OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2019.

Research Article

Performance of Broiler Chickens Fed 8% Crude Fibre Diets at Three Energy Levels With or Without Enzyme During the Starter and Finisher Phases

[1]R.I. Salami and [2]A.A. Odunsi

[1]Department of Agricultural Education (Animal Science Division), School of Vocational and Technical Education, Emmanuel Alayande College of Education, P.M.B 1010, Oyo, Oyo State, Nigeria
[2]Department of Animal Nutrition and Biotechnology, Faculty of Agricultural Sciences, Ladoke Akintola University of Technology, P.M.B 4000, Ogbomoso, Oyo State, Nigeria

Abstract

Background and Objective: Optimal inclusion levels of Crude Fibre (CF) and exogenous enzymes in poultry diets have beneficial effects on growth performance indices and feed cost per unit weight gain. This study was, therefore, conducted to evaluate the production performance and economy of unsexed Obamarshal broiler chickens fed ca 8% CF diets at three energy levels with or without Roxazyme®G^{2}G supplementation during the starter and finisher phases. **Materials and Methods:** One hundred and forty-four day-old unsexed Obamarshal broiler chicks were divided into six treatments at 24 birds each with three replicates per dietary treatment and fed for 28 days each for the starter and finisher phases with ca 8% CF diets at 2600, 2800 and 3,000ME (kcal kg^{-1} diet) with or without enzyme. Roxazyme®G^{2}G was incorporated at 0 and 200 mg kg^{-1} diet per energy level to produce six diets labeled A, B, C, D, E and F in ascending order of energy and enzyme levels. Live weight, average daily gain (ADG), feed intake, feed conversion ratio (FCR), protein intake, protein efficiency ratio (PER), calorie intake, fibre intake, water intake, water intake: feed intake, water intake: weight gain, faecal output and mortality rate were evaluated using standard methods. Data were analysed using 2×3 factorial arrangement and according to one-way Analysis of Variance. Means were separated with Duncan's Multiple Range Test at $p<0.05$. **Results:** Except for the non-supplemented diet A, birds on the other dietary treatments B, C, D, E and F had better ($p<0.05$) and comparable ($p>0.05$) performance indices, with the ADG ranging from 28-30 and 50-55 g b^{-1} during the starter and finisher phases respectively. The findings implied beneficial effect of enzyme inclusion at sub-optimal but not at optimal energy levels. Feed cost per unit weight gain was minimized in the birds fed ca 8% CF diet at 2600ME (kcal kg^{-1}) with enzyme, showing that energy is the most costly component of the feed. **Conclusion:** Feeding diet of about 8% CF at 2600 ME (kcal kg^{-1}) with Roxazyme®G^{2}G appeared to be nutritionally and economically feasible for broiler starters and finishers in the humid tropics.

Key words: Broiler chicken, crude fibre, enzyme supplementation, metabolisable energy, roxazyme®G2G

Received: Accepted: Published:

Citation: R.I. Salami and A.A. Odunsi, 2019. Performance of broiler chickens fed 8% crude fibre diets at three energy levels with or without enzyme during the starter and finisher phases. Int. J. Poult. Sci., CC: CC-CC.

Corresponding Author: R.I. Salami, Department of Agricultural Education (Animal Science Division), School of Vocational and Technical Education, Emmanuel Alayande College of Education, P.M.B 1010, Oyo, Oyo State, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

It has been shown that dietary Crude Fibre (CF) in excess of tolerance limits for monogastric animal species has growth depressant effects[1-3]. There is also an economic incentive in the inclusion of maximum safe levels of fibres (as growth stimulant) in the diets of monogastric animals[3-6]. Similarly, there is cost advantage in the inclusion of exogenous enzymes in poultry diets, especially at the sub-optimum energy level[7-9]. However, there are exceptions to this rule in some reports where supplemental enzymes failed in reducing diet cost nor improve biological performance[10-12].

Performance parameters such as weight gain, feed conversion ratio and protein efficiency ratio among others are frequently used to assess feed quality in simple stomached animals. Based on performance indices, Salami and Odunsi[3,6] reported that 2600 ME (kcal kg^{-1} diet) without enzyme supplementation irrespective of dietary CF level was inadequate to satisfy broiler chicken requirements for optimum growth performance. However, diets containing 8 and 12% CF levels at 2800 and 3000 ME (kcal kg^{-1}) without enzyme inclusion resulted in positive growth response[3,6] as against 3-5% CF level generally recommended for broiler chickens[13,14]. Meanwhile, Salami and Odunsi[9] further reported that Roxazyme®G^{2}G-supplemented 8% CF diet at 2600 ME (kcal kg^{-1}) was adequate nutritionally for raising broiler chickens in a tropical environment.

