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Growth Performance, Blood Profile, and Carcass Characteristics of Weaned Pigs Fed Low Crude Protein Diets Supplemented with Lysine

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ABSTRACT

Supplementing low crude protein (CP) diets for pigs with exogenous amino acid may help improve growth performance, minimize the environmental impact associated with nitrogen loss and improve the sustainability of pork production. A total number of thirty (30) Large white x Landrace weaned pigs between the age of 8-10 weeks and an average weight of 11.5 ± 0.39 kg were used to evaluate the effect of lysine supplementation of a low CP diet on growth performance, blood profile, and carcass characteristics of weaner piglets. Weaned pigs were acclimatized for seven days, randomly allotted to five (5) dietary treatments with six weaners per treatment and fed a weaner diet based on maize-soybean while wheat bran and dried cassava peel were added to balance the diet nutrients. The animals were allocated to either a control diet containing 22.6% CP or a diet with 2.5%, 5.0%, 7.5%, and 10% reduction in diet CP. Each animal consumed the respective diet for six weeks during which growth performance was monitored. Afterward, 5 mL of blood was sampled for analysis, and all the pigs were slaughtered for carcass analysis. Average daily gain, total weight gain, and average daily intake were not significantly different across the groups (p>0.05). While feed cost per kg was lower with the 7.5% and 10% diet CP reduction (p<0.05), feed cost per weight gain was not different across the animals. Most haematological and serum biochemical variables were not affected by CP reduction, while carcass weight was equally not affected by diet CP (p>0.05). However, the abdominal fat percentage of carcass reduced slightly with the reduced diet CP. Therefore, up to 10% reduction in diet CP from 22.6%, with 0.1% lysine supplementation, had no negative impact on growth without compromising the immunity indicators of weaned pigs. Furthermore, there was no negative consequence on carcass characteristics and the primal cuts.

Keywords: lysine; crude protein; feed cost; growth performance; meat quality

INTRODUCTION

Interest in alternative feeding strategies which are cost-effective and environmentally friendly with consistent pork quality is of mutual interest to farmers, environmentalists, researchers, and consumers. One of such strategies is the use of low crude protein diets (Toledo *et al*., 2014). Farmers want to stay in business, increase profit by reducing the cost of production and low CP diets afford them that opportunity (Wang *et al*., 2018). Reducing the environmental footprint of pork production can be achieved through a significant reduction in fecal and urine nitrogen losses by reducing diet CP (Toledo *et al*., 2014). When the AA requirement of the animal is met, excess dietary protein results in higher urea nitrogen excretion in the blood and consequently in urine (Zhang *et al*., 2016). Aside from the nutrient loss, the excretion of excess nitrogenous wastes from pig production increases odor emission from pig production units (Sajeev *et al*., 2018; Wang *et al*., 2018).

Furthermore, diet crude protein could affect carcass characteristics and meat quality that eventually influence consumer preferences (Suárez-Belloch *et al*., 2016). Crude protein restriction resulted in reduced hardness but increased intra-muscular fat (IMF) in finishing pigs which are desirable for dry-cured products (Grunert *et al*. 2004) although, Kumar (2021) noted that most consumers consider fat in meat is unhealthy. Nevertheless, Zhou *et al*. (2015) and Suárez-Belloch *et al*. (2016) demonstrated that intramuscular fat and carcass dressing percentage are not affected by the reduced dietary CP. Furthermore, Morazán *et al*. (2015) observed the increased back-fat thickness and reduced loin muscle area in grower and finisher pigs with lower diet CP.

The NRC (2012) nutrient standards showed that lower CP diets, with the addition of synthetic AA, especially the first four limiting AAs (L-Lysine, DL-methionine, L-threonine, and L-tryptophan) could improve nitrogen utilization by reducing nitrogen excretion, lower feed cost, and promote intestinal health without compromising pig growth response (Fan *et al*., 2017). Lysine is the first limiting AA for young pigs who utilize them for body protein synthesis (Kahindi *et al*., 2017). The availability of synthetic AAs has provided the opportunity to reduce diet CP in growing pigs and meet their AA requirement through exogenous AA supplementation.

