.626918518b | 0.353177156b | 0.026637013a |
| Beak Width | 0.000101936a | 0.708992636b | 0.016725624a | 0.022473058a | 0.003182766a | 0.458310485b | 0.745138627b |
| Earlobe Length | 5.63007E-06a | 0.67498365b | 0.009501889a | 0.238819617b | 6.98736E-07a | 6.07103E-08a | 3.46471E-07a |
| Earlobe Width | 1.26591E-07a | 0.150087127b | 0.017253275a | 0.001535036a | 0.150427985b | 9.54081E-09a | 5.84136E-10a |
| Back length | 6.78362E-11a | 0.245350012b | 0.020458639b | 0.003008063a | 0.007065866a | 0.159183321b | 0.093603124b |
| Tail length | 0.057237727b | 0.867250523b | 0.042441473a | 0.048198466a | 0.001542239a | 0.489627379b | 0.015433281a |
| Thigh length | 0.505204962b | 0.499623715b | 0.01224241a | 0.020403561a | 0.001616448a | 0.233356008b | 0.357721798b |
| Tarsus length | 1.0916E-06a | 0.222654682b | 7.89385E-06a | 0.004696786a | 0.008489072a | 1.86687E-06a | 7.93869E-11a |
| Tarsus diameter | 0.000109848a | 0.301272923b | 0.009272915a | 0.022678062a | 0.000693418a | 0.234521585b | 0.004058004a |

Significance noted at p≤0.05a and p≥0.05b

Table 6. Pearson Correlation Coefficient (*r*) between the morphometric characteristics in Pen-1 group

Table 6. Pearson Correlation Coefficient (*r*) between the morphometric characteristics in Pen-1 group

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *GC-1* | *GC-2* | *GC-3* | *H-1* | *H-2* | *H-3* | *H-4* | *H-5* | *H-6* | *H-7* | *H-8* | *H-9* | *H-10* | *B-1* | *B-2* | *EXT-1* | *EXT-2* | *EXT-3* |
| GC-1 | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-2 | 0.915 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-3 | 0.990 | 0.944 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-1 | 0.925 | 0.970 | 0.942 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-2 | 0.947 | 0.921 | 0.970 | 0.964 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-3 | 0.974 | 0.977 | 0.985 | 0.978 | 0.967 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| H-4 | 0.964 | 0.976 | 0.973 | 0.981 | 0.958 | 0.997 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |
| H-5 | 0.851 | 0.875 | 0.869 | 0.963 | 0.948 | 0.902 | 0.903 | 1.000 |  |  |  |  |  |  |  |  |  |  |
| H-6 | 0.328 | 0.625 | 0.374 | 0.648 | 0.463 | 0.507 | 0.538 | 0.655 | 1.000 |  |  |  |  |  |  |  |  |  |
| H-7 | 0.843 | 0.967 | 0.868 | 0.974 | 0.887 | 0.936 | 0.950 | 0.913 | 0.775 | 1.000 |  |  |  |  |  |  |  |  |
| H-8 | 0.851 | 0.910 | 0.846 | 0.963 | 0.874 | 0.916 | 0.926 | 0.936 | 0.734 | 0.965 | 1.000 |  |  |  |  |  |  |  |
| H-9 | 0.027 | 0.212 | 0.019 | 0.337 | 0.161 | 0.169 | 0.203 | 0.435 | 0.784 | 0.439 | 0.534 | 1.000 |  |  |  |  |  |  |
| H-10 | -0.306 | -0.073 | -0.311 | 0.013 | -0.190 | -0.151 | -0.098 | 0.085 | 0.673 | 0.173 | 0.224 | 0.902 | 1.000 |  |  |  |  |  |
| B-1 | 0.993 | 0.877 | 0.985 | 0.898 | 0.951 | 0.951 | 0.937 | 0.842 | 0.253 | 0.793 | 0.804 | -0.039 | -0.380 | 1.000 |  |  |  |  |
| B-2 | 0.952 | 0.933 | 0.947 | 0.933 | 0.909 | 0.963 | 0.977 | 0.839 | 0.470 | 0.904 | 0.878 | 0.121 | -0.126 | 0.926 | 1.000 |  |  |  |
| EXT-1 | 0.984 | 0.913 | 0.995 | 0.917 | 0.970 | 0.968 | 0.952 | 0.853 | 0.302 | 0.825 | 0.806 | -0.035 | -0.373 | 0.989 | 0.923 | 1.000 |  |  |
| EXT-2 | 0.551 | 0.766 | 0.583 | 0.773 | 0.622 | 0.677 | 0.714 | 0.741 | 0.901 | 0.865 | 0.805 | 0.539 | 0.432 | 0.490 | 0.719 | 0.514 | 1.000 |  |
| EXT-3 | 0.885 | 0.970 | 0.894 | 0.964 | 0.877 | 0.952 | 0.967 | 0.876 | 0.697 | 0.984 | 0.956 | 0.350 | 0.100 | 0.834 | 0.952 | 0.849 | 0.846 | 1 |

