FEDERAL UNIVERSITY WUKARI INTERNATIONAL JOURNAL OF BIOSCIENCES (FUWIJOB)
pISSN: 3121-9799, eISSN: 3121-973x; Volume 2, No. 2, June, 2026
https://fuwijob.com.ng

Growth Performance, Haematological and Biochemical Parameters of Broiler Chickens fed Dietary Betaine Supplementation

Wafar, R. J.*, Kabiru, B. O., Hassan, F., Elepu, P. I., Washima, K., Ejembi, E. A. & Musa, E. E.

Department of Animal Science, Faculty of Agriculture, Federal University Wukari, Taraba State

***Corresponding author:** wafar@fuwukari.edu.ng

ABSTRACT
This study evaluated the effects of dietary betaine supplementation on growth performance, haematological, and biochemical parameters of broiler chickens. Data were collected on growth performance, haematological and biochemical parameters. Data collected were analyzed using Analysis of Variance (ANOVA). The Results showed that final body weight, weight gain, feed intake, and FCR were significantly ($p < 0.05$) influenced by dietary betaine. Birds fed 0.4 g/100 kg betaine (T3) recorded superior performance, including the highest final body weight (1903.33 g), weight gain, and improved FCR (2.50), compared to those on 0.2 g/100 kg (T2) and the control (T1). Mortality was not affected by the treatments. Haematological parameters such as packed cell volume, haemoglobin concentration, red and white blood cell counts, and differential leukocytes, were not significantly ($p > 0.05$) influenced, indicating that betaine did not adversely affect physiological or immune status. Similarly, most serum biochemical indices remained unchanged, except for glucose, cholesterol, and aspartate aminotransferase, which showed significant differences. Notably, glucose levels decreased in supplemented groups. In conclusion, dietary betaine supplementation, particularly at 0.4 g/100 kg feed, enhanced growth performance and feed efficiency without adverse effects on blood profile or organ function, making it a viable additive in broiler production.

Keywords: betaine, broiler, growth, carcass, haematology

INTRODUCTION
The poultry industry, particularly broiler production, plays a critical role in meeting the increasing global demand for high-quality animal protein (Wafar *et al.,*2024). Broiler chickens are characterized by their rapid growth rate, high feed efficiency, and short production cycle, making them one of the most economically viable livestock species worldwide (FAO, 2020). In developing countries such as Nigeria, broiler production contributes significantly to food security, employment, and income generation (Wafar and Tarimbuka, 2023). However, rising feed costs, environmental stressors, and the need to optimize productivity have necessitated the exploration of nutritional strategies that enhance performance without compromising animal health (Ravindran, 2013). Among such strategies, the use of feed additives such as betaine has gained considerable attention. Betaine (trimethylglycine) is a naturally occurring compound derived from choline oxidation and is known for its dual role as a methyl donor and osmolyte (Eklund *et al.,* 2005). As a methyl donor, betaine participates in transmethylation reactions that are essential for protein synthesis and energy metabolism, while its osmoprotective

function helps maintain cellular integrity under stress conditions such as heat stress, which is prevalent in tropical environments (Attia *et al.,* 2009). These properties make betaine a promising dietary supplement in broiler nutrition. Growth performance is a primary indicator of productivity in broiler chickens, typically measured by body weight gain, feed conversion ratio, and overall efficiency. Several studies have reported that dietary betaine supplementation improves growth performance by enhancing nutrient digestibility, promoting protein accretion, and reducing maintenance energy requirements (Zhan *et al.,* 2006; Hassan *et al.,* 2019). Improved growth performance is often associated with better feed utilization, which directly impacts profitability in commercial poultry production. Feed intake is another critical factor influencing broiler performance, as it determines nutrient availability for growth and physiological functions. Betaine supplementation has been shown to influence feed intake variably, depending on environmental conditions and dietary composition. Under heat stress conditions, betaine may help stabilize osmotic balance and reduce the negative effects of stress on appetite, thereby maintaining or improving feed intake (He *et al.,* 2015). Conversely, in thermoneutral conditions, its effects on feed intake may be minimal but still contribute to improved feed efficiency. Carcass characteristics, including dressing percentage, breast muscle yield, and fat deposition, are important determinants of meat quality and market value. Research indicates that betaine supplementation can enhance carcass yield and lean meat deposition by promoting protein synthesis and reducing fat accumulation (Fernandez-Figares *et al.,* 2002). This is largely attributed to its role in methyl group donation, which supports lipid metabolism and reduces excessive fat deposition in broilers. In addition to carcass traits, the evaluation of internal organ weights provides insight into the physiological and metabolic status of birds. Organs such as the liver, heart, gizzard, and spleen are sensitive to dietary modifications and can reflect the health status of broilers. Betaine has been reported to influence liver function positively by reducing fat accumulation and improving hepatic metabolism, thereby maintaining normal organ development (Matthews *et al.,* 2001). Haematological and biochemical parametersst are essential indicators of the health and physiological status of animals. Parameters such as packed cell volume (PCV), haemoglobin concentration, red and white blood cell counts, serum proteins, and enzyme activities are commonly used to assess the effects of dietary interventions. Studies have shown that betaine supplementation generally maintains or improves these parameters, indicating enhanced physiological stability and immune competence in broiler chickens (Kidd *et al.,* 1997; Attia *et al.,* 2016). Stable haematological and biochemical indices suggest that betaine does not exert any deleterious effects and may support better metabolic functioning. Despite the documented benefits of betaine, variations in responses have been reported due to differences in dosage, environmental conditions, and diet composition. Therefore, further investigation is required to fully elucidate its effects on growth performance, feed intake, carcass characteristics, internal organ development, and haematological and biochemical parameters in broiler chickens. This study is therefore designed to evaluate the influence of dietary betaine supplementation on these key performance and physiological indices in broiler production.