Despite the standards set by the NRC (2012), which are based on prediction models, there could arise wide variations in animal requirement as a result of breed differences, housing, and management conditions and therefore necessitating scenario-specific evaluations (Zhang *et al*., 2013; Kahindi *et al*., 2017). Only limited studies were carried out under tropical rearing conditions that evaluated AA supplementation under varying diet crude protein regimes. Furthermore, the cost of synthetic AA supplementation juxtaposed with reduced diet crude protein (Kahindi *et al*., 2017; Wang *et al*., 2018). However, the extent to which diet CP can be reduced with lysine supplementation needs to be established in tropical housing conditions where pigs can be prone to additional heat stress, which often has a confounding impact on their nutritional physiology without compromising the growth performance of the piglet. Therefore, the objective of the current study was to evaluate the effect of a gradual reduction in diet crude protein, with exogenous lysine supplementation, on growth performance and carcass characteristics of piglets raised under warm humid tropical conditions.

MATERIALS AND METHODS

Ethics Statements

All procedures involving animal handling, management, and slaughtering were approved by the Animal and Research Ethics Committee of the Ladoke Akintola University of Technology with approval number: ANB/20/19/1132-19P.

Experimental Animals, Management, and Dietary Treatment

The experiment was carried out at the Piggery Unit of the University (Latitude, 8⁰08′N; Longitude 4⁰15′E; Elevation, 347m). A total number of thirty (30) Large white x Landrace male weaned piglets between the age of age 8-10 weeks and an average weight of 11.5 ± 0.39 kg were selected from the farm stock, adapted for seven days on a weaner feed before the commencement of the experiment. Piglets were weighed and randomly allotted to five (5) dietary treatments in a completely randomized design. Each piglet was housed individually in pens demarcated with iron mesh, and six replicate piglets were allocated to each treatment.

Piglets were offered a maize-soybean based diet with the control diet containing 22.6% CP or alternative diets with 2.5%, 5%, 7.5%, and 10% reduction in CP, corresponding to 22.0%, 21.5%, 20.9%, and 20.4% CP, respectively, while synthetic lysine (0.1% inclusion) was included across the diets (Table 1) to meet the 1.09% standard ileal digestible lysine for growing pigs gaining 600 g per day as recommended by Warnants *et al*. (2003).

Data Collection

Piglets were fed the respective diets in two daily installments at 07h00 and 16h00 and water was provided *ad-libitum* for 6 weeks. Feed offered and refusals were collected and weighed daily while the bodyweight of each piglet was taken every week. Thereafter, feed intake, average daily gain, and feed conversion ratio were calculated from body weight changes and feed consumption data (Adejoro *et al*., 2013). Feed cost per kg and the economic efficiency of growth were calculated as previously described (Ojediran *et al*., 2017).

At the end of the 6-week growth period, three piglets were randomly selected per treatment, corresponding to 15 piglets, and blood samples were collected via the jugular vein. A sample of blood was collected into sterilized bottles containing Ethylene Diamine Tetra-acetic Acid for the analysis of hematological parameters. A second blood sample was collected inside empty bottles to analyze serum biochemical parameters. Procedures for hematological analysis were as previously described (Ojediran *et al*., 2015). Alanine Transaminase (ALT), Aspartate Transaminase (AST), and Alanine phosphatase (ALP), Total serum protein, globulin, and albumin, total cholesterol, and triglycerides concentrations were analyzed using the Cobas Integra 400 Plus equipment.

All 30 pigs were stunned, slaughtered, and eviscerated using conventional slaughtering techniques and carcass characteristics expressed as bled weight, eviscer-

Table 1. Composition of the experimental diets

Ingredient (%)	Control (T1)	T2	T3	T4	T5
Maize	51.2	51.2	51.2	51.1	49.5
Soybean meal	29.0	29.0	29.0	29.0	28.0
Wheat offal	13.9	9.20	4.61	0.00	0.00
Fish meal	4.00	4.00	4.00	4.00	4.00
Cassava peel meal	0.00	4.70	9.29	13.9	16.5
Limestone	1.20	1.20	1.20	1.20	1.20
Lysine	0.10	0.10	0.10	0.10	0.10
Salt	0.50	0.50	0.50	0.50	0.50
[1]Premix	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100
Nutrient composition					
Crude protein	22.6	22.0	21.5	20.9	20.4
[2]Metabolizable energy (Kcal/kg)	2881	2876	2872	2866	2707
[2]Lysine	1.19	1.17	1.15	1.13	1.12

