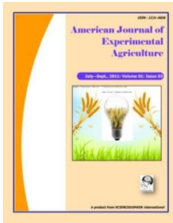

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Performance, Immune Response and Carcass Characteristics of Broilers Fed with Low Crude Protein and Ideal Methionine to Lysine Ratio Diets

S. M. Ogunbode[1*], A. A. Owoade[2] and E. A. Iyayi[3]

[1]Nutritional Biochemistry Research Laboratory, Biochemistry and Nutrition Unit, Department of Chemical Sciences, Fountain University, Osogbo, Nigeria.
[2]Department of Veterinary Medicine, University of Ibadan, Ibadan, Nigeria.
[3]Department of Animal Science, University of Ibadan, Ibadan Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author SMO wrote the protocol and the first draft of the manuscript. Authors SMO, AAO and EAI managed the analyses of the study. Author EAI designed the study. Author SMO managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The study was carried out to study the effect of supplementing low crude protein (CP) diet with ideal methionine to lysine ratio (IMLR) on the performance, carcass characteristics and immune response against Infectious Bursa Disease (IBD) and Newcastle Disease (ND) viruses in broilers.

Ten Diets Were Formulated: Diet 1 (control diet) contained 23% CP and IMLR of 47%. The remaining 9 test diets were formulated to contain 20, 17 and 14% CP each with 47, 52 and 57% IMLR in a 3x3 factorial arrangement.

The experiment was carried out at the pullet unit of the Teaching and Research Farm of the Department of Animal Science, Department of Veterinary Medicine, all at University of Ibadan, Ibadan Nigeria, between February and March 2011.

Day-old broiler chicks (160) were wing branded, weighed and randomly allocated into the 10 diets with four replicates of four birds each. The chicks were vaccinated against IBD virus on d 10 and against ND virus on d 16 posthatch via drinking water.

Results revealed that the feed intake (FI) in the control and in the 20% CP/47% IMLR (60.27g/b, 57.81g/b) diets were similar. Feed conversion ratio (FCR) in the control and in

**Corresponding author: Email: Nigeria.aowoade43@gmail.com, eaiyayi@yahoo.com;*

the 20% CP/47% IMLR (2.65, 2.70) diets were also similar. Breast's weights in the control and in the 20% CP/52% IMLR diets (148.75, 150.75) were similar. Birds on 17% CP with 52% IMLR (19,637 antibody titre) had the best immune response against IBD virus, while birds on 20% CP with 47% IMLR (1442 antibody titre) diet had the best immune response against ND virus.

Results suggest that diets of CP less than 23% with 47 and 52% IMLR for broilers resulted in similar performance as control diet and the bird's immune response against IBD and ND virus were not compromised.

Keywords: Immune response; ideal methionine to lysine ratio; performance; antibodies; carcass characteristics.

