NIGERIAN AGRICULTURAL JOURNAL
*ISSN: 0300-368X*
Volume 55, Number 3, December 2024, Page 148-154
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng


# Fortification of Broiler Chicken Feed with *Shistocerca americana* for Nutritional Improvement

**[1]Yerima, S.A., [1&2]Buba, F., [1]Pudza, J.S., [3,*]Dibal, N.I., [1]Ali, A.A. and [1&2]Milala, M.A.**
[1] Department of Biochemistry; [2] Department of Biotechnology; [3] Department of Human Anatomy, University of Maiduguri, Borno State, Nigeria
Corresponding author's email: nathandibal@gmail.com
ORCID; https://orcid.org/0000-0002-1805-7553

**Abstract**
Consumption of chicken and its products has remained one of the primary sources of protein globally. The study evaluated the protein content and weight of broiler chickens that received feed fortified with *Shistocerca americana* (SA). Thirty-day-old broiler chickens were grouped into 6 (n=5). Group A was fed with normal broiler feeds while the test groups B-F received the broiler feed fortified with SA at 90:10, 80:20, 70:30, 60:40, and 50:50 ratios, respectively. SA was found to have a protein content of 60.7%, 17% fibre, and 1.6% carbohydrate. Consumption of SA-fortified feed significantly increases ($p<0.05$) the body weight and feed intake of the broiler chicken compared to the control. The serum protein concentration of the broiler chickens that received SA-fortified feed at 70:30, 60:40, and 50:50 was significantly higher ($p<0.05$) relative to the control. In conclusion, the high protein content and flavour of SA are attributed to the increase in body weight and feed intake. Therefore, SA can be fortified in both human and animal feed for its palatability and high protein content.
**Keywords:** ***Broiler, fortification, protein, Shistocerca Americana, weight gain***

## Introduction

Protein sources have been a major challenge in society due to economic hardship in most countries. Consumption of chicken and its products has remained one of the primary sources of protein globally (Ibarz-Blanch *et al*., 2023). Chickens are expensive for average-income earners, and the protein content in most chicken feeds seems inadequate (Mallick *et al*., 2020). There is a need for chicken feed fortification using locally available resources such as Grasshopper, which could enhance the nutritional content of the feed and weight of the chicken, as well as reduce the market cost of chicken (Egonyu *et al*., 2021). Grasshopper, *Schistocerca americana* (Drury) is locally called *Fara* in the northern part of Nigeria. It is abundantly available in Maiduguri and its environs. and is commonly consumed as a local snack. Alternate protein sources are being considered as a result of factors such as health implications, availability, cost, and animal welfare concerns (Tilman, 2014). Insects serve as either human food or feed for livestock, and they have been added to feed at diverse phases of development. This is imperative since the nutritional composition of insects may change at different stages of life (Ordoñez-Araque *et al*., 2021).

A variety of insect species are consumed worldwide, but only a few have been evaluated for their nutritional content (Gasco *et al*., 2020). Many insects are consumed globally, the most common include crickets, grasshoppers/locusts,

cockroaches, beetles, true bugs, ants, bees, termites, caterpillars, butterflies, and moths. The use of insects in the commercial feed industry suggests the importance of insects as protein sources in both human and animal nutrition (Gasco *et al*., 2020). The increase in the supplementation of insects in animal diets showed that edible insect use in animal feed is gaining ground, and it was estimated that it will expand by 10-fold in 2029 (Guiné, 2021). Free-range chickens often eat insects in their natural environment and utilise them as a source of protein. Therefore, they must not be processed before addition to animal feed. Because insects are cheap and readily available, incorporating them into animal feed can be an alternative protein source that will be used concurrently with commercial feed in animal production to improve meat quality for human consumption. Similarly, some insect species have been shown to improve meat taste and palatability; consumers in the Philippines preferred the taste of chickens fed with grasshoppers compared to those fed with traditional feed (Tae-Kyung, 2019).