Based on the background information, this study was therefore conducted to assess and compare the biological performance of broiler chickens fed ca 8% CF diets at three ME levels with or without Roxazyme®G^{2}G during the starter and finisher phases of production.

MATERIALS AND METHODS

Experimental site: The study was conducted at the Poultry unit of the Teaching and Research farm, Emmanuel Alayande College of Education, Oyo, Nigeria. Oyo is located approximately along latitude 7°51^1 North of the equator and longitude 3°57^1 East of the Greenwich meridian and 850 m above sea level. The annual average rainfall is 1163 mm while annual mean temperature is 27°C and annual mean relative humidity is 82%[15].

Experimental diets: Three basal diets of ca 8% CF each for the starter and finisher phases (Table 1) were formulated to contain 2600, 2800 and 3000 ME (kcal kg^{-1}). Determined CF content of the basal diets ranged from 7.75-7.88% for the

Table 1: Gross composition of 8% crude fibre basal diets

	ME of starter diets (kcal kg^{-1})			ME of finisher diets (kcal kg^{-1})		
Feed ingredients (%)	2600	2800	3000	2600	2800	3000
Maize	33	32	24	39	38	30
Rice offal	12	11	11	12	10	10
Palm kernel cake	2	10	10	2	10	10
Wheat offal	18	10	10	19	12	12
Groundnut cake	17	15	15	15	12	12
Blood meal	6	8	10	4	6	8
Danish fish meal	3	4	5	2	3	4
Palm oil	3	5	10	2	4	9
Sterilized sand	1	-	-	-	-	-
[a]Fixed ingredients	5	5	5	5	5	5
Total	100.00	100.00	100.00	100.00	100.00	100.00
[b]Cost of feed (₦ kg^{-1})	61.62	67.85	74.03	57.13	63.63	69.81
Calculated fractions:						
Metabolisable energy (kcal kg^{-1})	2628.30	2820.30	3029.10	2621.90	2806.90	3015.00
Lysine (%)	1.10	1.20	1.31	0.90	1.00	1.06
Methionine (%)	0.30	0.48	0.54	0.31	0.39	0.45
Calorie:protein ratio	123.20	123.30	124.10	140.00	139.60	139.30
[c]Determined chemical fractions (%)						
Crude fat (%)	7.17	10.23	12.57	4.63	7.51	11.62
Dry matter	89.77	89.64	89.26	90.03	90.26	88.27
Crude Protein (%)	20.45	21.72	23.50	17.59	19.30	20.65
Crude fibre (%)	7.80	7.88	7.75	7.75	7.68	7.60
Phosphorus (%)	0.69	0.77	0.76	0.68	0.70	0.69
Calcium (%)	2.15	2.20	2.25	1.88	1.93	1.85

[a]Made up of 2.5% bone meal, 2% oyster shell, 0.25% salt and 0.25% broiler premix, [b]Excluding ₦0.96 being the cost of 200mg Roxazyme®G^{2}G per kg of enzyme-treated diets as at April, 2013, [c]Means of triplicate determinations

starter phase and 7.60-7.75% for the finisher phase. From these basal diets, were produced six treatment diets labeled A, B, C, D, E and F in 2×3 factorial arrangement in ascending order of ME level with or without enzyme supplementation. Diets B, D and F were supplemented with 200 mg of Roxazyme®G^{2}G kg^{-1} of the diets as per the recommendations of the manufacturer (DSM Nutritional Products Limited, Switzerland) and previous study by Salami and Odunsi[9]. The calorie:protein ratios were maintained at 123 and 140 for broiler starter and finisher phases respectively in accordance with the recommendations of Aduku[13] and Olomu[16].

Experimental protocol: One hundred and forty-four day-old unsexed Obamarshal broiler chickens were procured and divided into six treatment groups of 24 birds per treatment and three replicates per treatment. Treatment diets were allocated in Completely Randomised Design (CRD) to the replicate groups. During the starter and finisher phases, the birds were housed as described by Salami and Odunsi[9]. Routine vaccinations and medications were also carried out as at when due[6,9].

Data collection: Response data were measured by the procedures used by Salami and Odunsi[3,6].

Chemical analysis: Basal diets for the starter and finisher phases were analyzed according to AOAC[17] for dry matter, crude protein, crude fibre, crude fat, calcium and phosphorus.

Statistical analysis: Data were subjected to ANOVA in accordance with 2×3 factorial arrangement comprising 2 levels of Roxazyme®G^{2}G inclusion (0 and 200 mg kg^{-1} diet/energy level) and 3 levels of ME (2600, 2800 and 3000 (kcal kg^{-1} diet) using SAS[18] statistical package. Means were separated with Duncan's Multiple Range Test of the same package at 5% probability level.