MATERIALS AND METHODS

The study was conducted at the Poultry Unit of the Department of Animal Science, Federal University Wukari, located in Taraba State. Wukari lies at coordinates 9°47′0″ E longitude and 7°51′0″ N latitude, within a savannah vegetation zone and characterized by distinct wet and dry seasons, with the rainy season spanning from

March/April to October and the dry season from November to March/April, as reported in the Taraba State Diary (2008). A basal diet was formulated for both starter and finisher phases to meet the nutrient requirements of broiler chickens in accordance with National Research Council (1994) recommendations, and was supplemented with 0, 0.2, and 0.4 g/100 kg of Betaine HCl; the gross composition of the diets is presented in Tables 1and 2. A total of 135-day-old Marshal strain broiler chicks were procured from Obasanjo Farm Ota, Ado-Odo/Ota Local Government Area, Ogun State, Nigeria. The chicks were randomly allocated into three treatment groups of 45 birds each, with three replicates per treatment in a completely randomized design. The birds were managed under a deep litter system in pens equipped with feeders and drinkers, provided feed and water *ad libitum*, and the experiment lasted for a period of 49 days.

Growth performance parameters were evaluated by determining feed intake as the difference between the quantity of feed offered and the residual feed, while weight gain was calculated as the difference between final and initial body weights. Feed conversion ratio was computed as the ratio of feed intake to weight gain and used as an index of feed utilization across treatment groups. At the end of the experiment, two birds per replicate were randomly selected and fasted for 12 hours to ensure crop emptying and minimize carcass contamination. The birds were subsequently slaughtered, scalded, defeathered, and eviscerated, after which carcass components and internal organs were excised, weighed, and recorded. All data generated from the study were subjected to Analysis of Variance (ANOVA) using the General Linear Model procedure of Statistical Analysis System software, and treatment means were separated using the Least Significant Difference test.

Table 1: Ingredients and Percentage Composition of Broiler Starter Diets

Ingredients	T1 (0.0g/100kg)	T1 (0.2g/100kg)	T1 (0.4g/100kg)
Maize	55.00	55.00	55.00
Soybean meal	38.40	38.40	38.40
Groundnut cake	1.50	1.50	1.50
Limestone	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00
Methionine	0.25	0.25	0.25
Lysine	0.25	0.25	0.25
Salt	0.30	0.30	0.30
*Premix	0.30	0.30	0.30
Betaine	-	++	+++
Total	**100**	**100**	**100**
Calculated analysis			
ME kcal/kg	2853.00	2853.00	2853.00
Crude protein	23.00	23.00	23.00
Crude fibre	4.49	4.49	4.49
Ether extracts	4.75	4.75	4.75
Available phosphorus	0.52	0.52	0.52
Calcium	1.23	1.23	1.23