Note: [1]supplied the following (per kg feed): vitamin A, 12 500 IU; vitamin D3, 5 000 IU; vitamin E, 40 mg; vitamin K3, 2 mg; vitamin B1, 3 mg; vitamin B2, 5.5 mg; niacin, 55 mg; calcium pantothenate, 11.5 mg; vitamin B6, 5 mg; vitamin B12, 25 mg; folic acid, 1 mg; biotin, 50 mg; choline chloride, 500 mg; mangane¬se, 300 mg; iron, 120 mg; zinc, 80 mg; copper, 85 mg; iodine, 1.5 mg; cobalt, 3 mg; selenium, 1.2 mg; anti-oxidant, 120 mg. [2]Calculated composition.

ated weight, carcass weight, jowl, boston butt, picnic shoulder, loin, spare rib, belly, ham trotters, and head.

Data and Statistical Analysis

All collected data were analyzed using the one-way analysis of variance technique of SAS (SAS Institute. Inc.: Cary, NC, USA,). Significantly different means among variables were separated using New Duncan's Multiple Range Test at p<0.05.

RESULTS

The growth performances of the weaned pigs fed diets with varying CP levels with Lysine supplementation are shown in Table 2. Diet CP level did not affect total weight gain, average daily gain, average daily intake, and feed conversion ratio (p>0.05). The average daily gain of the pigs ranged from 490-550 g/day. Reducing diet CP with exogenous lysine supplementation did not have any linear or quadratic effect on any growth or feed intake parameters (p>0.05).

Reducing diet crude protein from 22.6% to 20.9% (7.5% reduction) and 20.4% (10% reduction) resulted in significantly lower feed cost (p<0.05). However, feed cost per weight gain and efficiency of gain was not significantly different across the animals regardless of their diet CP (p>0.05) (Table 3).

The varying crude protein contents of diets with supplemental lysine did not affect most of the hematological parameters in weaner pigs (p>0.05) (Table 4). Nevertheless, white blood cell counts and hematocrit concentration varied significantly across diet with different CP level (p<0.05). Decreased diet CP resulted in increased WBC and hematocrit concentration. Results on serum biochemistry analysis showed that decreasing diet CP from 22.6 to 20.4 in weaner pigs with supplementary lysine did not affect Aspartate Transaminase (AST), Alkaline Transaminase (ALT), Alkaline Phosphate (ALP), Creatinine, Urea, Uric acid, Total Cholesterol (TCHO), Triglyceride (TAG), High-density lipoprotein, Total Protein, and Albumin concentration of the pigs (p>0.05) (Table 5). However, globulin concentration was higher when diet CP was reduced by 5% and 7.5% but only slightly higher when diet CP reduced by 2.5% and 10%.

Table 6 shows the carcass characteristics and primal cuts of slaughtered pigs fed diet with different crude protein contents with added dietary lysine. The bled weight, eviscerated weight, buston butt, picnic shoulder, loin, spare rib, belly, ham, trotters, and head as a percentage of live weight were significantly influenced by diet CP (p<0.05). However, carcass weight and jowl (p>0.05) were not affected. Reducing the diet CP by 2.5% from 22.6 resulted in significantly lower live weight at slaughter but bled weight was only affected at a 10% reduction in CP (20.4% diet CP). Furthermore, the abdominal fat percentage was slightly lower with the reduced diet CP.

DISCUSSION

Gloaguen *et al*. (2014) observed that in pig production, the need for dietary protein is a need for amino acids, which affects the growth response. The addition of the first limiting AA (L-lysine, DL-methionine, L-threonine, and L-tryptophan) to low crude protein diets had been established for an ideal dietary protein ratio. However, Wang *et al*. (2018) reported that discrepancies in growth response owing to the use of low

Table 2. Growth performance of weaned pigs fed diets with decreasing crude protein, and with lysine supplementation

Variables	Treatments					SEM	Treatment	Lin	Quad
	Control (T1)	T2	T3	T4	T5				
Initial weight (kg)	11.4	11.4	11.5	11.6	11.7	0.39	0.99	0.84	0.97
Final weight (kg)	34.5	34.4	32.7	32.2	33.3	0.86	0.93	0.53	0.66
Total weight gain (kg)	23.1	22.9	21.2	20.6	21.7	0.68	0.79	0.35	0.57
Average daily gain (g/d)	550	546	504	491	516	16.2	0.76	0.35	0.57
Total feed intake (kg)	50.8	50.3	51.1	50.7	50.0	1.85	1.00	0.94	0.93
Average daily intake (g/d)	1209	1197	1216	1208	1189	44.0	1.00	0.94	0.93
Feed conversion ratio	2.19	2.18	2.42	2.47	2.29	0.05	0.24	0.16	0.20

Note: Diet includes control (22.6% CP) or T2 (22.0%), T3 (21.5%), T4 (20.9%) & T5 (20.4%) crude protein corresponding to 2.5%, 5.0%, 7.5%, and 10% reduction, respectively. Treatment, effect of treatment; Lin, linear effect of diet CP; Quad, quadratic effect of diet CP.