Insects have high amounts of essential and non-essential amino acids, including histidine, lysine, phenylalanine, threonine, and valine. The quantity present can exceed the recommended daily requirement (Rumpold, 2013; Egonyu *et al*., 2021). Insects were reported to be a rich source of chitin–the second-most available natural biopolymer after cellulose (Egonyu *et al*., 2021). Locusts, grasshoppers, and crickets are good alternative sources of protein for locals in northern Nigeria and are believed to provide the required essential amino acids for both human and animal growth and development (Yi *et al*., 2013). A previous study evaluated the adequacy of fish meal where a portion was replaced with grasshopper and lobster, they found that it was highly nutritious (Amobi, 2021). The Nutritional content of edible insects was reported to meet the WHO's requirement of amino acids due to the adequate amount of tyrosine, phenylalanine, threonine, and lysine (Rumpold, 2013). A previous study has reported the use of grasshoppers in the supplementation of pet and zoo animal feed and research is ongoing to develop adequate livestock feed using grasshoppers as the source of protein (Wang *et al*., 2005).

Besides climate change, insects such as grasshoppers constitute a common threat to crop production in many countries (Schell, 2023). While most countries use chemicals to control grasshopper infestation, some either consume them directly or supplement them in human and animal diets to serve as a biological control measure (Svanberg and Berggrens, 2021). The use of chemicals for insect control has contributed to land and air pollution and constitutes a health risk to humans, animals, and the environment (Dakhel *et al*., 2020). Therefore, this study was aimed at utilizing American grasshoppers (*Schistocerca americana*) for the fortification of broiler chicken feed for protein content and weight gain. This might reduce the population of grasshoppers, thereby reducing the threat they pose to crop production in the world as well as improving poultry production for meat and eggs.

## Materials and Methods

### *Chemicals and Reagents*

All the chemicals used for the research are of analytical grade. These chemicals include Turk's solution (containing 1% glacial acetic acid, sodium citrate, formaldehyde, caustic soda, bromocresol green, methyl red, sulphuric acid, sodium hydroxide, Coomassie brilliant G-250, ethanol, phosphoric acid, formal citrate, distilled water, and deionized water.

### *Experimental Animal*

Thirty-day-old broiler chicks were purchased from a local market in Maiduguri, Nigeria. Brooding was carried out for two weeks before the commencement of the study, and the chicks had free access to food and water during the experiment.

### *Feed Fortification*

*Shistocerca americana* (SA) was purchased from a local market in Maiduguri and authenticated by a Zoologist at the Department of Zoology, University of Maiduguri, Nigeria. The grasshoppers were washed with warm water, oven-dried, and ground. The feed was fortified with SA at 90:10, 80:20, 70:30, 60:40, and 50:50 ratios.

***Experimental Design***

Thirty-day-old broiler chickens were grouped into 6 groups with 5 chickens in each group. Group A (control) was fed with normal broiler feeds while the test groups (B, C, D, E, and F) received the broiler feed fortified with SA at 90:10, 80:20, 70:30, 60:40, and 50:50 ratios, respectively, for four weeks. The feeds are weighed before administration, and the leftover is deducted from the feed administered to obtain the amount of feed consumed. Similarly, the bird's faces are weighed daily while the broiler chicks are weighed weekly. The blood of each chicken was collected in a plain bottle, centrifuged, and the serum was used to evaluate total protein concentration using the method described by Kielkopf *et al*. (2020).

***Chemical Analysis***

The proximate analysis of the composition of SA was carried out following the method of Latimer (2016).