*premix composition (per kg of diet): vitamin A, 12500 IU; vitamin D_3, 2500 IU; vitamin E, 50.00 mg; vitamin K_3, 2.50 mg; vitamin B_1, 3.00 mg; vitamin B2, 6.00 mg; vitamin B_6, 6.00 mg; niacin, 40 mg; calcium pantothenic, 10 mg; biotin, 0.08 mg; vitamin B^{12}, 0.25 mg; folic acid, 1.00 mg; chlorine chloride, 300 mg; manganese, 100 mg; iron, 50 mg; zinc, 45 mg; copper, 2.00 mg; iodine, 1.55 mg;

cobalt, 0.25 mg; selenium, 0.10 mg; and antioxidant, 200 mg. **Betaine was supplemented at 0, 0.2, and 0.4g/100kg**

Table 2: Ingredients and Percentage Composition of Broiler Finisher Diets

Ingredients	T1 (0.0g/100kg)	T1 (0.2g/100kg)	T1 (0.4g/100kg)
Maize	62.00	62.00	62.00
Soybean meal	31.4	31.4	31.4
Groundnut cake	1.50	1.50	1.50
Limestone	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00
Methionine	0.25	0.25	0.25
Lysine	0.25	0.25	0.25
Salt	0.30	0.30	0.30
*Premix	0.30	0.30	0.30
Betaine	-	++	+++
Total	**100**	**100**	**100**
Calculated analysis			
ME kcal/kg	2927.00	2927.00	2927.00
Crude protein	20.00	20.00	20.00
Crude fibre	4.06	4.06	4.06
Ether extracts	4.55	4.55	4.55
Available phosphorus	0.51	0.51	0.51
Calcium	1.21	1.21	1.21

*premix composition (per kg of diet): vitamin A, 12500 IU; vitamin D_3, 2500 IU; vitamin E, 50.00 mg; vitamin K_3, 2.50 mg; vitamin B_1, 3.00 mg; vitamin B2, 6.00 mg; vitamin B_6, 6.00 mg; niacin, 40 mg; calcium pantothenic, 10 mg; biotin, 0.08 mg; vitamin B^{12}, 0.25 mg; folic acid, 1.00 mg; chlorine chloride, 300 mg; manganese, 100 mg; iron, 50 mg; zinc, 45 mg; copper, 2.00 mg; iodine, 1.55 mg; cobalt, 0.25 mg; selenium, 0.10 mg; and antioxidant, 200 mg.**Betaine was supplemented at 0, 0.2, and 0.4g/100kg**

RESULTS AND DISCUSSION

Effects of Betaine Supplementation on the Growth Performance of Broiler Chickens The results presented in Table 3 showed that initial body weight was similar ($p > 0.05$) across dietary treatments, indicating uniformity at the start of the trial. However, significant ($p < 0.05$) differences were observed in final body weight, total body weight gain, average daily weight gain, total feed intake, average daily feed intake, and feed conversion ratio. Birds fed 0.4 g/100 kg Betaine HCl (T3) recorded the highest ($p < 0.05$) final body weight (1903.33 g) and total weight gain (1767.33 g), followed by those on 0.2 g/100 kg (T2), while the control group (T1) had the lowest values. A similar trend was observed for average daily weight gain, where T3 (36.06 g) was significantly higher than T2 (31.57 g) and T1 (27.29 g). Feed intake was also significantly influenced by betaine supplementation, with birds on T3 recording higher ($p < 0.05$) total and daily feed intake compared to T1 and T2, which were similar. Feed conversion ratio (FCR) improved significantly with increasing levels of betaine, as T3 (2.50) had the best (lowest) FCR, followed by T2 (2.73), while T1 (3.12) had the poorest feed efficiency. Mortality was not significantly ($p > 0.05$) affected by the treatments. The improved growth performance and feed efficiency observed in birds fed betaine-supplemented diets, particularly at 0.4 g/100 kg, may be attributed to the role of betaine as an osmolyte and methyl group donor, which enhances nutrient utilization, protein synthesis, and gut integrity. These findings are consistent with reports by Eklund *et al.* (2005) who observed improved growth performance in broilers supplemented with betaine, and Attia *et al.* (2009) who reported enhanced feed efficiency and body weight gain due to improved nutrient digestibility. Similarly, Saunderson and Mackinlay, (1990)noted that betaine supplementation enhances metabolic efficiency and reduces maintenance energy requirements, thereby improving growth performance. The lack of significant effect on mortality agrees with findings from Zhan *et al.* (2006) who reported that betaine supplementation had no adverse effect on survivability of broiler chickens.