1. INTRODUCTION

Nutrition is a critical determinant of immune responses and malnutrition is the most common cause of immunodeficiency worldwide. Nutrients can influence the maturity of the immune system [1,2]. Nutritional strategy aimed at reducing the crude protein requirement of broilers involves the partial replacement of intact protein (e.g., soybean meal) with crystalline free amino acids, by which excess dietary amino acids are minimized in relation to their requirements, bringing the dietary protein closer to ideal protein and in turn decreasing the dietary CP content. The quality of dietary protein is an essential factor, which influences the synthesis of immunoglobulins and their functions. Protein-energy malnutrition is associated with a significant impairment of cell-mediated immunity, phagocytic function, complement system, secretory immunoglobulin A, antibody concentration, and cytokine production [3]. Protein deficiency inhibited antibody production and the development of antibody producing cells in response to T-dependent antigens [4]. An unbalanced amino acid composition may, apart from impaired production, also jeopardize animal health and welfare through negative effects on immune response [5,6,7]. The development of amino acid supplementation allows meeting the essential amino acid needs at low protein levels [8]. An ideal protein and amino acid profile in a feed means that the essential and non-essential amino acid levels exactly provide the requirements of the bird leaving no extra amino acid nitrogen for elimination. It provides a blend of indispensable amino acids that exactly meets an animal's requirement for protein accretion and maintenance, with no deficiencies and no excesses. The application of the ideal protein concept, in which part of amino acids from the diet is substituted by crystalline amino acids, improves the capacity of the birds to retain more nitrogen and potassium due to reduction of soybean meal in the diets. Several works have proven the benefits of this technique [9]. With the availability of some amino acids produced in commercial scale, it is possible to elaborate reduced-crude protein diets for birds. The metabolic systems of the birds fed ideal protein and amino acid diets are not working as hard to eliminate the excess nitrogen which thus keeps them cooler providing more useable energy for productive purposes. The ideal concept uses lysine as a reference amino acid, with the requirements for all other indispensable amino acids expressed as a percentage to lysine because it is used almost exclusively for protein accretion. Lysine is a limiting amino acid in reduced protein corn-soybean meal broiler diets [10]. It is an established fact that amino acids, especially in excess of NRC recommendation are needed for optimal immune performance. It has been suggested by [11] that the requirement for methionine for maximum antibody titers was greater than that for growth; this means that the IgG levels did increase in birds fed increasing percent of methionine. Lysine has also been reported by [12,13] as one of the amino acids which can influence the magnitude of antibody response. Information on the exact requirement of Ideal Methionine to Lysine Ratio needed for optimal immune response of broilers is still scanty. The objective of this study was therefore to determine the effect of supplementation of ideal methionine to lysine ratio to graded CP levels on performance, carcass measures and immune response to infectious bursal disease (IBD) and Newcastle disease (ND) viruses in broilers.

2. METHODOLOGY

2.1 Diets and Animals

Ten diets were formulated: diet 1 (control diet) contained 23% CP and 47% IMLR. The nine other experimental diets consisted of 20, 17 and 14% CP each with 47, 52 and 57% IMLR. The composition of diets for the Experiment is shown in Table 1. The calculated nutrients in the diets are shown in Table 2. One hundred and sixty 1-day-old broiler chicks (Arbor Acre strain, CHI Ltd, Ajanla Farms, Ibadan) were wing-banded, weighed (blocked by weight) and randomly allotted to 40 pens of 4 replicates with 4 birds per replicate after a week of group brooding. A group of 4 pens was fed any of the 10 experimental diets in a factorial arrangement (4 levels of CP and 3 levels of methionine). The birds were housed in a well illuminated and ventilated poultry house. Feed and water were provided ad libitum. The chicks were vaccinated against Infectious Bursal Disease (IBD) virus on d 10 and against ND virus on d 16 posthatch via drinking water. The broilers' maternal antibody against ND were monitored weekly and when it subsided at day 16, they were given the first lasota against routine practice of vaccinating broilers at day old against the disease because vaccinating broilers at day-old against a disease when the maternal antibody is still high will only result in neutralization of the given vaccine, and the birds will not be able to build antibody against such disease but will rather fall victim of such. The birds were fed the diets till day 35.

2.2 Sample Collection, Antibody Determination, Carcass Measures and Chemical Analysis

The proximate composition of the diets was determined according to the methods of AOAC, [14]. Blood samples were collected from two chicks per pen through the jugular vein at weekly interval pre and post vaccination for the period of the study. Serum was separated by centrifugation (8000 revolution per minute for 5 minutes) and antibodies specific for IBD was detected in the sera using an ELISA kit (ProFLOK^{R}, Synbiotics Corporation, CA, USA) according to manufacturer's instructions. One hundred microliters of each sample were used for the assay. Absorbance was measured at 405nm using an ELISA reader (SUNRISE Absorbance Reader, TECAN) by standard procedures, (Snyder et al.) [15]. Antibodies specific for ND virus was also determined in the sera of the chicks, using haemaglutination inhibition method as described by [16], so as to monitor the effect of the experimental diets on the immune responses of the birds. The antigen used was a reconstituted commercial NDV lasota vaccine (Bestar Vaccine, Nigeria). In brief: 5ml of blood was collected aseptically from each bird into a disposable syringe containing 1ml of sodium citrate (4% solution) as an anticoagulant. The blood was centrifuged at 1500 rpm for 15minutes and the plasma and buffy coat was pipetted off. After washing thrice with phosphate buffer saline (PBS), 1% suspension of the supernatant in PBS was used in HI test. 50µl of each serum sample diluted in 100µl of NDV antigen (10HA) was placed in the first column of 96-well plates. The rest of the wells in the plate contained 50µl of NDV antigen. A two-fold serial dilution followed by passing 50µl from one column to the next and to the end of the plate. Then, 50µl of prepared 0.5% chicken red blood cells were added into each well and allowed to incubate for 45 min at room temperature before haemaglutination inhibition activity was observed. The HI titer was recorded as the well with the highest serum dilution where a clear button was observed. For carcass measure, two birds per replicate were randomly selected, weighed, sacrificed by asphyxiation using CO_2 gas and then defeathered using moderately warm water. Carcass parts were weighed and their weights expressed as percent of body weight to determine the effect of the experimental diets on the cut parts.