***Determination of Percentage Nitrogen***

Kjeldahl's (1883) method for the estimation of the nitrogen content of substances was used. This procedure was used to analyze the nitrogen content of the grasshopper, 2g of the sample was weighed and transferred into a digestion tube, Kjeldahl tablets were added, 20mls of concentrated sulphuric acid (concentrated $H_2SO_4$) was added unto the tube and digested at 20$^oC$ for 3 to 5 hours and left to cool. After it was cooled, 80mls of distilled water was mixed with the digested solution. About 50mls of 40% caustic soda (NaOH) was added to 50mls of the digested solution and placed in a distillation chamber, and 30mls of 40% boric acid, bromocresol green, and methyl red (indicator) were pipetted into a conical flask and placed under the distillation chamber to collect ammonia, the solution changed from green colour to pink colour. The solution was titrated until a colour change was observed and the titrated value was calculated.

***Dry Matter Determination***

The dry matter content of the sample SA was determined by the Kjeldahl method (1883). Ten grams (10g) of the sample was weighed and transferred into a petri dish while placed in a hot oven at 105$^o$ °C for 24 hours. It was placed in a desiccator to cool and was weighed thereafter.

***Crude Protein Determination***

The crude protein content of SA was evaluated as described by Kjeldahl (1883). 1g of sample, one Kjeldahl tablet, and 20 ml of concentrated Sulphuric acid were mixed and digested at 420$^oC$ for 3 to 5 hours. After cooling, 80mls of distilled water was added to the solution, and 50mls of 40% caustic soda was added to 50% of the solution and placed in a distillation chamber. 30mls of 40% boric acid, plus bromocresol green and methyl red, was put into a conical flask and placed under the distillation chamber to collect ammonia; the solution changed from orange to green colour. About 0.1ml hydrochloric acid (HCL) was measured into the burette, while the solution in the conical flask was titrated until the colour changed from green to pink.

***Crude Fiber Determination***

The crude fiber content of SA meal was evaluated as follows: 2g of the sample and 50 mL of trichloroacetic acid were boiled and refluxed for 40 minutes in a flat-bottom flask. The residue was filtered and washed with hot water (four times) and petroleum ether (once). The sample was dried in an oven at 30 °C to 60 °C for 24 hours, after which it was reweighed and formed ash at 650 °C, which was then allowed to cool and finally weighed.

***Ether Extract (Fat) Determination***

Fat (ether extract) of SA meal was determined using the Soxhlet apparatus; 1g of the sample was mixed with 200 ml of petroleum ether and heated at 45$^oC$ for 1-2 hours in a flat-bottom flask. The flask was removed and left for 15 minutes to cool in a desiccator, and the fat content was calculated.

***Ash Determination***

The ash content of SA meal was determined as described by Kjeldahl (1983). 1g of the sample was measured into a crucible and dried at 105 °C for 24 hours, which was then cooled in a desiccator and weighed. It was then charred at 600$^oC$ in a muffle furnace for 2-3 hours, cooled in a desiccator, and weighed.

***Statistical Analysis***

One-way ANOVA was used to evaluate feed intake, nitrogen balance, body weight, and protein concentration between the groups. GraphPad Prism 9 was used for the analysis, and significance was considered at $p<0.05$.

**Results**

Table 1 shows the proximate composition of the SA with a high protein content of 60.7%, fiber 17%, ash 3%, moisture 5.2%, fat 12.5%, and carbohydrate 1.6%, respectively. Fortification of broiler feed with SA at different concentrations (90:10, 80:20, 70:30, 60:40, and 50:50 ratios) was shown to significantly increase ($p<0.05$) feed intake compared to the control, especially in weeks 3 and 4. In week one, a significant increase ($p<0.05$) in feed intake among broiler chickens fed with SA-fortified feed was seen in chickens that received 80:20, 70:30, 60:40, and 50:50 ratios compared to the control. However, by week 4, a significant increase ($p<0.05$) in feed intake was noticed in all the groups compared to the control (Table 2).

Table 3 showed a significant increase ($p<0.05$) in the weight of chicken fed on SA-fortified feed at different ratios (90:10, 80:20, 70:30, 60:40, and 50:50) compared to the control. The weight increase was shown to be week-dependent, i.e., the weight increases with continuous consumption, for four weeks. A non-significant ($p>0.05$) increase in nitrogen balance was also observed in the broiler chickens that received SA-fortified feed at different concentrations relative to the control. However, the serum protein concentration of the broiler chickens that received SA-fortified feed at 70:30, 60:40, and 50:50 was significantly higher ($p<0.05$) relative to the control (Table 4).