Table 3: Effects of Betaine Supplementation on the Growth Performance of Broiler chickens

Parameters	T_1 (Control)	T_2 (0.2g/100kg)	T_3 (0.4 g/100kg)	SEM	P-Value
Initial Body Weight (g)	136.00	136.00	136.00	1.02	0.08
Final Body Weight (g)	1473.33^{c}	1683.33^{b}	1903.33^{a}	104.40	0.02
Total Body Weight (g)	1337.33^{c}	1547.33^{b}	1767.33^{a}	104.40	0.01
Average daily weight gain (g)	2729.25^{c}	31.57^{b}	36.06^{a}	2.13	0.02
Total Feed Intake (g)	4160.07^{b}	4183.41^{b}	4409.33^{a}	135.12	0.03
Average daily Feed Intake (g)	84.89^{b}	85.37^{b}	89.98^{a}	2.75	0.01
Feed conversion ratio (g)	3.12^{b}	2.73^{ab}	2.50^{a}	0.12	0.03
Mortality (%)	0.33	1.00	0.00	0.38	0.25

SEM: Standard Error of the Mean
Means bearing different superscripts on the same row differ significantly ($p<0.05$)

The Haematological Profile of Broiler Chickens Fed Betaine Supplementation

The haematological profile of broiler chickens fed betaine supplementation (Table 4) revealed that all measured parameters were not significantly ($p>0.05$) affected by dietary treatments. Packed cell volume (PCV), haemoglobin concentration, and red blood cell (RBC) counts were statistically similar across treatments, suggesting that erythropoiesis and oxygen-carrying capacity were not compromised. The lack of significant differences in all haematological parameters implies that the experimental diets were nutritionally adequate and capable of maintaining normal physiological status of the birds. This suggests that betaine supplementation upto 0.4g/100kg is safe and does not adversely affect haematopoiesis or immune competence. These findings are consistent with those of *Attia et al.* (2009) who reported no significant effects of betaine on haematological indices and concluded that its primary benefits are more evident in growth performance and carcass traits rather than blood parameters. However, birds fed 0.4 g/100 kg betaine (T3) exhibited numerically higher values of PCV (29.00%), haemoglobin (101.89 g/L), and RBC (3.65×10^{12}/L) compared to the control group. This trend may suggest a potential improvement in erythropoiesis and oxygen-carrying capacity. The observed increases could be associated with the role of betaine as a methyl donor, which facilitates protein synthesis and nucleic acid metabolism essential for red blood cell formation. This observation agrees with findings of Hassan *et al.,* (2011) who reported increased RBC and haemoglobin levels in broilers supplemented with higher levels of betaine, although the present study did not show significance differences. In the same vein, El-Shinnawy, (2015) reported no significant differences in PCV, haemoglobin, and leukocyte counts in broilers fed betaine-supplemented diets, further supporting the present findings that betaine maintains physiological stability without markedly altering blood profiles under normal conditions. The absence of significant variation across treatments also suggests that the birds were not exposed to severe environmental or metabolic stress that could trigger pronounced haematological responses.

Similarly, white blood cell (WBC) counts and differential leukocyte indices (lymphocytes, monocytes, heterophils, and eosinophils) were not significantly influenced by dietary treatments. Nonetheless, slightly higher WBC (17.12×10^{12}/L) and lymphocyte (73.67%) values observed in T2 (0.2g/100kg) and T3 (0.4g/100kg) suggest a possible improvement in immune responsiveness. Although these increases were significant, they may reflect a mild immunomodulatory effect of betaine. This aligns with the report of Zhan *et al.* (2006) who observed enhanced immune-related parameters in broilers, particularly under stress conditions, indicating that betaine may play a supportive role in immune function.

Table 4: Haematological Profile of Broiler Chickens Fed Betaine Supplemented Diets

Parameter	**T_1 (Control)**	**T_2 (0.2g/100kg)**	**T_3 (0.4 g/100kg)**	**SEM**	**P-Value**
Packed cell volume (%)	27.66	27.03	29.00	2.53	0.36
Haemoglobin (g/l)	95.80	89.90	101.89	1.67	0.20
Total platelet (g/dl)	4.13	4.23	4.15	0.39	0.92
Red blood cell ($^x10^{12}$/l)	3.13	2.67	3.65	0.37	0.16
White blood cell ($^X10^{12}$/l)	16.00	17.12	17.04	2.77	0.65
Lymphocytes(%)	70.33	73.67	70.89	3.67	0.70
Monocytes (%)	0.11	0.33	0.36	0.02	0.60
Heterophils (%)	28.66	25.00	25.89	1.99	0.27
Eosinophil (%)	0.14	0.18	0.16	0.45	0.12