*Significance noted at r ≥0.5.*Body Weight (GC-1), Ornithological Measurement (GC-2), Wingspan (GC-3),Skull length (H-1), Skull width (H-2), Comb length(H-3), Comb Width (H-4), Ocular length (H-5), Ocular width (H-6), Beak length(H-7), Beak width(H-8), Earlobe length (H-9), Earlobe width (H-10), Back length(B-1), Tail length (B-2), Thigh length(Ext-1), Tarsus length (Ext-2) and Tarsus diameter (Ext-3)

Table 7. Pearson Correlation Coefficient (*r*) between the morphometric characteristics in Pen-2 group

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *GC-1* | *GC-2* | *GC-3* | *H-1* | *H-2* | *H-3* | *H-4* | *H-5* | *H-6* | *H-7* | *H-8* | *H-9* | *H-10* | *B-1* | *B-2* | *EXT-1* | *EXT-2* | *EXT-3* |
| GC-1 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-2 | 0.987 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-3 | 0.966 | 0.976 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-1 | 0.852 | 0.908 | 0.923 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-2 | 0.899 | 0.931 | 0.945 | 0.969 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-3 | 0.938 | 0.968 | 0.954 | 0.970 | 0.976 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| H-4 | 0.951 | 0.954 | 0.947 | 0.902 | 0.953 | 0.971 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |
| H-5 | 0.848 | 0.906 | 0.909 | 0.996 | 0.976 | 0.973 | 0.909 | 1.000 |  |  |  |  |  |  |  |  |  |  |
| H-6 | 0.083 | 0.163 | 0.170 | 0.401 | 0.433 | 0.352 | 0.367 | 0.455 | 1.000 |  |  |  |  |  |  |  |  |  |
| H-7 | 0.884 | 0.917 | 0.896 | 0.926 | 0.971 | 0.968 | 0.969 | 0.948 | 0.532 | 1.000 |  |  |  |  |  |  |  |  |
| H-8 | 0.893 | 0.936 | 0.921 | 0.967 | 0.924 | 0.978 | 0.924 | 0.960 | 0.316 | 0.915 | 1.000 |  |  |  |  |  |  |  |
| H-9 | -0.083 | 0.005 | -0.008 | 0.334 | 0.287 | 0.244 | 0.181 | 0.379 | 0.867 | 0.356 | 0.263 | 1.000 |  |  |  |  |  |  |
| H-10 | -0.258 | -0.158 | -0.180 | 0.179 | 0.104 | 0.075 | 0.000 | 0.222 | 0.819 | 0.186 | 0.122 | 0.973 | 1.000 |  |  |  |  |  |
| B-1 | 0.989 | 0.997 | 0.977 | 0.893 | 0.912 | 0.952 | 0.934 | 0.885 | 0.092 | 0.885 | 0.923 | -0.060 | -0.221 | 1.000 |  |  |  |  |
| B-2 | 0.711 | 0.733 | 0.822 | 0.782 | 0.868 | 0.756 | 0.780 | 0.784 | 0.441 | 0.799 | 0.652 | 0.153 | -0.021 | 0.719 | 1.000 |  |  |  |
| EXT-1 | 0.993 | 0.980 | 0.960 | 0.832 | 0.884 | 0.914 | 0.919 | 0.827 | 0.026 | 0.856 | 0.858 | -0.148 | -0.321 | 0.987 | 0.723 | 1.000 |  |  |
| EXT-2 | 0.313 | 0.308 | 0.333 | 0.339 | 0.409 | 0.411 | 0.552 | 0.362 | 0.698 | 0.541 | 0.392 | 0.451 | 0.377 | 0.256 | 0.390 | 0.223 | 1.000 |  |
| EXT-3 | 0.848 | 0.890  *Significance noted at r ≥0.5.*Body Weight (GC-1), Ornithological Measurement (GC-2), Wingspan (GC-3),Skull length (H-1), Skull width (H-2), Comb length(H-3), Comb Width (H-4), Ocular length (H-5), Ocular width (H-6), Beak length(H-7), Beak width(H-8), Earlobe length (H-9), Earlobe width (H-10), Back length(B-1), Tail length (B-2), Thigh length(Ext-1), Tarsus length (Ext-2) and Tarsus diameter (Ext-3) | 0.874 | 0.943 | 0.958 | 0.968 | 0.955 | 0.961 | 0.570 | 0.988 | 0.941 | 0.441 | 0.281 | 0.856 | 0.751 | 0.806 | 0.577 | 1.000 |

