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Effects of Lysine Supplemented on Growth, Apparent Nutrient Digestibility, and Slaughter Yield of Noi Broilers from 56–84 Days of Age

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ABSTRACT

A total of 192 Noi broilers at 56 days of age were allotted in a completely randomized design consisting of four treatments and four replicates to evaluate the effect of dietary lysine added on body weight gain (BWG), feed conversion ratio (FCR), apparent nutrient digestibility (AND), and carcass characteristics. Treatments included a control with 0.8% lysine in the diet and three experimental treatments ($Lys_{+0.1}$; $Lys_{+0.2}$; $Lys_{+0.3}$) with lysine added at 0.1, 0.2, and 0.3%, respectively. Crude protein (CP) was 15%, and metabolizable energy was 3,000 kcal/kg of feed. At 77 days of age, for each replicate, one male and one female chicken were selected for the estimation of AND by using Fe_2O_3 marker. The chickens were fed ad libitum and vaccinated against common diseases. The results showed that lysine's addition to the diet at 0.2–0.3% significantly improved the BWG and FCR ($P<0.05$). Furthermore, the addition of 0.1–0.3% lysine to the diet resulted in a significant increase in apparent CP digestibility and overall amino acid digestibility ($P<0.05$) but did not affect the apparent digestibility of Ca and P of Noi broilers. Finally, concerning the breast weight and yield of both male and female chickens, whereas the male broilers' dressing improved with the addition of 0.3% lysine to the diet, the breast yield of their female counterparts bettered when supplemented with 0.2% lysine.

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Introduction

Chickens, whose meat accounts for more than 20% of Vietnam's livestock meat products, have been a vital food source for humans (Vietnam Animal production, 2020). Backyard chickens are mainly raised in Vietnam and comprise a higher percentage of total chickens than industrial chicken breeds (Van Duy *et al.*, 2015). The demand for indigenous broilers in Vietnam has been on the rise, and the Noi broiler breed is the top choice of consumers (Khoa *et al.*, 2019).

A balanced diet is an essential factor for the growth of chickens and economic efficiency. However, to achieve the best development of chickens and metabolic factors, protein needs to be provided in the diet to ensure the entire balance of the amino acid (AA) requirements for the chickens. Thus, special attention is paid to the diet's lysine content since it is the first limiting AA used to calculate the remaining AAs in the diet (Mack *et al.*, 1999; Baker *et al.*, 2002; Baker, 2003). Besides, Araújo *et al.* (2005) and Corzo *et al.* (2005) also indicated that the addition of AA at different levels in the diet affects the growth and quality of chicken meat. Furthermore, the addition of lysine has been proven to contribute to a higher meat yield of chicken breast (Hickling *et al.*, 1990; Moran and Bilgili, 1990). Other findings on broilers have also noted that additional lysine in the diet leads to better crude protein (CP) digestibility and AA as well as meat yield (Tao *et al.*, 1971; Hickling *et al.*, 1990; Selle *et al.*, 2007; Hung and Ngu, 2017; Lam Thai Hung, 2019). This study aimed to evaluate the effects of extra lysine in the diet on body weight gain (BWG), apparent nutrient digestibility (AND), and carcass characteristics.

Materials and methods

Experimental design

A total of 192 Noi broilers at 56 days old were arranged in a completely randomized design with four treatments and four replicates (12 chickens per replicate with equal ratios of males and females). Treatments included a control (with 0.8% lysine) and three experimental diets ($Lys_{+0.1}$, $Lys_{+0.2}$, and $Lys_{+0.3}$) added to the control treatment with lysine levels of 0.1, 0.2, and 0.3%, respectively. The experimental diets contained CP of 15% and metabolizable energy (ME) of 3,000 kcal/kg of feed. The experiment was carried out on chickens from 56 to 84 days of age, and they were raised on rice husks in an area of 3 m^2/plot surrounded by a net. Chickens received

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similar care and were fed *ad libitum*. The feeding and drinking troughs were individually designed for each experimental unit. All chickens were vaccinated against diseases following a common procedure.