2.3 Statistical Analysis

Data were analysed by the two-way analysis of variance procedure appropriate for completely randomized design with a factorial arrangement using the General Linear Models (GLM) procedure of SAS [17]. Means were further separated using Duncan Multiple Range test.

3. RESULTS AND DISCUSSION

Gross composition (g/100gmDM) of experimental diets used for the study is as presented in Table 1.

The crude protein level in the diets was between 14.22 to 23.10% while the crude fibre was between 3.0 to 6.0% as shown in the proximate compositions of experimental diets (Table 2).

With the availability of some amino acids produced on commercial scale, it is possible to feed reduced-crude protein diets to birds when such diets are supplemented with crystalline amino acid. A diet based on ideal protein is established by selecting a reference amino acid, and every other amino acid will be expressed in terms of the selected reference amino acid. Lysine was standardized as the reference amino acid since it can be easily evaluated and is available in crystalline form. Besides, lysine has been previously described in studies and has great importance in protein synthesis. The proportion of lysine to all other EAA is of great concern for optimal performance of broilers [18].

The results of effect of treatments on performance of the birds showed that the final weights of birds on 23 and 20% CP (931.25 and 890.63, respectively) each with 47% IMLR were similar (Table 3). Statistically, birds on 52% IMLR with 20% CP had the best FCR of 2.49. There was a significant ($P<0.05$) reduction in the body weight of birds as the level of CP was reduced to 14% irrespective of the IMLR. Birds on 52% IMLR with 20% CP had the best FCR of 2.49 (Table 3). This result is supported by the earlier report of [19] who observed an improvement in the feed conversion ratio of birds fed diets with CP contents reduced from 23 to 19% and supplemented with essential amino acids in hot summer months.

The results of the effect of IMLR, CP, and their interactions on final weight, weight gain, feed intake and feed conversion ratio showed that the IMLR had no significant effect on final weight and weight gain but there was a significant (P=.05) effect of IMLR on feed intake and feed conversion ratio (FCR), with birds on 52% IMLR having the best FCR of 2.78 (Table 4).

Table 1. Gross composition (g/100gm) of experimental diets

IMLR (%)*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	47	**47**	**52**	**57**	**47**	**52**	**57**	**47**	**52**	**57**
Crude protein (g/100g)	**23**	**20**	**20**	**20**	**17**	**17**	**17**	**14**	**14**	**14**
Corn	41.5	45.5	45.5	45.5	50.00	50.00	50.00	53.00	53.00	53.00
Soybean meal	23.00	15.00	15.00	15.00	9.5	9.5	9.5	4.6	4.6	4.6
Groundnut cake	8.00	8.00	8.00	8.00	5.0	5.0	5.0	3.0	3.0	3.0
Fishmeal	3.50	3.50	3.50	3.50	2.50	2.50	2.50	2.0	2.0	2.0
Methionine	0.25	0.19	0.24	0.30	0.14	0.19	0.23	0.10	0.14	0.18
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Palm Kernel Cake	7.00	10.00	10.00	10.00	10.00	10.00	10.00	6.00	6.00	6.00
Brewers Dry Grain	6.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.00
Rice bran	5.0	5.0	5.0	5.0	10.00	10.00	10.00	20.50	20.50	20.50
Palm oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
*Vitamin mineral premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dicalcium phosphate	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78
Limestone	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