Table 8. Pearson Correlation Coefficient (*r*) between the morphometric characteristics in Pen-3 group

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *GC-1* | *GC-2* | *GC-3* | *H-1* | *H-2* | *H-3* | *H-4* | *H-5* | *H-6* | *H-7* | *H-8* | *H-9* | *H-10* | *B-1* | *B-2* | *EXT-1* | *EXT-2* | *EXT-3* |
| GC-1 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-2 | 0.977 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GC-3 | 0.960 | 0.915 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-1 | 0.887 | 0.962 | 0.775 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-2 | 0.931 | 0.968 | 0.888 | 0.932 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H-3 | 0.972 | 0.988 | 0.898 | 0.952 | 0.967 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| H-4 | 0.944 | 0.978 | 0.885 | 0.957 | 0.954 | 0.984 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |
| H-5 | 0.908 | 0.974 | 0.846 | 0.981 | 0.950 | 0.957 | 0.973 | 1.000 |  |  |  |  |  |  |  |  |  |  |
| H-6 | 0.583 | 0.730 | 0.510 | 0.837 | 0.800 | 0.730 | 0.763 | 0.846 | 1.000 |  |  |  |  |  |  |  |  |  |
| H-7 | 0.910 | 0.973 | 0.836 | 0.983 | 0.968 | 0.972 | 0.986 | 0.989 | 0.845 | 1.000 |  |  |  |  |  |  |  |  |
| H-8 | 0.886 | 0.957 | 0.831 | 0.958 | 0.983 | 0.938 | 0.939 | 0.970 | 0.864 | 0.975 | 1.000 |  |  |  |  |  |  |  |
| H-9 | 0.852 | 0.941 | 0.739 | 0.996 | 0.914 | 0.930 | 0.940 | 0.980 | 0.874 | 0.975 | 0.952 | 1.000 |  |  |  |  |  |  |
| H-10 | 0.869 | 0.951 | 0.752 | 0.996 | 0.939 | 0.945 | 0.944 | 0.972 | 0.863 | 0.980 | 0.967 | 0.994 | 1.000 |  |  |  |  |  |
| B-1 | 0.980 | 0.993 | 0.926 | 0.938 | 0.952 | 0.972 | 0.948 | 0.955 | 0.692 | 0.942 | 0.940 | 0.917 | 0.927 | 1.000 |  |  |  |  |
| B-2 | 0.977 | 0.971 | 0.961 | 0.891 | 0.949 | 0.975 | 0.969 | 0.938 | 0.678 | 0.937 | 0.907 | 0.868 | 0.875 | 0.963 | 1.000 |  |  |  |
| EXT-1 | 0.983 | 0.971 | 0.943 | 0.896 | 0.896 | 0.948 | 0.942 | 0.916 | 0.565 | 0.907 | 0.873 | 0.862 | 0.867 | 0.971 | 0.953 | 1.000 |  |  |
| EXT-2 | 0.942 | 0.975 | 0.911 | 0.939 | 0.973 | 0.977 | 0.990 | 0.975 | 0.788 | 0.982 | 0.956 | 0.925 | 0.930 | 0.951 | 0.981 | 0.929 | 1.000 |  |
| EXT-3 | 0.850 | 0.906 | 0.847 | 0.874 | 0.975 | 0.895 | 0.904 | 0.914 | 0.831 | 0.932 | 0.971 | 0.864 | 0.888 | 0.883 | 0.895 | 0.820 | 0.943 | 1.000 |