RESULTS

At the starter phase, superior ($p<0.05$) growth rate was attained on the 2800 ME (kcal kg^{-1} diet) while the birds on 2600 ME (kcal kg^{-1} diet) had poorer ($p<0.05$) growth rate as reflected in the mean body weight at 28 days of age (Table 2). Feed conversion ratio (FCR) was also depressed in broilers fed 2600 ME (kcal kg^{-1} diet) but it was better ($p<0.05$) for broilers fed higher dietary energy levels. Feed and CF intakes were higher ($p<0.05$) in birds fed 2800 ME diet while calorie intake was better ($p<0.05$) for birds fed on 2800 and 3000 ME (kcal kg^{-1} diets) compared to those on 2600 ME (kcal kg^{-1} diet). Water: feed intake and water intake: weight gain ratios of the order of 2:1 and 4:1 respectively were significantly influenced by dietary energy levels. Daily faecal output increased with dietary energy level.

The main effect of enzyme supplementation (Table 3) showed that body weight, weight gain and feed conversion ratio were positively enhanced in broilers given 200 mg kg^{-1} diet. Other response criteria were not significantly influenced by inclusion of enzyme.

The interaction effects of dietary energy and enzyme inclusion levels on performance of broiler starters are shown in Table 4. Results indicated that broiler starters on 2800 and 3000 ME (kcal kg^{-1} diet) did not benefit from enzyme inclusion while those on 2600 ME (kcal kg^{-1} diet) did. This was reflected in the superior weight gain in the birds fed on diet B in comparison with diet A. In addition, the daily weight gain of broilers fed on diet B was comparable to those fed diets of higher energy levels with or without enzyme. There was no interaction effect on the intakes of fibre and water as well as water intake: feed intake ratio. However, interaction effect was noticeable in the water intake: weight gain ratio, which was wider for diet A. Intakes of protein and calories increased with increasing energy level, while enzyme inclusion numerically ($p>0.05$) decreased faecal output irrespective of energy level.

Table 2: Main effect of varying dietary energy levels on performance indices of broiler starters

	Dietary energy levels (kcal kg^{-1} diet)			
Parameters	2600	2800	3000	±SEM
Body weight at 28days (g b^{-1})	819.51^b	880.86^a	839.91^b	10.19
Daily weight gain (g b^{-1})	27.93^b	30.12^a	28.64^{ab}	0.37
Daily feed intake (g b^{-1})	57.29^{ab}	60.14^a	56.19^b	1.11
Feed conversion ratio	2.06^a	2.00^{ab}	1.96^b	0.04
Protein efficiency ratio	2.29	2.18	2.16	0.07
Daily protein intake (g b^{-1})	12.15	13.83	13.45	0.26
Daily calorie intake (kcal b^{-1})	148.96^b	168.39^a	168.07^a	3.18
Daily crude fibre intake (g b^{-1})	4.54^b	4.81^a	4.45^b	0.09
Daily water intake (mL b^{-1})	125.91	125.57	119.90	10.92
Daily water intake: feed intake	2.20^a	2.05^b	2.15^a	0.03
Daily water intake: weight gain	4.55^a	4.17^b	4.19^b	0.09
Daily faecal output (oven-dried basis) at 26-28 days (g b^{-1})	41.91^b	43.38^{ab}	45.90^a	0.59

^{a,b}Means within the same row bearing identical or no superscript are similar ($p>0.05$) while those with non identical superscripts differ significantly ($p<0.05$)

Table 3: Main effect of enzyme supplementation of 8% crude fibre diets on performance of broiler starters

	Dietary enzyme levels (mg kg^{-1} diet)		
Parameters	0	200	±SEM
Body weight at 28days (g b^{-1})	832.43^{b}	861.09^{a}	8.31
Daily weight gain (g b^{-1})	28.32^{b}	29.34^{a}	0.29
Daily feed intake (g b^{-1})	57.92	57.83	0.91
Feed conversion ratio	2.04^{a}	1.97^{b}	0.03
Protein efficiency ratio	2.23	2.25	0.06
Daily protein intake (g b^{-1})	13.18	13.11	0.21
Daily calorie intake (kcal b^{-1})	161.78	161.83	2.60
Daily crude fibre intake (g b^{-1})	4.63	4.60	0.07
Daily water intake (mL b^{-1})	121.19	123.40	8.92
Daily water intake: feed intake	2.15	2.13	0.03
Daily water intake: weight gain	4.38	4.20	0.07
Daily faecal output (oven-dried basis) at 26-28 days (g b^{-1})	44.57	42.88	0.36