**Ideal Methionine to Lysine Ratio - IMLR, CP-crude protein *Premix supplied the following information kg of diet: Vitamin A (12,500,000 I.U), Vit D3 (2,500,000 I.U), Vit E (40,000mg) Vitamin K3 (2,000mg), Vit B, (3,000mg), Vit B2 (5,500mg), Naicin (55,000mg), calcium panthothenate (11,500mg) Vit B6 (5000mg) Vit B12 (25mg), choline chloride (500, 000mg), folic acid (1,000mg), Biotin (80mg), Mn (120,000,mg), Fe (100,000mg), Zn (80,000mg), Cu (8,500mg), I (1,500mg) Co (300mg), Se (120mg)*

Table 2. Proximate composition (g/100gDM) of experimental diets

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Crude protein	**23**	**20**	**20**	**20**	**17**	**17**	**17**	**14**	**14**	**14**
IMLR *	**47**	**47**	**52**	**57**	**47**	**52**	**57**	**47**	**52**	**57**
Dry matter	93.40	92.22	91.60	93.20	92.23	92.40	91.58	91.20	91.10	91.42
Crude protein	23.10	20.11	20.23	19.97	17.65	17.43	17.53	14.22	14.78	14.75
Ash	10.00	10.12	9.73	9.00	7.00	8.00	7.50	7.00	9.00	8.50
Ether extract	7.00	8.00	8.00	7.50	7.50	7.00	8.00	8.50	8.50	7.50
Crude fibre	3.00	3.00	4.00	4.00	4.50	6.00	4.00	4.50	4.00	5.00
Nitrogen free extract	56.90	58.77	58.04	59.53	63.35	61.57	62.97	65.78	63.72	64.25

**IMLR=Ideal methionine to lysine ratio*

Table 3. Performance of broiler chickens on low crude protein Ideal Methionine to Lysine Ratio (IMLR) supplemented diets (n=4 replicates of 4 birds each)

IMLR (%)*	**Crude protein**	**Initial Weight (g/b)**	**Parameters**			
			Final weight (g/b/35days)	**Weight gain (g/b/day)**	**Feed intake (g/b)**	**Feed Conversion ratio**
47	23	123.3	931.25^{a}	23.08^{a}	60.27^{a}	2.65^{cd}
47	20	133.3	890.63^{a}	21.64^{ab}	57.81^{b}	2.70^{cd}
52	20	119.8	868.75^{ab}	21.40^{abc}	52.90^{d}	2.49^{d}
57	20	116.7	832.29^{abc}	20.45^{abc}	52.68^{d}	2.58^{cd}
47	17	117.9	743.75^{cd}	17.88^{cd}	52.08^{d}	2.97^{cd}
52	17	107.5	781.25^{bc}	19.25^{bc}	52.46^{d}	2.73^{cd}
57	17	113.5	781.25^{bc}	19.08^{bc}	56.69^{c}	2.90^{cd}
47	14	116.7	550.00^{e}	12.38^{e}	43.97^{f}	3.61^{ab}
52	14	117.7	644.79^{de}	15.06^{ed}	46.43^{e}	3.12^{bc}
57	14	114.4	528.13^{e}	11.82^{e}	44.36^{f}	3.77^{a}
SEM**			39.37	1.14	0.36	0.17
P-value			<0.0001	<0.0001	<0.0001	<0.0001

*^{a,b,c,d} Means within same column with different superscripts are significantly different, (P=.05) *IMLR=Ideal methionine lysine ratio*

There was a significant effect (P<0.05) of CP on the performance parameters. But the FCR of birds on 23 and 20% CP (2.65 and 2.59, respectively) were similar. Interaction of CP with IMLR had a significant (P<0.01) effect on feed intake. Final weight, weight gain and feed conversion ratio of birds on 23 and 20% CP levels were not significantly different (Table 4). This result is supported by the earlier report of [20] that reducing dietary protein by 10% had no adverse effect on broiler performance. Furthermore, increase in methionine level by 20% according to [21] could improve broiler performance. Decrease in crude protein level up to 16% with adequate methionine and lysine supplementation as reported by [22] had no deleterious effect on body weight gain of broilers. As reduction in crude protein exceeded 3 units and ideal methionine to lysine ratio inclusion was above 52%, the performance of the birds was reduced. Several studies with broiler chicks [23,24,25,26,27] and growing pigs [28,29] have shown that growth performance and carcass composition of broiler chicks or pigs become inferior to those of broiler chicks or pigs fed standard high CP diets when the dietary CP content is lowered by more than 3 to 4 percentage points.