*Significance noted at r ≥0.5.*Body Weight (GC-1), Ornithological Measurement (GC-2), Wingspan (GC-3),Skull length (H-1), Skull width (H-2), Comb length(H-3), Comb Width (H-4), Ocular length (H-5), Ocular width (H-6), Beak length(H-7), Beak width(H-8), Earlobe length (H-9), Earlobe width (H-10), Back length(B-1), Tail length (B-2), Thigh length(Ext-1), Tarsus length (Ext-2) and Tarsus diameter (Ext-3)

**Pearson’s correlation coefficients**

The correlation coefficients between morphometric traits of broilers fed with three different feeds during the study period revealed that the correlation coefficients (r) of Pen-1 (P-1)ranged between 0.510 to 0. 990.The highest correlation was obtained between H-4 and EXT-2(r=0.990), while low correlation between the GC-3 and H-6 (r=0.510) and all the characters showed positive correlation in between them (Table 6). While the correlation coefficients for Pen-2 (P-2) ranged from -0.008 to 0.993 in Table 7 and thehighest correlation was observed between GC-1 and EXT-1 and lowest wasobserved between H-9 and GC-3. It was further observed that GC-1 was positively correlated with most of the traits and H-9, H-10 and EXT-2 showed the negative correlation between the traits (Table 7). The correlation coefficients for Pen-3 (P-3) showed the highest correlation to range between GC-3 and EXT-1 (*r*=0.995) and lowest correlation between the H-9 and EXT-1(*r*=-0.034). Similarly,GC-1 had positive correlation with other traits, while H-9 and H-10 had negative correlation with most of the traits (Table 8). The above observations revealed that GC-1 had highest correlation amongst all other traits and characteristics like H-9 and H-10 which showed negative relationship with other cohort characteristics in the broilers during the entire study period.