^{a,b}Means within the same row bearing identical or no superscript are similar (p>0.05) while those with non-identical superscripts differ significantly (p<0.05)

Table 4: Interaction effects of varying levels of dietary energy with enzyme supplementation of 8% crude fibre diets on performance parameters of broiler starters

	2600 ME (kcal kg^{-1} diet)		2800 ME (kcal kg^{-1} diet)		3000 ME (kcal kg^{-1} diet)		
Parameters	A	B	C	D	E	F	±SEM
Body weight at 28 days (g b^{-1})	798.58^{d}	840.45^{b}	878.39^{a}	883.33^{a}	820.33^{c}	859.50^{ab}	14.39
Daily weight gain (g b^{-1})	27.16^{c}	28.61^{abc}	30.03^{a}	30.20^{a}	27.97^{c}	29.36^{ab}	0.52
Daily feed intake (g b^{-1})	56.37^{b}	58.21^{ab}	61.88^{a}	58.40^{ab}	55.50^{b}	56.88^{ab}	1.57
Feed conversion ratio	2.08^{a}	2.03^{ab}	2.06^{ab}	1.93^{b}	1.98^{ab}	1.94^{b}	0.05
Protein efficiency ratio	2.47^{a}	2.34^{ab}	2.11^{b}	2.25^{ab}	2.10^{b}	2.15^{ab}	0.10
Daily protein intake (g b^{-1})	11.99^{c}	12.26^{bc}	14.23^{a}	13.43^{ab}	13.32^{a}	13.65^{a}	0.37
Daily calorie intake (kcal b^{-1})	146.57^{c}	151.34^{c}	173.27^{a}	163.27^{ab}	165.50^{a}	170.64^{a}	4.50
Daily crude fibre intake (g b^{-1})	4.51	4.57	4.95	4.64	4.44	4.55	0.12
Daily water intake (mL b^{-1})	124.27	127.55	129.84	121.30	118.46	121.34	15.44
Daily water intake: feed intake	2.20	2.20	2.10	2.07	2.14	2.13	0.04
Daily water intake: weight gain	4.58^{a}	4.45^{ab}	4.33^{bc}	4.01^{c}	4.25^{bc}	4.14^{bc}	0.13
Daily faecal output (oven-dried basis) at 26-28 days (g b^{-1})	42.65^{bc}	41.17^{c}	43.63^{bc}	42.12^{bc}	47.43^{a}	44.36^{ab}	0.89
Cost of production:							
[1]Cost of feed (N kg^{-1})	61.62	62.58	67.85	68.81	74.03	74.99	-
[2]Feed cost kg^{-1} weight gain (₦)	128.16^{c}	127.03^{c}	139.77^{ab}	132.80^{bc}	146.68^{a}	145.48^{a}	2.45

$^{a-d}$Means within the same row bearing identical or no superscript are similar (p>0.05) while those with unidentical superscripts differ significantly (p<0.05), [1]Computed from Table 1, [2]Obtained as product of feed conversion ratio and cost per kg diet and 1 US dollar = ₦160 as at April, 2013 (source: CBN), Diets B, D and F were treated with 200 mg Roxazyme®G[2]G per kg diet while diets A, C and E were untreated

The main effects of energy levels and enzyme inclusion on performance of broiler finishers are shown in Table 5 and 6 respectively. Birds fed 3000 ME (kcal kg^{-1} diet) had lower (p<0.05) feed intake, water intake and protein efficiency ratio compared to those fed 2600 or 2800 ME levels. Faecal output, calorie and protein intakes recorded higher (p<0.05) values in broilers fed 3000 ME (kcal/kg diet) compared to those fed on 2600 ME (kcal kg^{-1} diet). Dietary energy levels had no significant effects on daily weight gain, feed conversion ratio, fibre intake, water: feed intake ratio and water intake: weight gain ratio. Inclusion of enzyme at 200 mg kg^{-1} diet improved feed conversion ratio (Table 6) but reduced (p<0.05) calorie intake and faecal output of broiler finishers. Mean body weight of the birds at 56 days of age, weight gain, feed intake, PER and the intakes of fibre, protein or water were comparable (p>0.05) on the enzyme-supplemented and un-supplemented diets.

The interaction effect of dietary energy and enzyme inclusion (Table 7) revealed that birds fed 2600 ME (kcal kg^{-1}) +enzyme (diet B) had comparable (p>0.05) daily weight gain, FCR and PER as diets C, D, E and F (with or without enzyme). Interaction effect of energy and enzyme levels did not significantly affect fibre intake as well as water intake: feed intake and water intake: weight gain ratios. However, intakes of calorie and protein were higher (p<0.05) in the birds fed 3000 ME (kcal kg^{-1}) diet as compared with birds fed 2600ME (kcal kg^{-1}) diet. Feed cost per kg diet increased as energy and enzyme levels increased in the starter (Table 4) and finisher phases (Table 7). The feed cost per kg weight gain was significantly and numerically the cheapest (₦127.03 and ₦174.3 in the starter and finisher phases respectively) on 2600 ME (kcal kg^{-1} diet) containing 200 mg of enzyme per kg diet.