SEM Standard Error of the Mean

Serum Biochemical Profile Of Broiler Chickens Fed Betaine-Supplemented Diets

The serum biochemical profile of broiler chickens fed betaine-supplemented diets showed that most parameters were not significantly ($p>0.05$) affected, except for glucose, cholesterol, and aspartate aminotransferase (AST), which differed significantly among treatments. Total protein, albumin, and globulin values were statistically similar across treatments, indicating that dietary betaine did not adversely affect protein metabolism or liver synthetic function. Although not significant, higher numerical values of total protein and albumin were observed in T2 and T3, suggesting a possible improvement in protein utilization and metabolic activity. This agrees with findings by Attia *et al.* (2009) who reported no significant effect of betaine on serum protein fractions in broilers. Serum urea and creatinine concentrations were also not significantly influenced by dietary treatments, indicating normal kidney function and efficient nitrogen metabolism across all groups. The similarity in these parameters suggests that betaine inclusion did not impair renal function or protein catabolism. This observation is consistent with reports by El-Shinnawy, (2015) who found no adverse effects of betaine on renal-related biochemical indices. Glucose levels, however, were significantly ($p<0.05$) reduced in the supplemented groups (T2 and T3) compared to the control. Birds in T1 recorded the highest glucose value (211.33 mg/dL), while T3 had the lowest (170.00 mg/dL). This reduction may indicate improved glucose utilization and metabolic efficiency in birds fed betaine. Betaine has been reported to enhance energy metabolism and reduce circulating glucose levels by improving insulin sensitivity and nutrient partitioning. This finding aligns with the report of Zhan *et al.*(2006) who observed reduced blood glucose levels in broilers supplemented with betaine. Cholesterol levels were significantly ($p<0.05$) reduced with increasing levels of betaine supplementation, with T3 recording the lowest value (122.00 mg/dL) compared to the control (259.00 mg/dL). This indicates a hypocholesterolemic effect of betaine, which may be attributed to its role in lipid metabolism and methyl group donation involved in lipid mobilization and oxidation. This result agrees with findings of Hassan *et al.,* (2011) who reported significant reductions in serum cholesterol in broilers fed betaine-supplemented diets. Triglyceride levels were not significantly affected, although slight numerical variations were observed. This suggests that while betaine may influence cholesterol metabolism, its effect on triglycerides at the tested levels may be minimal. Similarly, alanine aminotransferase (ALT) values did not differ significantly among treatments, indicating that liver integrity was not compromised. In contrast, aspartate aminotransferase (AST) levels increased significantly ($p<0.05$) with increasing betaine inclusion, with T3 recording the highest value. Although elevated AST is sometimes associated with liver stress, the values remained within physiological limits, suggesting that the increase may be related to enhanced metabolic activity rather than tissue damage. This is supported by Zhan *et al.* (2006) who reported increased enzyme activity associated with improved metabolic processes rather than pathological conditions.

Table 5: Serum Biochemical Profile of Broiler Chickens Fed Betaine Supplemented Diets

Parameter	**T_1 (Control)**	**T_2 (0.2g/100kg)**	**T_3 (0.4 g/100kg)**	**SEM**	**P-Value**
Total protein (g/l)	40.67	45.66	46.33	3.74	0.66
Albumin (g/l)	12.01	19.66	19.67	1.34	0.19
Globulin (g/l)	28.66	26.00	26.66	4.03	0.13
Serum Urea (mg/dl)	5.10	5.16	5.10	0.22	0.51
Creatinine (mg/dl)	0.11	0.41	0.21	0.32	0.34
Glucose (mg/dl)	211.33^{a}	178.00^{b}	170.00^{b}	0.21	0.02
Cholesterol (mg/dl)	259.00^{a}	205.00^{b}	122.00^{c}	18.98	0.04
Triglyceride (mg/dl)	51.99	57.56	54.89	0.54	0.20
Alanine aminotransferase (u/l)	22.60	22.66	23.33	1.76	0.10
Aspartate aminotransferase(u/l)	14.33^{c}	16.08^{b}	18.34^{a}	0.53	0.11

Means on the same row with different superscript are significantly different (P<0.05)
SEM Standard Error of the Mean

CONCLUSION

It was concluded that dietary supplementation of betaine significantly improved the growth performance of broiler chickens, particularly at 0.4 g/100 kg feed, as evidenced by higher final body weight, weight gain, average daily gain, and better feed conversion ratio. Despite these improvements, haematological parameters were not significantly affected, although slight numerical increases in PCV, haemoglobin, and RBC were observed, suggesting maintained physiological stability without adverse effects on blood formation or immune function.