Table 3. Economic indices of weaned pigs fed diets with decreasing crude protein, and with lysine supplementation

Variables	Treatments					SEM	P-value
	Control (T1)	T2	T3	T4	T5		
Feed Cost (₦/kg)	125^{a}	123^{ab}	120^{abc}	118^{bc}	115^{c}	0.02	0.02
Feed Cost/Weight gain (₦/kg)	189	190	208	212	202	0.43	0.43
Economic efficiency of gain	233	236	219	224	253	0.70	0.71

Note: ₦= Nigerian Naira; SEM= standard error of mean. Diet includes control (22.6% CP) or T2 (22.0%), T3 (21.5), T4 (20.9%) & T5 (20.4%) crude protein corresponding to 2.5%, 5.0%, 7.5%, and 10% reduction, respectively. ^{a,b,c} means in the same row with different superscripts differ significantly (p<0.05).

Table 4. Hematological variables of weaned pigs fed diets with decreasing crude protein, and with lysine supplementation

Variables	Treatments					SEM	P-value
	Control (T1)	T2	T3	T4	T5		
White blood cell (x 10^9/μL)	3.45[b]	6.40[ab]	12.90[a]	10.70[ab]	7.70[ab]	1.21	0.05
Red blood cell (x 10^{12}/μL)	4.56	6.11	7.76	4.14	7.55	0.62	0.21
Hematocrit (%)	30.5[b]	42.3[ab]	48.9[ab]	29.4[b]	54.6[a]	3.78	0.01
Hemoglobin (g/dL)	8.90	11.20	14.30	8.35	14.60	1.00	0.13
MCV (fl)	73.9	71.6	64.0	74.5	73.1	1.86	0.41
MCH (pg)	27.0	21.3	18.5	20.1	19.9	1.39	0.53
MCHC(g/L)	35.0	29.2	28.1	28.4	27.1	1.36	0.49
Lymphocytes (%)	41.4	41.9	61.0	35.6	55.0	4.97	0.52
Granulocyte (%)	44.3	40.6	31.8	54.3	38.3	3.94	0.5
RDW (%)	17.1	14.4	14.2	14.3	14.3	0.43	0.31
Platelets (x 10^9/μL)	524	375	555	571	364	60.4	0.75
MPV (fl)	12.90	8.92	9.08	11.48	10.05	0.75	0.54
PDW	41.3	35.5	34.0	38.8	39.0	1.45	0.63
PCT (%)	0.63	0.35	0.54	0.64	0.37	0.08	0.67

Note: MCV= mean corpuscular volume; MCH= mean corpuscular hemoglobin; MCHC= mean corpuscular hemoglobin concentration, MPV= mean platelet volume; PDW= platelet distribution width; PCT= platelet count. Diet includes control (22.6% CP) or T2 (22.0%), T3 (21.5), T4 (20.9%) & T5 (20.4%) crude protein corresponding to 2.5%, 5.0%, 7.5%, and 10% reduction, respectively. [a,b,c] means in the same row with different superscripts differ significantly (p<0.05).

Table 5. Serum biochemistry of weaned pigs fed diets with decreasing crude protein, and with lysine supplementation