Table 4. Effect of IMLR*, crude protein and their interaction on performance of broilers on experimental diets (n = 4 replicates of 4 birds each)

Treatment	Final weight (g/b)	Weight gain (g/b)	Feed intake (g/b)	Feed Conversion ratio
IMLR (%)*				
47	778.91	18.75	53.53^{a}	2.98^{ab}
52	764.93	18.57	50.60^{b}	2.78^{b}
57	713.89	17.12	50.58^{b}	3.09^{a}
SEM	39.37	1.14	0.36	0.17
Crude protein (g/100g)				
23	931.25^{a}	23.08^{a}	60.27^{a}	2.65^{b}
20	863.89^{a}	21.16^{a}	54.46^{b}	2.59^{b}
17	768.75^{b}	18.74^{b}	53.08^{c}	2.87^{b}
14	574.31^{c}	13.09^{c}	44.92^{d}	3.50^{a}
SEM**	39.37	1.14	0.36	0.17
Factorial Effect		*P (ANOVA)*		
IMLR	0.2764	0.2514	0.0337	0.0546
CP	<0.0001	<0.0001	<0.0001	<0.0001
IMLR x CP	0.4228	0.5380	<0.001	0.5643

*[a,b,c,d] Means within the column with different superscripts are significantly different (P=.05) *IMLR= Ideal methionine lysine ratio*

The weights of breast of birds on 23% CP with 47% IMLR and 20% CP with 52% IMLR at 148.75 and 150.75 respectively are statistically similar. Also, the weights of drumstick of birds on 23% CP with 47% IMLR and birds on 20% CP each with 52 and 57% IMLR were similar. Results of carcass measures showed that the weights of breast of birds on 23% CP with 47% IMLR and 20% CP with 52% IMLR that is, 148.75 and 150.75 respectively are not significantly different. Also, weights of drumstick of birds on 23% CP with 47% IMLR (90.38g/100g live weight) and birds on 20% CP each with 52 and 57% IMLR (83.63 and 85.25 g/100g live weight, respectively) are statistically similar (Table 5). This is in agreement with the report of [30,31,32] who suggested that levels of lysine and methionine in excess of

[33] recommendations may result in enhanced performance, especially in regards to breast meat yield. Optimal breast tissue accretion in finishing broilers can be obtained by feeding levels of methionine [32,34,35] and lysine [30,31,36,37,38] above suggested recommendations [33]. Lowering the dietary CP level below 20% significantly reduced carcass weight (*P*=.05). The findings of [27] also showed that broilers do not seem to do as well when intact protein is reduced to a greater extent and replaced with crystalline essential amino acids.

Table 5. Effect of dietary treatment on carcass measures (g/100g live weight) in broilers on IMLR experimental diets

IMLR (%)*	Parameters					
	Crude protein	Dressed weight	Breast	Thigh	Liver	drumstick
47	23	539.88^{a}	148.75^{a}	83.88^{a}	24.00^{a}	90.38^{a}
47	20	491.63^{ab}	133.25^{abc}	78.38^{ab}	23.00^{ab}	80.13^{ab}
52	20	501.63^{ab}	150.75^{a}	76.37^{ab}	23.00^{ab}	83.63a
57	20	484.50^{ab}	143.25^{ab}	74.63^{ab}	23.63^{ab}	85.25^{a}
47	17	342.38^{cd}	92.38^{def}	52.00^{c}	14.50^{c}	69.38^{abc}
52	17	404.75^{bc}	113.25^{bcd}	59.63^{bc}	18.00^{bc}	67.38^{abc}
57	17	393.00^{cd}	107.75^{cde}	60.13^{bc}	17.13^{c}	66.25^{abc}
47	14	281.38^{d}	71.50^{cde}	42.88^{c}	13.00^{c}	50.00^{c}
52	14	322.75^{cd}	78.25^{ef}	50.25^{c}	15.38^{c}	56.25^{bc}
57	14	325.50^{cd}	85.63^{def}	50.63^{c}	12.63^{c}	55.75^{bc}
SEM		35.21	10.67	6.04	1.76	7.60
P-value		<0.0001	<0.0001	<0.0001	<0.0001	0.0059