**Discussion**

**Effect of feeds on the body weight**

In the present study the broiler chickens that were exposed to feed stress condition revealed no reduction in the body weight in the first week and significant changes were observed during the final week and this was in accordance to the findings of Plavnik and Hurwitz(**1985**).There was an increase in the body weight in the early weeks and this proved earlier by Patbandha*etal.*2017. There was also a progressive growth that occurred at the initial three weeks with the commercial feed and this was also proved by Hafizu *et al.* (**2020**) and the feed given with the addition of Y β-g also showed good growth, as reported earlier (**Wang *etal*., 2021; Abd-Elsamee*etal.*,2021**) and this is mainly because Y β-g boosts gut immunity (**Bu*et al*., 2019; Omara*etal*., 2021; Bilal*etal*., 2023**) and has good antimicrobial properties(**Ding *etal*., 2019; Schwartz *et al*., 2021**). In the third week of experimentation, adequate differences were observed in the body weight in all the three pens due to feed stress condition and this made the experimental birds to experience appetite depression which made them to consume less feed and this can be attributed to changes in lower feed conversion, age and environmental factors (**Osti *et al.* 2017**).Moreover, environmental conditions such as low temperature can exacerbate the effects of dietary composition on growth and climatic stress can lead to reduced feed intake, thereby negatively affecting the body weight. This interplay between diet and environmental stressors underscores the necessity of careful management of feeding strategies to ensure the health and growth of broilers (**Orlowski *et al*., 2020**).In the present study, low body weight was observed in the experimental birds and this was due to the acclimatization to low environmental temperatures that involves changes in body weightbecause in cooler environment more energy is dissipated as heat and thus weight declines (**Suk and Washburn,1995; Yahav *et al.,* 1996**). In comparison with commercial and conventional rearing, where feed is provided *ad libitum*, in this study the body weight of the experimental birds attained moderate growth in the entire study period because of less feed provided. The other reason being the form and composition of the experimental diets, which are typically fed in mash rather than the pellet form which contributes to reduced growth potential (Griffin *et al.,*2005). In this study, the experimental diets had good amount of carbohydrate sources and less crude protein may be an another reason for the low body weight in the experimental birds and has been reported earlier (**Babatunde*etal*., 2021**). Besides this, the problem of male-to-male aggressiveness was recorded among the experimental birds in this study and this activity has been observed earlier (**Millman *et al.*, 2000**).

**Effect of feeds on other morphometric characters**

In this present study, the Yeast β-glucan play a beneficial role in the development of the morphological characters in broiler chickens. The results indicated improvement in body weight and morphometric traits that can lead to the corresponding improvement of carcass yield in broiler chicken. The result of these positive correlation coefficient between body weight and morphometric traits agrees with the findings of Ige*et al.* (**2016**) and Sam *et al.* (**2019**) where they had reported high significance among the morphological traits. Similarly other studies have also observed positive correlations between the morphometric characteristics (**Amao *et al*., 2012; Nosike*etal*., 2017**).The significant correlations between the body weight and morphometric characteristics from this study suggest that body weight could be reliably predicted with the other morphometric traits such as head length, ornithological measurement and back length and these findings are comparable with Fayeye *et al.*(**2014**). The results obtained in this study had indicated that morphometric body parameters contribute significantly to overall body weight and this was according to Ibe (**1995**) who also had proved the same.The high correlation between the comb length and width withother morphological traits indicated good health of the experimental birds in this study, whereas bright fleshy combs indicate physical strength and good health. As according to Mustefa *et al.*(**2021**) combs help the broiler chicken to regulate their body temperature and especially the ones with large combs are able to circulate blood faster through their combs that helps release body heat. On the other hand, the relationship between the wingspan of a chickenand its ocular characteristics has garnered significant attention and in an inverse manner. The results of this study suggests that there can be a deeper physiological and evolutionary mechanisms that play in broiler science. Therefore, the current study suggested that the supplementation of yeast beta-glucan in broiler chicken dietshave a positive influence on various morphometric characteristics. In addition, it was also noted that the combination of yeast beta-glucan with other feed additives can lead to enhanced morphometric characteristics in broiler chickens.

**Conclusion**

In conclusion, the present study showed that the addition of Yeast β-glucan in broiler diet can positively impact on the body weight and other morphometric characteristics even in a feed stress condition. The administration of Yeast β-glucan has demonstrated significant positive effects and has enhanced growth performance on the morphometric characteristics of male broilers, which indicated its potential as a valuable feed additive in poultry feed production.While the current research highlighted the positive impacts of Yeast β-glucan on the morphometric characteristics of broilers, several areas warrant further investigations to optimize its use in poultry diets such asdosage optimization, long time effects and physiological impacts of Yβ-g. In conclusion, Yeast β-glucan holds significant promise as a natural feed additive that can enhance the growth and overall health of broiler chickens. With further research and optimization, it could become a cornerstone for sustainable and profitable poultry feed production, meeting the growing global demand for high-quality poultry products.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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