Variables	Treatments					SEM	P-value
	Control (T1)	T2	T3	T4	T5		
AST (U/L)	31.9	31.5	34.3	42.3	50.6	3.83	0.49
ALT (U/L)	18.6	17.5	20.2	21.7	22.8	1.50	0.84
ALP (U/L)	54.5	63.7	79.4	46.7	36.8	6.37	0.23
Creatinine (μmol/L)	95.5	84.5	71.6	65.5	66.7	5.20	0.41
Urea (μmol/L)	19.0	19.6	15.4	16.6	18.6	1.37	0.89
Uric acid (mg/dL)	7.11	9.26	19.6	17.0	12.8	1.90	0.24
TCHO (mg/dL)	127	115	124	123	118	7.00	0.99
Triglyceride (mg/dL)	77.3	68.6	100	94.1	88.4	6.73	0.64
HDL (mg/dL)	35.5	46.9	44.7	53.1	50.4	5.69	0.95
Total protein (g/L)	4.81	6.88	8.42	8.42	8.14	0.52	0.20
Albumin (g/L)	2.63	3.25	3.62	3.61	3.60	0.15	0.27
Globulin (g/L)	2.18[b]	3.63[ab]	4.80[a]	4.81[a]	4.53[ab]	0.37	0.02

Note: AST= Aspartate Transaminase; ALT= Alkaline Transaminase; ALP= Alkaline Phosphate; TCHO= Total Cholesterol; TAG= Triglyceride. Diet includes control (22.6% CP) or T2 (22.0%), T3 (21.5), T4 (20.9%) & T5 (20.4%) crude protein corresponding to 2.5%, 5.0%, 7.5%, and 10% reduction, respectively. [a,b,c] means in the same row with different superscripts differ significantly (p<0.05).

crude protein (LCP) diets might be attributed to CP levels used in relation to the control diet, feed ingredient type, the pattern of feeding (restricted or ad-libitum), and the experimental conditions. The lack of differences in growth response observed in the current study agrees with the report of Aquilani *et al.* (2019) on Cinta Senese pigs reared in a temperate environment. Similarly, A 3% reduction in diet CP with the exogenous supplementation of essential AA showed that growth performances of grower-finisher pigs were not affected (Prandini *et al*., 2013), but a reduction in growth response was observed by Roux *et al*. (2011). Consequently, Mansilla *et al*. (2017) noted that total nitrogen availability might be the reason for the declining growth response associated with reduced diet CP.

The use of LCP diets in pigs had been demonstrated to reduce the cost of feed (Wang *et al*., 2018), and although the current result validates this, feed cost per weight gain was not different across the treatments. Zhang *et al*. (2010) stated that in China, 10 g/kg of diet CP reduction could translate to about a 1.50% decrease in feed cost. However, this decrease feed cost is subject to the other market forces like feed ingredient price, feed efficiency to weight gain, and premium price of the product. From this experiment, feed cost per weight gain and the economic efficiency of gain were not affected by diet CP reduction. This is contrary to the report of Ojediran *et al*. (2017) on broiler chickens.

The white blood cell count (WBC) and hematocrit concentrations increased as diet CP reduced although

Table 6. Carcass characteristics and primal cuts of weaned pigs fed diets with decreasing crude protein, and with lysine supplementation

Variables (% liveweight)	Treatments					SEM	P-value
	Control (T1)	T2	T3	T4	T5		
Bled Weight	97.07[a]	96.31[a]	97.55[a]	97.49[a]	93.95[b]	0.38	<0.01
Eviscerated Weight	69.72[b]	70.20[ab]	72.55[a]	70.75[ab]	71.45[ab]	0.39	0.01
Carcass Weight	59.44	59.2	59.03	58.97	58.47	0.41	0.97
Jowl	1.51	1.38	2.39	3.06	2.9	0.28	0.16
Boston butt	8.70[b]	8.07[b]	11.50[a]	9.36[b]	9.35[b]	0.38	0.02
Picnic Shoulder	11.38[b]	12.35[ab]	10.63[b]	13.70a	11.13[b]	0.37	0.04
Loin	11.94[a]	10.34[ab]	10.16[b]	10.06[b]	10.16[b]	0.24	0.03
Sparerib	3.91[a]	3.64[ab]	3.44[b]	3.46[b]	2.94[c]	0.1	<0.01
Belly	3.92[b]	4.86[a]	4.43[a]	3.79[b]	4.52[a]	0.12	<0.01
Ham	16.86[a]	15.57[ab]	15.01[b]	16.51[a]	16.77[a]	0.25	0.04
Trotters	0.02[b]	0.02[b]	0.03[b]	0.50[a]	0.03[b]	0.003	0.01
Head	9.16[a]	8.36[ab]	7.22[c]	7.47[bc]	7.89[bc]	0.22	0.01
Abdominal fat	0.60[a]	0.51[ab]	0.40[ab]	0.48[ab]	0.30[b]	0.04	0.01