^{a,b,c,d,e} *Means within the column with different superscripts are significantly different, (P=.05)*
**IMLR=Ideal methionine lysine ratio*

The results of antibody titer against IBD virus in broilers on experimental diets showed that there was no significant effect of dietary treatment on antibody titre (Table 6). Numerically, birds on 52% IMLR with 17% CP produced the highest concentration of antibody titre against IBD virus (Fig. 1). Better immune response can still be obtained with adequate supplementation of methionine, which has been identified to be in marginal quantities in poultry feed ingredients. Typical poultry diets in which much of the protein is furnished by soybean meal may contain less than the desired quantity of methionine. In such cases, it is preferable to add methionine rather than to raise the total protein content. Deficiency or excesses of dietary protein or amino acids has previously been said to alter immune response in chickens [5,6]. The results of antibody titer against IBD virus in broilers on experimental diets (Table 6) showed no significant differences at any level of IMLR and CP combinations. This shows that the bird's immune response is not compromised at any level of IMLR (47, 52 and 57%) and CP (23, 20, 17 and 14%). Numerically, birds on 52% IMLR with 17% CP produced the best immune response against IBD virus. This is in line with the work of [39,40] which reported that essential amino acid level in the feed higher than NRC specifications is needed to achieve optimal growth performance, immunocompetence and disease resistance. Also, [11] reported that supplementary methionine, but not choline, optimized the response to phyto-hemagglutinin as well as total antibody response to SRBC a

T-dependent antigen. It has also been stated by [39] that the methionine level to optimize leukocyte migration inhibition assay was also higher than the level to improve growth in broiler chicks.

Table 6. IBD antibody titres of broilers on low CP/IMLR supplemented diets using Enzyme linked immunosorbent assay kit (ELISA)

IMLR (%)*	Crude protein (%)	AT**
47	23	18,891.00
47	20	18,704.00
52	20	16,208.00
57	20	18,868.00
47	17	18,572.00
52	17	19,637.00
57	17	19,466.00
47	14	19,380.00
52	14	19,394.00
57	14	18,951.00
SEM		1305.95
P-value		0.8116

**IMLR=Ideal methionine lysine ratio, **AT=Antibody titre*

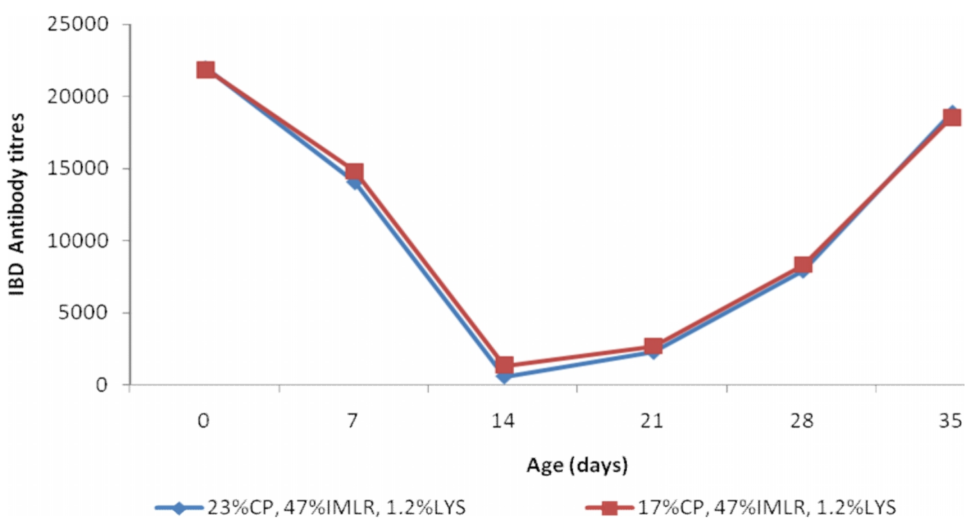

Fig. 1. Infectious bursal disease virus antibody titre in broilers on 23%CP, 47%IMLR with1.2% lysine and 17%CP, 52%IMLR with 1.2% lysine

