

Nutrient digestibility and haematological profile of broiler chickens fed graded levels of raw Bambara nut sievate supplemented with Biozyme®

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ABSTRACT: One hundred and fifty unsexed day-old Ross 308 broiler chicks were randomly allotted to five dietary treatments in a completely randomised design (CRD), with five replicates per treatment. The starter diets contained 0, 12.5, 15.0, 17.5 and 20.0% raw BNS, whereas the corresponding finisher diets contained 0, 17.5, 20.0, 22.5 and 25.0% raw BNS. In the last week of the study, three birds were randomly selected per treatment replicate and put in metabolic cages where faecal samples were collected for a digestibility study. Also, 5 ml blood samples from 3 birds randomly selected per treatment replicate were withdrawn via left wing vein puncture into sterile test-tubes containing EDTA as anticoagulant and labelled according to the corresponding bird number and then placed in a thawing flask containing ice cubes before being moved to the laboratory within an hour of collection for the determination of haematological parameters. Dietary treatments significantly affected crude protein, crude fibre, ether extract and nitrogen-free extract digestibility, whereas dry matter digestibility was not significantly affected. There was no significant difference ($p > 0.05$) between the test diets and the control for all haematological parameters except for MCHC. It was concluded that raw bambara nut sievate supplemented with Biozyme® supported acceptable haematological values and did not adversely affect most nutrient digestibility indices, although crude protein digestibility was markedly reduced at the 20% finisher inclusion level.

Keywords: Bambara nut sievate, Biozyme, broiler chickens, haematological profile, nutrient digestibility.

INTRODUCTION

Animal production is increasingly challenged by the high cost of conventional feed ingredients, which has stimulated interest in the use of cheaper and locally available alternative feed resources. Feed represents a major proportion of total livestock production costs, particularly in intensive poultry systems, thereby creating the need for less expensive alternative feed ingredients

(Orayaga, 2016). Broiler chickens have the ability to feed intensively; hence, the smartest choice to reduce feed cost will be to adopt less expensive feedstuffs that can still meet their nutrient requirement order than the highly expensive conventional broiler feeds (Esonu *et al.*, 2003; Ekenyem and Onyeago, 2006). Bambara nut sievate is a nutritious by-product obtained from the processing of Bambara nut

(Sylva-Nyom, 2013). It is an inexpensive source of high-quality protein of 18.92% (Sylva-Nyom *et al.*, 2021). AOAC (2019) recorded up to 19.16%. Bambara nut sieveate very readily available due to its extensive use and consumption in Nigeria (Sylva-Nyom, 2013).

Haematological parameters serve as an index of general physiology, nutrition and health status of animals (Okwelum *et al.*, 2018). Nutrition, management and stress are some of the factors that influence the haematological profile of any animal (Tambuwal *et al.*, 2002). The life of all flesh is in the blood and is useful for assessing the health status (Okwelum *et al.*, 2018). Also, haematological values give a reflection of the effects of diets on the animals in terms of the type and amount of feed ingested and were available for the animals to meet its physiological, biochemical and metabolic necessities (Ewuola *et al.*, 2004). Furthermore, (Mohammed *et al.*, 2016) reported that blood constituents are markers to determine the efficacy of feed nutrient content and its utilisation. If the feed fed to the animals has a negative effect, it will also reflect on the blood composition (Akinmutimi, 2004; Okwelum *et al.*, 2018).

Although previous studies have evaluated Bambara nut by-products in broiler diets, limited information is available on the digestibility and haematological responses of broilers to graded levels of raw Bambara nut sieveate supplemented with Biozyme® under the present production conditions. Therefore, this study evaluated the effects of graded levels of raw Bambara nut sieveate supplemented with Biozyme® on nutrient digestibility and haematological profile of broiler chickens.

MATERIALS AND METHODS

Study location

The experiment was conducted at Farm Craft Farms, Judges' Quarters, Makurdi, Benue State, Nigeria. Makurdi is located at latitude 7.45°N and longitude 8.32°E within the Southern Guinea Savanna agro-ecological zone of Nigeria (TAC, 2011).