CONFLICTS OF INTEREST

The authors declare that there is no conflicts of interest regarding the publication of this paper. The research was conducted without any commercial, financial, or personal relationships that could be interpreted as influencing the findings or conclusions presented in this study

REFERENCES

Attia, Y. A., Al-Harthi, M. A., & El-Shafey, A. S. (2016). Influence of betaine on growth, carcass traits, and blood parameters of broilers. *South African Journal of Animal Science*, 46(3), 291–301.

Attia, Y. A., Hassan, R. A., Qota, E. M., & Zeweil, H. S. (2009). *Recovery from adverse effects of heat stress on slow-growing chicks in the tropics using natural antioxidants: Effect of betaine*. Tropical Animal Health and Production, 41(5), 857–864.

Eklund, M., Bauer, E., Wamatu, J., & Mosenthin, R. (2005). Potential nutritional and physiological functions of betaine in livestock. *Nutrition Research Reviews*, 18, 31–48.

El-Shinnawy, A. M. (2015). *Effect of dietary betaine supplementation on growth performance, carcass traits, and some blood parameters of broiler chickens*. Egyptian Poultry Science Journal, 35(2), 473–489.

FAO (2020). Poultry Development Review. Food and Agriculture Organization of the United Nations.

Fernandez-Figares, I., Wray-Cahen, D., Steele, N. C., & Campbell, R. G. (2002). Effect of dietary betaine on nutrient utilization and partitioning in animals. *Journal of Animal Science*, 80, E291–E298.

Hassan, R. A., Attia, Y. A., El-Ganzory, E. H., & Abd El-Hady, S. B. (2011). *Influence of dietary betaine supplementation on growth, carcass characteristics, and blood constituents of broiler chickens under heat stress conditions*. Egyptian Poultry Science Journal, 31, 521–537.

Hassan, R. A., Attia, Y. A., & El-Ganzory, E. H. (2019). Betaine supplementation and its effects on broiler performance. *Poultry Science Journal*, 7(2), 45–52

He, S., Zhao, S., Dai, S., Liu, D., & Bokhari, S. G. (2015). Effects of dietary betaine on growth performance and physiological responses of broilers under heat stress. *Asian-Australasian Journal of Animal Sciences*, 28(6), 879–885.

Kidd, M. T., Ferket, P. R., & Garlich, J. D. (1997). Nutritional and osmoregulatory functions of betaine. *World's Poultry Science Journal*, 53, 125–139.

Matthews, J. O., Southern, L. L., Bidner, T. D., & Persica, M. A. (2001). Effects of betaine on nutrient metabolism and organ characteristics. Journal of Animal Science, 79, 722–728.

Ravindran, V. (2013). Feed enzymes: The science, practice, and metabolic realities. *Journal of Applied Poultry Research*, 22, 628–636.

Saunderson, C. L., & Mackinlay, J. (1990). *Changes in body-weight, composition and hepatic enzyme activities in response to dietary methionine, betaine and choline levels in growing chicks*. British Journal of Nutrition, 63(2), 339–349

Taraba State Diary. (2008). State Annual Official Diary Reports; Pp 34

Tarimbuka, L.I. and Wafar, R.J. (2023). Impact of Various Processing Methods of Okra Seed Meal on the Growth Performance, Carcass and Blood indices of Broiler Chickens. *FUW Journal of Agriculture & Life Sciences Vol. 6 (2):22*

Wafar, R.J., Bako, M.I., Adi, Z.A., Abdullahi, U.,Tsejime, S.A., Tyoalumun J.T., Ternongo, S.(2024). Utilization Of Varying Levels Of Zinc Supplementation On Growth Performance, Carcass Characteristics And Blood Profile Of Broiler Chickens. FUW Journal of Agriculture & Life Sciences vol (7) 1: 126 - 136

Zhan, X. A., Li, J. X., Xu, Z. R., & Zhao, R. Q. (2006). *Effects of methionine and betaine supplementation on growth performance, carcass composition, and metabolism of lipids in male broilers*. British Poultry Science, 47(5), 576–580.