The results of Antibody titer against ND vaccine in broilers on experimental diets showed that the results though showed a significant (*P*=.005) effect on the antibody titre values, did not follow a definite pattern (Table 7). Statistically, birds on 20% CP and 47%IMLR diet gave the highest antibody titre against Newcastle Disease virus as further depicted in Fig. 2. The result also revealed that second lasota should be given on or before the 12th day of administering the first dose. The results of antibody titer against ND virus in broilers on experimental diets showed that significant differences (*P*=.05) existed in the various level of IMLR (47, 52 and 57%) and CP (23, 20, 17 and 14%) combinations, with birds on 47% IMLR and 20% CP being more significantly different, producing the best immune response against ND virus. It had earlier been reported by [12] that dietary supplementation with methionine or cysteine was beneficial to the immune system in chickens infected with Newcastle virus through T-cell proliferation, IgG secretion, leucocyte migration and antibody titre. This show that even at 47% IMLR, crude protein could still be reduced by as much as three units without compromising the birds' immune response against ND virus.

Table 7. NCD antibody titres of broilers on low CP/IMLR diets using Haemaglutination Inhibition (HI)

IMLR (%)*	Crude protein (%)	AT**
47	23	602.00[ab]
47	20	1442.00[a]
52	20	664.00[ab]
57	20	800.00[ab]
47	17	303.00[b]
52	17	185.00[b]
57	17	271.00[b]
47	14	656.00[ab]
52	14	531.00[ab]
57	14	904.00[ab]
SEM		337.11
P-value		0.3413

[a,b] *Means within the column with different superscripts are significantly different (P=.05) *IMLR=Ideal methionine lysine ratio, **AT=Antibody titre*

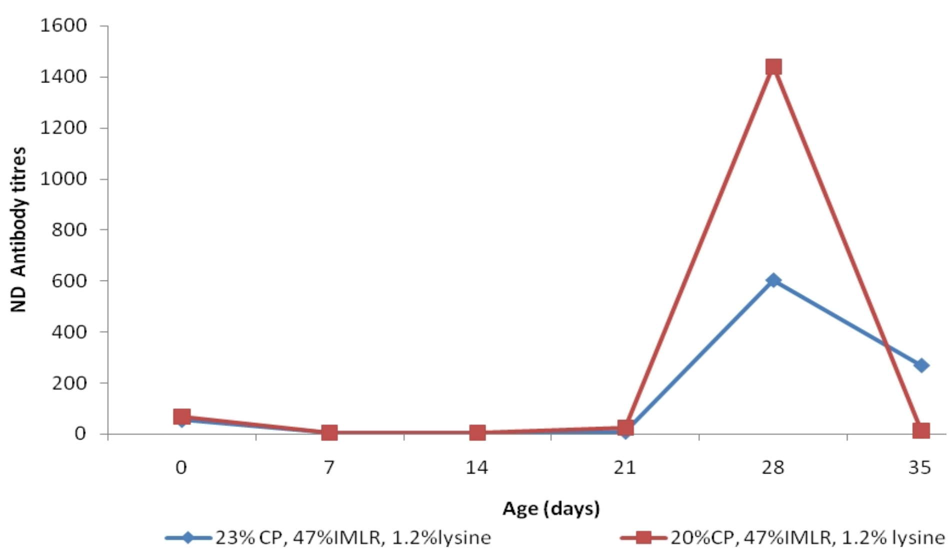

Fig. 2. Newcastle disease virus antibody titre in broilers on 23%CP, 47%IMLR with1.2%lysine and 20%CP, 47%IMLR with1.2% lysine

4. CONCLUSION

A 17% crude protein with 52% IMLR diet produced the best immune response against Infectious Bursal Disease, while a 20% CP with 47% IMLR diet produced the best immune response against Newcastle Disease viruses in broilers.

Increasing ideal methionine to lysine ratio up to 52% with 20% CP enhanced performance of broilers. Decreasing the CP level to 17 and 14% with any level of IMLR combination reduced broiler performance, perhaps due to its imbalance with other amino acids in the diet.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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