Experimental birds and management

A total of 150 unsexed day-old Ross 308 broiler chicks were used for the experiment. The birds were randomly allotted to five dietary treatments in a completely randomised design (CRD), with five replicates per treatment. The experimental diets were designated T1, T2, T3, T4 and T5. The birds were managed under the same experimental conditions throughout the six-week feeding trial.

The feeding trial lasted six weeks and was divided into two phases: a three-week starter phase and a three-week finisher phase. Starter diets were offered during the first three weeks, while finisher diets were fed during the

subsequent three weeks. Feed and other routine management practices were provided throughout the experimental period.

Collection and processing of Bambara nut sieveate

Raw Bambara nut sieveate (BNS) used in the experiment was obtained from Fiidi Market, Makurdi, Benue State. The sieveate was collected immediately after the sieving of processed Bambara nut flour. It was sundried, ground to a uniform particle size and stored under dry conditions until required for feed formulation.

Experimental diets

Five experimental diets were formulated for both the starter and finisher phases. The starter diets contained 0, 12.50, 15.00, 17.50 and 20.00% raw BNS for T1, T2, T3, T4 and T5, respectively. The corresponding finisher diets contained 0, 17.50, 20.00, 22.50 and 25.00% raw BNS, respectively.

T1 served as the control diet and contained no BNS and no enzyme. Raw BNS was included in T2–T5, and Biozyme® was incorporated into each of these test diets at 100 g per 100 kg of feed, corresponding to the manufacturer's recommended inclusion rate. The diets were formulated using maize, full-fat soybean, rice offal, raw BNS, blood meal, bone ash, salt, lysine, methionine, vitamin-mineral premix and Biozyme®, as applicable. The detailed ingredient composition and calculated nutrient contents of the starter and finisher diets are presented in Tables 1 and 2, respectively.

Average daily feed intake

Average daily feed intake per bird was calculated by dividing the total quantity of feed consumed by the number of days during which the feed was offered.

Average daily feed intake per bird

$$= \frac{\text{Total feed intake}}{\text{No. of birds} \times \text{No of days consumed}}$$

Determination of nutrient digestibility

At the last week of the experiment, three birds were randomly selected from each treatment replicate and transferred to metabolic cages for the digestibility study. Faecal samples were collected individually from the selected birds for seven consecutive days. The faecal samples from each bird were pooled, weighed, dried, milled and stored for laboratory analysis.

The samples were analysed for dry matter, crude protein, crude fibre, ether extract and nitrogen-free extract.

Table 1. Gross calculated nutrient composition of broiler chicks' diets.

Ingredients	T1	T2	T3	T4	T5
Maize	40.17	31.93	30.28	28.63	26.98
FFSB	50.28	46.02	45.17	44.32	43.47
Rice offal	3.00	3.00	3.00	3.00	3.00
Raw BNS	0.00	12.50	15.00	17.50	20.00
Blood meal	2.00	2.00	2.00	2.00	2.00
Bone ash	3.50	3.50	3.50	3.50	3.50
Salt	0.30	0.30	0.30	0.30	0.30
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Vitamin Premix	0.25	0.25	0.25	0.25	0.25
Biozyme® (g)	0.00	100.00	100.00	100.00	100.00
Total	100	100	100	100	100
Calculated nutrient composition (%)					
Crude protein	21.88	21.88	21.88	21.88	21.88
Crude fibre	7.66	9.86	9.60	10.57	10.47
NFE	48.54	40.76	42.77	39.34	45.31
EE	3.60	7.39	8.29	9.13	3.20
Ash	12.52	14.86	12.97	13.70	14.20
Methionine	0.67	0.73	0.75	0.76	0.77
Lysine	2.83	1.69	1.67	1.64	1.61
Calcium	2.35	1.38	1.38	1.39	1.39
Phosphorus	0.87	0.85	0.85	0.85	0.84
ME (kcal/kg)	2824.33	2855.13	2999.39	2945.66	2677.27

*Premix content provides the following per Kg: Vitamin A, 1500 UI; Vitamin E, 11.00mg; Biotin, 0.25mg; Pantothenic acids, 11.00mg, Vitamin K₃, 3.00mg; B₂, 2.5mg, B₆, 8.00mg; Nicotinic Acid, 8.00mg; Fe, 5.00mg; Mn, 10.00mg; Zn, 4.5mg; Co, 0.2mg; Se, 0.01mg, FFSB=full fat soybean, NFE= nitrogen free extract, EE = ether extract and ME = metabolisable energy. BNS = Bambaranut Sievate, T₁ = Control Diet with 0% BNS and no enzyme, T₂ = Diet containing 12.50% BNS with enzyme, T₃ = Diet containing 15.00% BNS with enzyme, T₄ = Diet containing 17.50 % BNS with enzyme, T₅ = Diet containing 20.00% BNS with enzyme.