**Discussion**

The high protein content is an indication that American grasshopper can serve as a good source of protein, particularly in developing countries where protein is rare and costly. The addition of locust meal to other protein sources was reported to improve the protein content and increase the water and oil-conveying capacity of the feed (Clarkson *et al*., 2018). Nutritive values of grasshoppers are of high reputation, but for stable consumption and as food supplements. Insects are a common source of protein in Africa and some parts of Asia, excluding Europe and America. Hence, consumers have to be convinced by the dietary benefits, palatability, and general physical appeal (Wendin *et al*., 2017).

The significant increase in feed intake that was observed in the current study is similar to the previous report by Sajid (2023), which stated that incorporating insects in broiler feeds increases the level of feed intake at the starter phase. Palatability is the measure of food intake, and it indicates acceptance and preference of a particular food over another (Samant *et al*., 2021). Taste is considered one of the important factors that increase food palatability and acceptance/preference in both animals and humans (Aldrich and Koppel, 2015). The increase in feed intake that was observed in the current study might be associated with good taste and palatability, leading to the increase in body weight that was observed. Therefore, the flavour of SA might have served as an appetizer to increase feed consumption.

The significant increase in body weight that was observed in chickens fed with SA-fortified feed is an indication that the fortified feed had no adverse effect on the chickens for four weeks. A previous study reported weight gain as a predictor for broiler economic value and suggested that weight gain is associated with feed intake and feed conversion to meat (Martinez *et al*., 2022). Also, a combination of feed ingredients and fortification of diets with protein-rich constituents was reported to enhance growth rate, weight gain, and meat production in broiler chickens (Rocha *et al*., 2022). The result is similar to the one obtained by Awoniyi *et al*. (2003), reporting that broiler chickens' weight increased in direct proportion to an increase in dietary protein-rich silkworm pupae meal. We suggest that the body weight increase observed in the current study is proportional to the increase in feed intake.

Nitrogen balance is an indicator of adequate protein intake (Dickerson, 2016). A positive nitrogen balance means that the amount of protein ingested is greater than the amount excreted, while a negative nitrogen balance signifies higher protein excretion compared to the intake (Kondrup, 2008). The result contrasts with that of Faria *et al*. (2005), which stated that protein decreases in diet bring about higher retention. This

confirms the use of nitrogen by birds and the suitable amino acid balance propitiated by the crystalline amino acid inclusion. The positive nitrogen balance that was noticed in the present study suggests that supplementation of the diet with SA will enhance protein intake to enhance the repair of worn-out tissues and proper protein balance in the body. Hence, we hypothesized that the high crude protein content of SA is responsible for the positive nitrogen balance, which reflected proper protein utilization.

Blood proteins are vital pointers to feather development and well-being in birds. Their estimation can be used to identify metabolic alterations and/or some pathological problems in biochemistry (Filipovic *et al*., 2007). Several conditions were reported to cause changes in the serum biochemical parameters, including fatigue, liver disease, and several physiological as well as exogenous factors (Tothova *et al*., 2017). The high protein content of SA is capable of increasing body weight and can supplement other sources of protein. Previous studies also reported that high protein concentration promotes good health and well-being as well as positive changes in body composition (Campbell *et al*., 2015; Dibal *et al*., 2022). Therefore, SA can be safely consumed as a supplement in broiler chickens and humans to serve as a cheap and affordable alternative protein source.

**Conclusion**

This high protein content of SA may be the reason for a significant increase in food intake and body weight in broiler chickens. The flavour of SA might serve as an appetizer and could be a contributing factor to the increased feed intake. Therefore, SA can be fortified in both human and animal feed because of its palatability and high protein content.