Table 5: Main effects of varying levels of dietary energy of 8% crude fibre diets on performance parameters of broiler finishers

	Dietary enzyme levels (mg kg^{-1} diet)			
Parameters	2600	2800	3000	±SEM
Initial body weight at 28 days (g b^{-1})	819.89^{b}	881.24^{a}	840.54^{b}	10.19
Body weight at 56days (kg b^{-1})	2.14^{b}	2.35^{a}	2.24^{ab}	0.06
Daily weight gain (g b^{-1})	50.50	53.65	51.23	1.63
Daily feed intake (g b^{-1})	153.70^{a}	152.18^{ab}	147.97^{b}	2.07
Feed conversion ratio	3.06	2.85	2.90	0.08
Protein efficiency ratio	1.76^{a}	1.81^{a}	1.58^{b}	0.05
Daily protein intake (g b^{-1})	29.21^{b}	30.43^{b}	32.56^{a}	0.42
Daily calorie intake (kcal b^{-1})	399.62^{b}	426.10^{a}	430.42^{a}	0.16
Daily crude fibre intake (g b^{-1})	12.30	12.17	11.84	6.04
Daily water intake (mL b^{-1})	341.29^{a}	341.78^{a}	330.24^{b}	1.98
Daily water intake: feed intake	2.23	2.25	2.34	0.04
Daily water intake: weight gain	6.78	6.40	6.49	0.22
Daily faecal output (oven-dried basis) at 46-48 days (g b^{-1})	78.15^{b}	86.71^{a}	82.36^{ab}	2.15

^{a,b}Means within the same row bearing identical or no superscript are similar (p>0.05) while those with unidentical superscripts differ significantly (p<0.05)

Table 6: Main effects of enzyme supplementation of 8% crude fibre diets on performance parameters of broiler finishers

	Dietary enzyme levels (mg kg^{-1} diet)		
Parameters	0	200	±SEM
Initial body weight at 28 days (g b^{-1})	832.85^{b}	861.59^{a}	8.31
Body weight at 56 days (kg b^{-1})	2.26	2.22	0.05
Daily weight gain (g b^{-1})	52.20	51.39	1.33
Daily feed intake (g b^{-1})	153.03	149.53	1.55
Feed conversion ratio	2.96^{a}	2.91^{b}	0.07
Protein efficiency ratio	1.71	1.71	0.04
Daily protein intake (g b^{-1})	31.13	30.33	0.34
Daily calorie intake (kcal b^{-1})	428.71^{a}	417.71^{b}	0.14
Daily crude fibre intake (g b^{-1})	12.24	11.96	4.93
Daily water intake (mL b^{-1})	337.34	338.19	3.04
Daily water intake: feed intake	2.21	2.27	0.03
Daily water intake: weight gain	6.52	6.59	0.18
Daily faecal output (oven-dried basis) at 46-48 days (g b^{-1})	84.86^{a}	79.95^{b}	1.89

^{a,b,}Means within the same row bearing identical or no superscript are similar (p>0.05) while those with unidentical superscripts differ significantly (p<0.05)

Table 7: Interaction effects of varying levels of dietary energy and enzyme supplementation of 8% crude fibre diets on performance parameters of broiler finishers