Nutrient digestibility was determined from the nutrient contents of the feed and corresponding faecal samples using the standard digestibility calculation:

$$\text{Nutrient digestibility (\%)} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

Haematological analysis

During the last week of the feeding trial, blood samples were collected from three randomly selected birds per treatment replicate. Approximately 5 mL of blood was collected from each bird by puncture of the left wing vein into sterile test tubes containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant. The tubes were properly labelled according to the corresponding bird identification and immediately placed in a cooling container. The samples were transported to the laboratory

within one hour of collection for haematological analysis.

Packed cell volume (PCV) was determined using the microhaematocrit method. Haemoglobin concentration was determined according to the method described by Jain (1986), while erythrocyte and leukocyte counts were determined following the method of Schalm *et al.* (1975). Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated using standard haematological equations. The haematological parameters determined included PCV, red blood cell (RBC) count, white blood cell (WBC) count, haemoglobin (Hb), MCV, MCH, MCHC, lymphocytes, heterophils, eosinophils, basophils and monocytes.

Statistical analysis

Data obtained from the nutrient digestibility and haematological assessments were subjected to one-way

Table 2. Gross calculated nutrient composition of broiler finisher diets.

Ingredients	T1	T2	T3	T4	T5
Maize	54.35	42.16	41.16	39.51	37.86
FFSB	36.10	30.14	29.29	25.44	27.59
Rice offal	3.00	3.00	3.00	3.00	3.00
Raw BNS	0.00	17.50	20.00	22.50	25.00
Blood meal	2.00	2.00	2.00	2.00	2.00
Bone ash	3.50	3.50	3.50	3.50	3.50
Salt	0.30	0.30	0.30	0.30	0.30
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Vit-min Premix	0.25	0.25	0.25	0.25	0.25
Biozyme® (g)	0.00	100.00	100.00	100.00	100.00
Total	100	100	100	100	100
Calculated nutrient composition (%)					
Crude protein	17.50	17.50	17.50	17.43	17.50
Crude fibre	5.17	10.19	11.06	14.77	9.29
NFE	56.88	52.27	48.16	44.02	50.41
Ether Extract	2.30	3.06	6.61	6.60	5.59
Ash	13.08	11.76	10.93	12.08	12.55
Methionine	0.60	0.69	0.71	0.70	0.73
Lysine	1.46	1.28	1.25	1.14	1.20
Calcium	1.32	1.36	1.36	1.36	1.76
Phosphorus	0.80	0.77	0.77	0.75	0.84
ME (kcal/kg)	2853.04	2744.95	2892.59	2742.22	2889.85

*Premix content provides the following per Kg: Vitamin A, 1500 UI; Vitamin E, 11.00mg; Biotin, 0.25mg; Pantothenic acids, 11.00mg; Vitamin K₃ 3.00mg; B₂, 2.5mg, B₆, 8.00mg; Nicotinic Acid, 8.00mg; Fe, 5.00mg; Mn, 10.00mg; Zn, 4.5mg; Co, 0.2mg; Se, 0.01mg. NFE= nitrogen free extract, EE = ether extract and ME = metabolisable energy. BNS = Bambara nut sieveate, T₁ = Control Diet with 0% BNS and no enzyme, T₂ = Diet containing 17.50% BNS with enzyme, T₃ = Diet containing 20.00% BNS with enzyme, T₄ = Diet containing 22.50% BNS with enzyme, T₅ = Diet containing 25.00% BNS with enzyme.

analysis of variance (ANOVA) appropriate for a completely randomised design. Where significant treatment effects were detected, treatment means were separated using Fisher's least significant difference (LSD) test. Statistical significance was declared at $p < 0.05$.