***Conflicts of Interest:*** *The authors declare that they have no conflicts of interest.*

**References**


Aldrich, G.C. and Koppel, K. (2015). Pet Food Palatability Evaluation: A Review of Standard Assay Techniques and Interpretation of Results with a Primary Focus on Limitations. *Animals,* 5, 43-55.

Amobi, M., Saleh, A., Okpoko, V. and Abdullahi, A. (2021). Growth performance of broiler chickens based on grasshopper meal inclusions in feed formulation. *Zoologist,* 18, 39–43.

Awoniyi, T.A.M., Aletor, V.A. and Aina, J.M. (2003). Performance of broiler chickens fed on maggot meal in place of fishmeal. *International Journal of Poultry Science,* 2, 271-274

Campbell, W.W., Kim, J.E., Amankwaah, A.F., Gordon, S.L. and Weinheimer-Haus, E.M. (2015). Higher Total Protein Intake and Change in Total Protein Intake Affect Body Composition but Not Metabolic Syndrome Indexes in Middle-Aged Overweight and Obese Adults Who Perform Resistance and Aerobic Exercise for 36 Weeks. *Journal of Nutrition,* 145, 2076-2083.

Clarkson, C., Mirosa, M. and Birch, J. (2018). Consumer acceptance of insects and ideal product attributes. *British Food Journal,* 12, 2898-2911.

Dakhel, W.H., Jaronski, S.T. and Schell, S. (2020). Control of Pest Grasshoppers in North America. *Insects,* 11, 566.

Dibal, N.I., Garba, S.H. and Jacks, T.W. (2022). Onion Peel Quercetin Attenuates Ethanol-Induced Liver Injury in Mice by Preventing Oxidative Stress and Steatosis. *Biomedical Research Therapy,* 9(6), 5101-5111.

Dickerson, R.N. (2016). Nitrogen Balance and Protein Requirements for Critically Ill Older Patients. *Nutrients,* 8, 226.

Egonyu, J.P., Kinyuru, J., Fombong, F., Nganga, J., Ahmed, Y.A. and Niassy, S. (2021). Advances in insects for food and feed. *International Journal of Tropical Insect Science,* 41(3), 1903-1911.

Faria, F.D.E., Rosa, P.S., Vieira, B.S., Macari, M. and Furlan, R.L. (2005). Protein levels and environmental temperature effects on carcass characteristics, performance, and nitrogen excretion of broiler chickens from 7 to 21 days of age. *Revista Brasileira de Ciência Avícola, Campinas,* (7)4, 247-253.

Filipovic, N., Stojevic, Z., Milinkovic-Tur, S., Ljubic, B. & Zdelar-Tuk, M. (2007). Trends in concentrations of total proteins and their fractions in blood serum of chickens during fattening. *Veterinary Archive,* 77: 319-326.

Gasco, L., Biancarosa, I. and Liland, N. (2020). From waste to feed: A review of recent knowledge on insects as producers of protein and fat for animal feeds. *Current Opinion in Green and Sustainable Chemistry,* 23, 67–79.

Guiné, R., Correia, P., Coelho, C. and Costa, C. (2021). The role of edible insects in mitigating challenges for sustainability. *Open Agriculture,* 6: 24–36.

Ibarz-Blanch, N., Alcaide-Hidalgo, J.M., Cortés-Espinar, A.J., Albi-Puig, J., Suárez, M., Mulero, M., Morales, D. & Bravo, F.I. (2023). Chicken slaughterhouse by-products: A source of protein hydrolysates to manage non-communicable diseases. *Trends in Food Science and Technology,* 104125.

Kielkopf, C.L., Bauer, W. and Urbatsch, I.L. (2020). Bradford Assay for Determining Protein Concentration. *Cold Spring Harbor Protocols,* 4, 102269.

Kjeidahl, J. (1883). Neue Methode zur Bestimmung des Stickstoffs in organischen Korpern. *Fresenius Journal of Analytical Chemistry,* 22, 366-382.