	2600 ME (kcal kg^{-1} diet)		2800 ME (kcal kg^{-1} diet)		3000 ME (kcal kg^{-1} diet)		
Parameters	A	B	C	D	E	F	± SEM
Initial body weight at 28 days (g b^{-1})	798.58^{d}	841.20^{b}	878.89^{a}	883.58^{a}	821.08^{c}	860.00^{ab}	14.39
Body weight at 56 days (kg b^{-1})	2.12^{c}	2.15^{bc}	2.39^{a}	2.30^{ab}	2.26^{abc}	2.22^{abc}	0.09
Daily weight gain (g b^{-1})	48.74^{b}	52.26^{ab}	55.28^{a}	52.02^{ab}	52.58^{ab}	49.88^{b}	2.31
Daily feed intake (g b^{-1})	151.09^{ab}	156.31^{a}	153.57^{ab}	150.79^{b}	154.44^{a}	141.50^{c}	2.92
Feed conversion ratio	3.11^{a}	3.00^{ab}	2.79^{b}	2.90^{ab}	2.97^{ab}	2.83^{ab}	0.11
Protein efficiency ratio	1.70^{ab}	1.81^{a}	1.88^{a}	1.73^{a}	1.55^{b}	1.60^{ab}	0.07
Daily protein intake (g b^{-1})	28.71^{b}	29.70^{ab}	30.71^{ab}	30.15^{ab}	33.98^{a}	31.13^{a}	0.59
Daily calorie intake (kcal b^{-1})	392.83^{d}	406.41^{cd}	429.99^{b}	422.20^{bc}	463.32^{a}	424.51^{b}	0.23
Daily crude fibre intake (g b^{-1})	12.09	12.51	12.28	12.06	12.35	11.32	8.54
Daily water intake (mL b^{-1})	337.72^{ab}	344.85^{a}	343.75^{a}	339.81^{ab}	330.56^{b}	329.92^{b}	5.28
Daily water intake: feed intake	2.24	2.21	2.24	2.26	2.14	2.33	0.06
Daily water intake: weight gain	6.95	6.61	6.25	6.55	6.35	6.62	0.31
Daily faecal output (oven-dried basis) at 46-48 days (g b^{-1})	76.73^{c}	79.56^{bc}	92.78^{a}	80.64^{bc}	85.06^{ab}	79.65^{bc}	3.01
Cost of production:							
[1]Cost of feed (₦ kg^{-1})	57.13	58.09	63.63	64.59	69.81	70.77	-
[2]Feed cost kg^{-1} weight gain(₦)	177.68^{bc}	174.27 ^{c}	177.53^{bc}	187.31^{b}	207.34^{a}	200.23^{a}	3.16

^{a,b,c,d}Means within the same row bearing identical or no superscript are similar (p>0.05) while those with unidentical superscripts differ significantly (p<0.05), [1]Computed from Table1, [2]Obtained as product of feed conversion ratio and cost per kg diet and 1 US dollar = ₦160 as at April, 2013 (source: CBN), A-F denote treatment diets as described in Table 4

DISCUSSION

This study was designed to revisit the previous studies by Salami and Odunsi[3,6,9] in order to re-examine the performance of broiler chickens fed on about 8% CF diets at three energy levels with or without enzyme inclusion. Hence, ca 8% CF diets of similar formulation and chemical composition to the ones fed in the previous studies were applied. The determined chemical profile of the treatment diets with or without enzyme was in close agreement with the nutritional specifications for the broiler chickens at both phases[13,16].

At the starter phase, growth rate and FCR were poorer on 2600 ME (kcal kg^{-1}) diet, indicating a restriction in calorie and protein intakes which caused poor growth[3]. However, daily weight gain (DWG) and FCR were better on 2800 and 3000 ME (kcal kg^{-1} diets) to confirm that high energy is essential for optimum growth rate as earlier reported by Salami and Odunsi[3]. Similar CF level and calorie: protein ratio in the starter diets accounted for the similar values of PER, protein and water intakes and for inconsistent values of feed intake, crude fibre intake, faecal output, water intake:feed intake ratio and water intake:weight gain ratio[3].

Broilers fed diet supplemented with enzyme showed better weight gain and FCR than those fed unsupplemented diet but PER was similar for birds fed on both diets[9]. However, intakes of feed, water, crude fibre and protein, water intake: feed intake and water intake: weight gain ratios of the birds were not affected by enzyme supplementation since *ca* 8% CF level was within their tolerance limit as against the commonly recommended tolerance limit of 3-5%[13,14,19].

Interaction effect of energy and enzyme levels showed that birds fed 2800 and 3000 ME (kcal kg^{-1}) diets did not benefit from enzyme treatment since there was no significant difference in the response criteria of the birds. The birds grew optimally on both diets without supplemental enzyme to suggest adequacy of the energy levels as previously observed by Salami and Odunsi[3,6]. This finding is concordant with the earlier reports of Acamovic[10], Khattak *et al.*[11] and Altaf-ur-Rahman[12]. However, birds fed 2600 ME (kcal kg^{-1}) diet with enzyme (i.e. diet B) recorded better growth indices than those on same energy level without enzyme and it accords with the observation of Salami and Odunsi[9]. In the starter phase, DWG ranged from 28-30 g b^{-1} for all diets except diet A which was poorer as confirmed by wider water intake: weight gain ratio[9]. Narrower water intake: weight gain ratio for diets B, C, D, E and F showed similar and superior DWG by the birds; this result is in agreement with the previous studies by Ani and Omeje[7], Bawa *et al.*[8] and Oldale and Hoffman[20]. Expectedly, consumption of CF but not calorie by the birds was uniform across treatment diets. This was reflected in the similar values of water intake, which gave comparable water intake: feed intake ratio of 2:1[9], indicating that voluntary water intake was a function of dietary CF content.