RESULTS

Nutrient digestibility

The effects of graded levels of raw Bambara nut sieveate (BNS) supplemented with Biozyme® on nutrient digestibility of broiler chickens are presented in Table 3. Dry matter digestibility ranged from 57.94% in T3 (20.00% BNS) to 73.19% in the control diet (T1), with no significant difference among the treatments ($p > 0.05$).

Dietary treatment significantly affected crude protein digestibility ($p < 0.05$). The highest value was recorded in T1 (59.81%), while the lowest value occurred in T3 (24.03%). The crude protein digestibility of T3 was significantly lower than those recorded in T1, T2, T4 and

T5, which had values of 59.81, 45.62, 48.79 and 50.71%, respectively.

Crude fibre digestibility also differed significantly among the treatments ($p < 0.05$). The highest value was observed in T4 (63.84%), followed by T2 (52.90%), while the lowest value was recorded in T3 (30.22%). The values for T1, T2 and T5 were 40.56, 52.90 and 37.65%, respectively.

Ether extract digestibility was significantly influenced by dietary treatment ($p < 0.05$). The highest digestibility values were recorded in T5 (83.47%) and T4 (80.92%), while T1 and T2 recorded 45.77 and 42.17%, respectively. T3 had an intermediate value of 53.02%.

Nitrogen-free extract (NFE) digestibility was significantly affected by dietary treatment ($p < 0.05$). The control treatment (T1) recorded the highest value of 86.87%, followed by T2 and T5 with 80.23 and 77.82%, respectively. The lowest NFE digestibility was observed in T3 (62.90%), while T4 recorded 69.12%. Overall, dietary inclusion of raw BNS supplemented with Biozyme® resulted in significant differences in crude protein, crude fibre, ether extract and NFE digestibility, whereas dry matter digestibility was not significantly affected.

Table 3. Nutrient digestibility by broiler chickens fed diets containing different levels of raw bambara nut sievate with biozyme supplementation.

Parameters (%)	T1	T2	T3	T4	T5	SEM
Dry matter	73.19	63.95	57.94	62.44	64.31	3.24
Crude protein	59.81 ^a	45.62 ^a	24.03 ^b	48.79 ^a	50.71 ^a	3.70
Crude fibre	40.56 ^{bc}	52.90 ^{ab}	30.22 ^c	63.84 ^a	37.65 ^{bc}	3.86
Ether extract	45.77 ^c	42.17 ^c	53.02 ^b	80.92 ^a	83.47 ^a	4.75
NFE	86.87 ^a	80.23 ^b	62.90 ^d	69.12 ^c	77.82 ^b	2.35

^{a,b,c,d} = Means with different superscripts within the same row are significantly different ($p < 0.05$). NFE= nitrogen free extract, BNS = Bambara nut sievate, T₁ = Control Diet with 0%BNS and no enzyme, T₂ = Diet containing 17.50% BNS with enzyme, T₃ = Diet containing 20.00% BNS with enzyme, T₄ = Diet containing 22.50% BNS with enzyme, T₅ = Diet containing 25.00% BNS with enzyme.

Table 4. Haematological profile of broiler chickens fed diets containing different levels of raw Bambara nut sievate with biozyme supplementation.

Parameters	T1	T2	T3	T4	T5	SEM
Packed cell volume (%)	29.00	31.67	30.00	31.33	31.00	0.57
Red blood cell ($\times 10^{12}/L$)	2.03	2.70	2.57	2.63	2.57	0.10
White blood cell ($\times 10^9/L$)	6.20	6.80	6.27	6.53	6.33	0.12
Haemoglobin (g/dL)	9.67	10.55	10.00	10.44	10.33	0.19
MCV (fL)	151.60	117.20	118.37	120.53	122.47	5.41
MCH (pg)	50.24	39.08	39.49	40.18	40.83	1.80
MCHC (g/dL)	33.36 ^a	33.32 ^b	33.33 ^{ab}	33.33 ^{ab}	33.33 ^{ab}	0.01
Lymphocyte (%)	44.67	46.00	45.33	45.00	46.67	0.49
Heterophil (%)	48.33	46.00	46.33	46.33	46.67	0.46
Eosinophil (%)	2.00	3.33	3.00	2.33	2.67	0.23
Basophils (%)	0.67	0.00	0.33	0.67	0.00	0.13
Monocyte (%)	4.33	4.67	5.00	5.67	4.00	0.27

^{a,b} = Means in the same row with different superscripts are significantly different ($p < 0.05$), MCV = Mean Corpuscular Volume, MCH = Mean Corpuscular Haemoglobin, MCHC = Mean Corpuscular Haemoglobin Concentration, SEM = Standard Error of Mean.