Kondrup, J. (2008). Basic concepts in nutrition: Energy and protein Balance. *e-SPEN, the European e-Journal of Clinical Nutrition and Metabolism,* 3, 117-120.

Latimer, G.W. (2016). Official methods of Analysis of AOAC International: Gaithersburg, MD, USA.

Mallick, P., Muduli, K., Biswal, J.N. and Pumwa, J. (2020). Broiler poultry feed cost optimization using linear programming technique. *Journal of Operations and Strategic Planning,* 3(1), 31-57.

Martinez, D.A., Weil, J.T., Suesuttajit, N., Umberson, C., Scott, A. and Coon, C.N. (2022). The Relationship between Performance, Body Composition, and Processing Yield in Broilers: A Systematic Review and Meta-Regression. *Animals,* 12, 2706.

Ordoñez-Araque, R. and Egas-Montenegro, E. (2021). Edible insects: A food alternative for the sustainable development of the planet. *International Journal of Gastronomy and Food Science,* 23, 100304.

Rocha, A.G., Paulo, D.P., Neto, R.M., Schaefer, C. and Mallmann, C.A. (2022). Growth performance of broiler chickens fed on feeds with varying mixing homogeneity. *Veterinary Animal Science,* 17, 100263.

Rumpold, B.A. and Schlüter, O.K. (2013). Nutritional composition and safety aspects of edible insects. *Molecular Nutrition and Food Research,* 57, 802–823.

Sajid, Q.U.A., Asghar, M.U., Tariq, H., Wilk, M. and Platek, A. (2023). Insect meal as an Alternative to Protein Concentrates in Poultry Nutrition with Future Perspective (An Updated Review). *Agriculture,* 13(6), 1239.

Samant, S.S., Crandall, P.G., Arroyo, S.E.A. and Seo, H-S. (2021). Dry Pet Food Flavor Enhancers and Their Impact on Palatability: A Review. *Foods,* 10, 2599.

Schell, P.S. (2023). Grasshopper infestations and the risks they pose to western North America range and croplands, North of Mexico. In Sivanpillai and Schroder (eds). Biological and Environmental Hazards, Risks, and Disasters, 2nd edition.

Svanberg, I. and Berggren, A. (2021). Insects as past and future food in entomophobic Europe. *Food, Culture and Society,* 24, 624-638.

Tae-Kyung, K., Young-Boong, K., Hyun-Wook, K. and Yun-Sang, C. (2019). Edible Insects as a Protein Source: A Review of Public Perception, Processing Technology, and Research Trends. *Food Science and Animal Resource,* 39, 521–540.

Tilman, D. and Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature,* 515: 518-522

Tothova, C.S., Major, P., Molnar, L. and Nagy, O. (2017). Protein electrophoresis in avian medicine. In: Mitchell, G.H., editor. Gel Electrophoresis: Types, Applications and Research. Nova Science Publishers, Inc., New York. 157-187.

Wang, D., Shao, W., Chuan, X., Yao, Y., Shi, H. and Ying, N. (2005). Evaluation on Nutritional Value of Field Crickets as a Poultry Feedstuff. *Asian Australia Journal of Animal Science,* 18, 667–670.

Wendin, K., Norman, C., Forsberg, S., Langton, M., Davidsson, F., Josell, A., Prim, M. and Berg, J. (2017). Eat them or not? Insects as a culinary delicacy. In: Mikkelsen B, Ofei KT, Olsen TD, Quinto RA, Sudzina F. Eds., Aalborg, Denmark 100-106.

Yi, L., Lakemond, C.M.M., Sagis, L.M.C., *et al*. (2013). Extraction and characterisation of protein fractions from five insect species. *Food Chemistry,* 141, 3341–3348.