On the basis of the optimum growth performance of the broiler starters, diets B, C, D, E and F were nutritionally adequate for raising the birds. However, it was economically cheaper to raise birds on diet B at minimal feed cost per kg weight gain. This confirms the potential of exogenous enzyme in improving poor quality diets as well as reducing cost of feeding borne by farmers[9,21,22].

Unlike in the starter phase, the growth rate of the broiler finishers was similar across the energy levels. Growth rate was also not affected by enzyme treatment except the birds fed on 2600 ME (kcal kg^{-1} diet) without enzyme as confirmed by the interaction effect. The daily growth rates recorded for all test diets except diet A ranged from 50-55 g b^{-1}. These values are comparable with those reported by authors in their respective reports by Ani and Omeje[7], Bawa *et al.*[8] and Lawal *et al.*[23]. The values of other response criteria for all diets except diet A (2600 ME (kcal kg^{-1}) diet without enzyme) also confirmed that these diets were nutritionally adequate to sustain optimum growth performance. This result was partly attributed to the better development of the gut in the broiler finishers in coping with the challenge of lower dietary energy concentration through increased feed intake[9]. It also showed the beneficial effect of exogenous enzymes in upgrading the nutritional value of low-energy diets such as the 2600 ME (kcal kg^{-1}) diet[9,22,24,25]. The reduced feed and water consumption of the broiler finishers fed 3000 ME (kcal kg^{-1}) diet in comparison with 2600 and 2800 ME (kcal kg^{-1}) diets was at variance with the earlier study by Salami and Odunsi[6]. It might be caused by chance variation. However, the higher intake of calorie and protein by the birds receiving 3000 ME (kcal kg^{-1} diet) as compared with 2600 ME (kcal kg^{-1} diet) was in line with the previous report by Salami and Odunsi[6]. As in the earlier reports by Salami and Odunsi[3,6,9], there was no adverse effect of the treatment diets on the health status of the birds since mortality rate did not exceed 5% (data not presented).

Nutritionally, all the experimental diets except diet A were equally adequate to sustain optimum biologic performance in broiler starters and finishers[3,6]. However, it is economically cheaper to raise broiler chickens on diet B with supplemental enzyme which accords with the beneficial effects of exogenous enzymes as previously reported[8,10,20]. Diets containing 2800 and 3000 ME (kcal kg^{-1}) with *ca* 8% CF were also suitable for feeding broiler starters and finishers without enzyme but at higher cost, indicating that dietary energy level is the most costly component of feed.

CONCLUSIONS AND RECOMMENDATION

Broilers at starting and finishing phases could tolerate ca 8% CF diet at the sub optimal and optimal ME levels with and without supplemental enzyme respectively. This is an indication for caution in the application of exogenous enzymes. Growth depressant effect of dietary ME at 2600 kcal kg^{-1} indicated that this energy level is not adequate to meet the energy requirement of broiler chickens unless it is treated with enzyme. Roxazyme®G^2G-supplemented 8% CF diet at 2600 ME (kcal kg^{-1}) could be used to raise broiler chickens during the starter and finisher phases. This diet was nutritionally adequate and also economically cheaper than other nutritionally adequate but costlier diets.

SIGNIFICANCE STATEMENT

This study showed that broiler chickens could tolerate up to about 8% CF (which is beyond the commonly recommended 3-5% dietary CF level) in enzyme-treated 2600 ME (kcal kg^{-1}) diet and untreated 2800 and 3000 ME (kcal kg^{-1}) diets. The finding assists to relate the CF tolerance limit of broiler chickens to dietary ME level with or without enzyme inclusion. It also eliminates abuse in the indiscriminate use of exogenous enzymes in broiler chicken diets. Thus, a new theory on dietary CF-energy relationship with or without enzyme for optimum performance may be arrived at.

ACKNOWLEDGMENT

Authors are indebted to TETFUND (Nigeria) for the provision of grant in support of this research.