Haematological profile

The haematological profile of broiler chickens fed diets containing graded levels of raw BNS supplemented with Biozyme® is presented in Table 4. There were no significant differences ($p > 0.05$) among the dietary treatments for packed cell volume (PCV), red blood cell (RBC) count, white blood cell (WBC) count, haemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), lymphocyte, heterophil, eosinophil, basophil and monocyte percentages.

Packed cell volume values ranged from 29.00% in T1 to 31.67% in T2. Red blood cell counts ranged from $2.03 \times 10^{12}/L$ in T1 to $2.70 \times 10^{12}/L$ in T2, while WBC counts ranged from $6.20 \times 10^9/L$ in T1 to $6.80 \times 10^9/L$ in T2. Haemoglobin concentration ranged from 9.67 g/dL in T1 to 10.55 g/dL in T2.

Mean corpuscular volume ranged from 117.20 fL in T2 to 151.60 fL in T1, whereas MCH values ranged from 39.08 pg in T2 to 50.24 pg in T1. Lymphocyte percentages ranged from 44.67% in T1 to 46.67% in T5, while heterophil percentages ranged from 46.00% in T2 to 48.33% in T1. Eosinophil, basophil and monocyte values

ranged from 2.00 to 3.33%, 0.00 to 0.67% and 4.00 to 5.67%, respectively.

Mean corpuscular haemoglobin concentration (MCHC) was the only haematological parameter significantly affected by dietary treatment ($p < 0.05$). The control treatment (T1) recorded the highest MCHC value of 33.36 g/dL, while T2 recorded the lowest value of 33.32 g/dL. T3, T4 and T5 recorded intermediate values of 33.33, 33.33 and 33.33 g/dL, respectively. Thus, apart from MCHC, the graded inclusion of raw BNS supplemented with Biozyme® did not significantly alter the measured haematological parameters of the broiler chickens.

DISCUSSION

The results of the present study showed that dietary inclusion of raw Bambara nut sievate (BNS) supplemented with Biozyme® significantly influenced several nutrient digestibility indices of broiler chickens. Dry matter digestibility was not significantly affected by the dietary treatments, indicating that the birds were able to utilise the diets for overall dry matter to a comparable extent.

However, the significant differences observed in crude protein, crude fibre, ether extract and nitrogen-free extract digestibility suggest that the increasing inclusion of raw BNS altered the utilisation of specific nutrients. This variation may be associated with differences in the nutrient composition of the diets and the presence of inherent factors in raw BNS that may influence nutrient availability.

Dietary treatment particularly affected crude protein digestibility, with the lowest value recorded at the 20.00% BNS inclusion level (T3). The marked reduction from 59.81% in the control diet to 24.03% in T3 suggests that the inclusion of BNS at this level may have reduced the availability or utilisation of dietary protein. The result differs from the findings reported by Ani *et al.* (2012) and Tuleun *et al.* (2020), who evaluated Bambara nut by-products in broiler diets. The differences may be related to variations in the type and processing status of the Bambara nut by-product, dietary formulation, enzyme preparation, inclusion levels and experimental conditions. The present result therefore indicates that the response of crude protein digestibility to raw BNS inclusion may not be linear and that an intermediate inclusion level may produce less favourable protein utilisation under the conditions of the present study.

Crude fibre digestibility varied significantly among the dietary treatments. The highest value was obtained at the 22.50% BNS inclusion level (T4), while the lowest value occurred at 20.00% BNS inclusion (T3). The irregular pattern across the treatments indicates that increasing BNS inclusion did not consistently decrease or increase fibre utilisation. This observation may be associated with differences in the fibre fractions contributed by the BNS and the ability of the supplemented enzyme to improve the availability of nutrients associated with the fibre matrix. The relatively high crude fibre digestibility recorded in T4 suggests that Biozyme® supplementation may have supported fibre utilisation at this inclusion level (Tuleun *et al.*, 2020; Ani *et al.*, 2012).