**Table 1: Proximate composition of *Schistocerca Americana***

| Constituents | Values (%) |
|---|---|
| Moisture | 5.2 |
| Ash | 3.0 |
| Crude protein | 60.7 |
| Crude fat | 12.5 |
| Fibre | 17.0 |
| Total carbohydrate | 1.6 |

**Table 2: Weekly consumption of feed fortified with *Schistocerca Americana***

| Groups | 1st Week (g) | 2nd Week (g) | 3rd Week (g) | 4th Week (g) |
|---|---|---|---|---|
| Control | 306.4±16.958 | 433.4±15.722 | 753.4±62.242 | 771.4±21.932 |
| Feed/SA at a 90:10 ratio | 309.9±12.343 | 461.0±18.5066* | 866.7±54.724* | 778.1±28.984* |
| Feed/SA at an 80:20 ratio | 339.6±6.568* | 478.7±20.159* | 877.7±56.338* | 777.0±27.335* |
| Feed/SA at a 70:30 ratio | 331.9±9.412* | 480.9±20.614* | 879.3±53.839* | 771.4±22.102* |
| Feed/SA at a 60:40 ratio | 327.1±17.709* | 471.0±18.835* | 877.1±56.589* | 779.2±29.452* |
| Feed/SA at a 50:50 ratio | 319.3±14.379* | 465.6±20.447* | 844.4±53.290* | 772.9±24.895* |

***Quantity given-Quantity left= Quantity consumed (Qg - Ql= Qc). Data presented as Mean ± SEM, n=5. *= Significant difference with the control (p<0.05). SA= Schistocerca americana, SEM= standard error of the mean***

**Table 3: Body weight change following feed fortification with *Schistocerca Americana***

| Groups | IBW (g) | 1st Week (g) | 2nd Week (g) | 3rd Week (g) | 4th Week (g) |
|---|---|---|---|---|---|
| Control | 316.4±27.602 | 592.8±56.625 | 973.2±94.720 | 1541.41±137.201 | 1900.6±168.247 |
| Feed/SA at a 90:10 ratio | 302.6±12.02* | 612.4±29.974* | 1045.8±39.663* | 1636.8±67.538* | 1986.0±48.562* |
| Feed/SA at an 80:20 ratio | 346.2±7.123* | 652.0±37.068* | 1101.4±66.221* | 1693.8±103.492* | 1983.2±108.623* |
| Feed/SA at a 70:30 ratio | 348.2±25.14* | 653.2±33.413* | 1072.8±42.927* | 1674.8±80.280* | 1906.8±54.341* |
| Feed/SA at a 60:40 ratio | 349.6±23.122* | 640.4±42.067* | 1078.8±68.161* | 1687.0±113.086* | 1955.8±150.808* |
| Feed/SA at a 50:50 ratio | 312.2±34.978* | 600.0±66.360* | 1061.2±95.411* | 1664.4±111.570* | 2007.6±136.009* |

***Data presented as Mean ± SEM, n=5. *= Significant difference with the control (p<0.05). SA= Schistocerca americana, IBW= Initial body weight, SEM= standard error of the mean***

**Table 4: Effects of feed fortified with *Schistocerca Americana* on Nitrogen Balance and Serum Protein in Broiler Chickens**

| Groups | Nitrogen Balance (g/kg/day) | Serum protein (mg/dL) |
|---|---|---|
| Control | 1.08±0.09 | 1.29±0.08 |
| Feed/SA at a 90:10 ratio | 1.41±0.21 | 1.28±0.07 |
| Feed/SA at an 80:20 ratio | 1.58±0.13 | 1.32±0.06 |
| Feed/SA at a 70:30 ratio | 1.35±0.16 | 1.34±0.08* |
| Feed/SA at a 60:40 ratio | 1.04±0.16 | 1.41±0.06* |
| Feed/SA at a 50:50 ratio | 1.09±0.74 | 1.37±0.08* |

***Data Presented as Mean ± SEM, n=5. *= Significant difference with the control (p<0.05). SA= Schistocerca americana***