REFERENCES

1. Choct, M., 2001. Carbohydrate and fibre digestion in monogastric animals. ASA Technical Bulletin AN34-2001, American Soybean Association, Singapore, pp: 1-10.
2. Hetland, H., M. Choct and B. Svihus, 2004. Role of insoluble non-starch polysaccharides in poultry nutrition. World's Poult. Sci. J., 60: 415-422.
3. Salami, R.I. and A.A. Odunsi, 2017. Growth performance of broiler starter chickens fed varying levels of fibre and energy in multi-fibre source-based diets. Niger. J. Anim. Sci., 19: 83-93.
4. Lee, J.J., N. Sally, R. Antonio and S. Jerry, 2003. Feeding by-products high in concentration of fibre to non-ruminants. Proceedings of the 3rd National Symposium on Alternative Feeds for Livestock and Poultry, November, 4-5, 2003, Kansas City, MO., USA.
5. Sundu, B., A. Kumar and J. Dingle, 2006. Palm kernel meal in broiler diets: Effect on chicken performance and health. World's Poult. Sci. J., 62: 316-325.
6. Salami, R.I. and A.A. Odunsi, 2017. Effect of varying dietary fibre and energy levels in multi-fibre source-based diets on growth performance of broiler finisher chickens. Niger. J. Anim. Sci., 19: 72-82.
7. Ani, A.O. and O.D. Omeje, 2007. Response of broiler finishers to graded levels of raw bambara nut (*Vigna subterranea* (L) Verdc) waste and supplementary enzyme. Trop. J. Anim. Sci., 10: 281-288.
8. Bawa, G.S., L.A. Alayande and S.O. Ogundipe, 2012. Effect of Maxigrain® supplementation on the utilization of brewers dried grain and maize offal based diets for broiler chickens. Niger. J. Anim. Sci., 12: 29-40.
9. Salami, R.I. and A.A. Odunsi, 2018. Crude fibre versus Roxazyme® G^2G inclusion levels in sub optimum energy diets for broiler chickens: Performance and carcass characteristics at 8 weeks of age. Int. J. Agric. Biosci., 7: 36-42.
10. Acamovic, T., 2001. Commercial application of enzyme technology for poultry production. Word's Poult. Sci. J., 57: 225-242.
11. Khattak, F.M., T.N. Pasha, Z. Hayat and A. Mahmud, 2006. Enzymes in poultry nutrition. J. Anim. Plant Sci., 16: 1-7.
12. Altaf-ur-Rahman, M. Ali, S. Sultan and N. Ahmad, 2007. Economic importance of exogenous enzymes in broiler rations. Sarhad J. Agric., 23: 489-492.
13. Aduku, A.O., 2004. Feed ingredient and diet composition tables for the tropics. Davcon Computers and Business Bureau, Kaduna, Nigeria.
14. NRC., 1994. Nutrient Requirement of Poultry. 9th Rev. Edn., National Academy Press, Washington, DC., USA., ISBN-13: 978-0-309-04892-7, Pages: 176.
15. Iwena, O.A., 2012. Essential Geography for Senior Secondary Schools. 6th Edn., Tonad Publishers Limited, Lagos, Nigeria.
16. Olomu, J.M., 1995. Monogastric Animal Nutrition: Principles and Practice. Jachem Publication, Benin, pp: 67-99.
17. AOAC., 2000. Official Methods of Analysis. 17th Edn., Association of Official Analytical Chemist, Washington, DC., USA.
18. SAS., 2000. SAS User's Guide. SAS Institute Inc., Cary, NC., USA.
19. BIS., 1992. Requirement for chicken feeds. IS 1374: 1992, Bureau of Indian Standards, New Delhi, India.

20. Oldale, P.M.D. and F. Hoffman, 1996. Enzymes-a tool for unlocking nutrients in animal feed. Roche Nigeria Seminar, Sheraton Lagos Hotel, Nigeria.
21. Aguihe, P.C., A.S. Kehinde and E.A. Iyayi, 2015. Effect of enzyme (Maxigrain®) supplementation on performance characteristics and nutrient digestibility of growing Japanese quails (*Cortunix cortunix japonica*) fed diets containing yam peel meal. Niger. J. Anim. Sci., 17: 65-74.
22. Rambabu, D., V.R. Reddy, V.K. Reddy and G.V.B. Reddy, 2016. Efficacy of fibre degrading and proteolytic enzymes supplemented high fibre diets on performance of broilers. Int. J. Sci. Environ. Technol., 5: 2972-2981.
23. Lawal, T.E., E.A. Iyayi, B.A. Adeniyi, O.A. Adaramoye, F.A. Aderemi and O.M. Alabi, 2007. Growth responses and relative organ weight of Broilers fed biodegraded cassava root sievate. Trop. J. Anim. Sci., 10: 77-81.
24. Iyayi, E.A. and B.A. Yahaya, 1999. Performance of broiler maintained on diets supplemented with commercial polysaccharide enzyme in the humid tropics. Trop. Anim. Prod. Invest., 2: 125-130.
25. Agbede, J.O., K. Ajaja and V.A Aletor, 2002. Influence of *Roxazyme* G. supplementation on the utilization of sorghum dust-based diets for broiler-chicks. Proceedings of the 27th Annual Conference Nigerian Society for Animal Production, March 17-21, 2002, Federal University of Technology, Akure, Nigeria, pp: 105-108.