Ether extract digestibility increased considerably in the higher BNS treatments, with the highest values recorded in T4 and T5. The values of 80.92 and 83.47% in T4 and T5, respectively, were substantially higher than the 45.77% recorded in the control. This indicates that the diets containing higher levels of BNS supported greater utilisation of dietary ether extract under the conditions of the experiment. The response may partly reflect differences in the contribution of BNS to the dietary nutrient profile and the action of the enzyme supplement on nutrient availability. Nevertheless, the variation among treatments demonstrates that the effect of BNS inclusion on nutrient utilisation was nutrient-specific rather than uniform (Tuleun *et al.*, 2020; Ani *et al.*, 2012).

Nitrogen-free extract digestibility was highest in the control treatment and progressively lower in the BNS-containing diets, although T5 showed an improvement relative to T3 and T4. The lowest value was recorded at the 20.00% BNS inclusion level. The reduced NFE digestibility in the test diets may indicate reduced

availability of readily digestible carbohydrate fractions associated with increasing replacement of conventional ingredients by raw BNS. The subsequent increase at the highest inclusion level suggests that the relationship between BNS inclusion and NFE utilisation was not strictly dose-dependent. The findings further demonstrate that the effects of raw BNS on nutrient digestibility varied according to the nutrient fraction considered (Tuleun *et al.*, 2020; Ani *et al.*, 2012).

The haematological results indicate that inclusion of raw BNS supplemented with Biozyme® had generally limited effects on the blood profile of the broiler chickens. Packed cell volume, red blood cell count, white blood cell count, haemoglobin concentration, mean corpuscular volume, mean corpuscular haemoglobin, lymphocyte, heterophil, eosinophil, basophil and monocyte percentages were not significantly affected by dietary treatment. This suggests that the inclusion of raw BNS at the levels evaluated did not produce measurable adverse effects on the major haematological indices of the birds. Haematological parameters are commonly used as indicators of the physiological and health status of animals (Isaac *et al.*, 2013), and the absence of significant changes in most of the measured indices suggests that the test diets were generally tolerated by the birds.

Mean corpuscular haemoglobin concentration was the only haematological parameter significantly affected by dietary treatment. Although the statistical difference indicates a treatment effect, the numerical differences among the treatments were very small, ranging from 33.32 to 33.36 g/dL. Furthermore, the values remained within the normal range of 32–36 g/dL reported by Etim *et al.* (2014) for healthy birds. Thus, the statistical difference in MCHC does not appear to indicate a biologically adverse response. The relatively stable values of PCV, RBC, WBC and haemoglobin across treatments further support the view that the dietary inclusion of raw BNS supplemented with Biozyme® did not substantially alter erythropoietic or immune-related haematological responses.

The haematological findings are consistent with the report of Torhemen *et al.* (2020), who observed no significant effects of processed and unprocessed Bambara nut by-product diets on several haematological parameters of broiler finisher chickens. The agreement between the studies suggests that Bambara nut by-products can be incorporated into broiler diets without necessarily causing adverse changes in the major blood indices. However, the present study also demonstrates that nutrient digestibility responses require careful consideration, particularly because crude protein and NFE digestibility were substantially reduced in some treatment groups.

Conclusion

In conclusion, the findings demonstrate that raw BNS supplemented with Biozyme® produced nutrient-specific

responses in broiler chickens. While dry matter digestibility and most haematological indices were maintained, crude protein, crude fibre, ether extract and NFE digestibility varied significantly among treatments. The absence of significant changes in most haematological parameters suggests that the dietary treatments were generally well tolerated, but the inconsistent nutrient digestibility responses indicate that increasing the inclusion level of raw BNS does not necessarily result in proportional improvements in nutrient utilisation.

Recommendation

Based on the present findings, raw Bambara nut sievate supplemented with Biozyme® may be included in broiler diets up to the highest level tested without adverse effects on the measured haematological parameters; however, further studies should establish an appropriate inclusion level that balances the potential feed-resource benefits of BNS with efficient nutrient utilisation.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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