Note: Diet includes control (22.6% CP) or T2 (22.0%), T3 (21.5), T4 (20.9%) & T5 (20.4%) crude protein corresponding to 2.5%, 5.0%, 7.5%, and 10% reduction, respectively. [a,b,c] means in the same row with different superscripts differ significantly (p<0.05).

the data was characterized by a wide variability due to the smaller number of animals sampled for analysis. It is not clear if the marked increases in WBC values in diets T3-T5 are associated with the reduced diet CP because reduced blood iron profile can result in elevated WBC (Estienne *et al*., 2019). Both reduced iron and high WBC above the normal range are indicators of impaired immune function in animals. Bhattarai *et al*. (2015) observed a wide range of normal WBC values (8.7-37.9 × 10^3 cells/μL) in weaner pigs under experimental conditions. Nevertheless, Kim *et al*. (2007) proved that LCP diets with adequate AA have the same biological effects on protein synthesis and the immunological defense of weaned pigs as higher CP diets. Van der Meer *et al*. (2017) reported that pigs fed LCP diets supplemented with AA under stress could modify immune status and improve the resistance to subclinical and clinical diseases. However, lysine deficiency would not directly affect the host immune response but would limit the synthesis of proteins (including cytokines) and the proliferation of lymphocytes (Peng *et al*., 2016). Lysine inclusion in this study may have helped sustain the concentration of immune indicators in the pigs receiving reduced CP since lysine could modulate the metabolism of arginine, a key amino acid linked with immune function (Peng *et al*., 2016). Hematocrit level reported in this study and the corpuscular parameters is the indications that the pigs were not in anemic condition (Oluwole and Omitogun, 2016).

The non-significant serum biochemistry parameters showed that the feeds were well tolerated and reduced CP did not affect the animal's physiology as noted by Zheng *et al*. (2016). This result is similar to the observation of Bindas *et al*. (2015). Serum urea nitrogen, the main nitrogenous end-product of protein catabolism (Zhang *et al*., 2016), is an indicator of reduced nitrogen excretion from blood to urine used as a measure of nitrogen released to the environment advantage of using LCP diets (Morales *et al*., 2015). Serum albumin will increase when protein intake exceeds the amount required for growth and maintenance. Cholesterol level is influenced by the type of feed consumed, while triglycerides are chains of high energy fatty acids necessary to provide energy for the cell to function. High levels of cholesterol and triglycerides have been associated with heart diseases (He *et al*., 2004). From this study, reducing diet CP did not have any deleterious effect on the liver and kidney function based on the concentration of the diagnostic markers such as AST, ALT, ALP and creatinine. These serum enzymes are very reliable indicators of liver and kidney function in animals (Ojediran *et al*., 2019).

Contrary to reports of some researchers (Figueroa *et al*., 2012; Wang *et al*., 2018) that pigs fed LCP diets had challenges of fatter carcasses, this study proves otherwise. However, while these authors focused on backfat thickness, the current study evaluated abdominal fat deposition in the growing pigs. Kerr *et al*. (2003) had noted the relationship between abdominal fat deposition and the availability of excess dietary energy in LP diets. The reason for the low fat-deposition in LCP diets compared to the pigs fed control diet in this study could be linked to the balance of amino acids, particularly the balance between lysine and branched-chain AA (L-leucine/arginine) (Zhang *et al*., 2016). Balanced AA favors tissue protein synthesis compared to fat deposition because the metabolism of energy substrates is regulated through nitric oxide production (Rezaei *et al*., 2013; Liu *et al*., 2015). Previous studies on finishing pigs showed that decreasing diet CP with adequate lysine and proper AA balance resulted in lower fat deposition, whereas decreasing diet CP without balancing AA resulted in higher fat deposition (Wood *et al*., 2013). Furthermore, Wang *et al*. (2018) reported that an imbalance of energy to nitrogen might be the primary reason for the fatter carcass in pigs fed LCP diets which may be avoided by adopting the net energy system and balanced AA.

CONCLUSION

Adequate lysine supplementation when diet CP is reduced by up to 10% had no negative impact on the growth performance of the growing pigs. Although feed cost was slightly lower at 7.5% CP reduction, feed cost per kg weight gain was not significantly different across the animals. Equally, there was no negative impact on pig's hematological, serum biochemical, and carcass characteristics.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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