At 77 days of age, one male and one female chicken were selected in each experimental unit to identify AND. The chickens in this experiment were raised in cages with an area of 40x50x40 cm that had a plastic tray for collecting manure. Chicken feed intake (FI) was limited to 80% of the actual need, and the chickens were fed at 6:00 and 14:00 daily. The AND was indirectly determined by the Fe_2O_3 marker, which was mixed into the diet at a rate of 0.1%. The chickens were fed for four days, and then fecal samples were taken for three days. All daily fecal samples were collected and stored in a freezer (-20°C). At the end of the experiment, the fecal samples were thawed and mixed well, then dried at 60oC and ground to analyze the chemical components in one sample in each experimental unit.

Diets

Diets consisted of yellow corn, soybean meal, rice bran, synthetic AA, dicalcium phosphate, shell, salt, vitamin premix, and micromineral premix (Table 1 and Table 2). The ratios of AA methionine+cystine and threonine were calculated according to the ideal AA pattern proposed by Baker (2003). The chemical compositions of feed and manure were analyzed based on the method by AOAC (2000), and the AA levels in feed and feces were analyzed by high-performance liquid chromatography (AOAC, 2006).

Data collection

The identified indicators included FI, BWG, FCR, and AND. The chicken BWG was determined by subtracting the early-stage weight from the final-stage weight. FCR was calculated by the amount of FI (g) over BWG (g). Besides, AND was determined basing the difference in the content of the non-digestible marker in feces and feed calculated by the formula:

Apparent nutrient digestibility (%)

$$= \frac{(N.feed/Fe.feed - N.feces/Fe.feces)*100}{N.feed/Fe.feed}$$

Where N. feed: nutrient in feed, N. feces: nutrient in feces, Fe. feed: Fe_2O_3 in feed, and Fe. feces: Fe_2O_3in feces.

Data analysis

Data were analyzed by the General Linear Model on Minitab 16.0 software. The mean difference between the treatments was compared using Tukey's test, with $\alpha < 0.05$.

Results

Effects of levels of dietary lysine on body weight gain and feed efficiency of Noi chickens

Feed intake, BWG, and FCR of Noi broilers at 56–84 days of age are presented in Table 3. The results showed that the FI was not significantly different (P>0.05), unlike the daily BWG

Table 1. Chemical composition of feedstuffs

Feedstuffs	Chemical composition (% of feed)							
	DM	ME, kcal/kg	CP	Lys	Met+Cys	Thr	Ca	P
Yellow corn	85.81	3,335	6.94	0.25	0.369	0.234	0.21	0.31
Soybean meal	87.94	2,631	44.87	0.949	1.277	2.124	0.4	0.69
Rice bran	87.86	2,624	12.01	0.61	0.22	1.17	0.375	1.58

Note: DM: dry matter, ME: metabolizable energy, CP: crude protein, lys: lysine, Met+Cys: Methionine + Cystine and Thr: threonine, Ca: calcium, and P: phosphorus.

Table 2. Experimental diets

Feedstuffs	Diets			
	Control	$Lys_{+0.1}$	$Lys_{+0.2}$	$Lys_{+0.3}$
Yellow corn (%)	66.79	67.07	67.34	67.67
Soybean meal (%)	19.5	19.05	18.6	18
Rice bran (%)	9.85	9.85	9.85	9.85
Lysine (%)	0.35	0.49	0.59	0.7
Methionine* (%)	0.06	0.13	0.21	0.29
DCP (%)	1	1	1	1
Shell (%)	1.76	1.76	1.76	1.76
Premix** (%)	0.25	0.25	0.25	0.25
Salt (%)	0.4	0.4	0.4	0.4
Nutritional value of diets				
ME (kcal/kg of feed)	2,999	2,996	2,994	2,989
CP (%)	15	15	15	15
Lysine (%)	0.8	0.9	1	1.1
Methionine (%)	0.57	0.64	0.72	0.79
Threonine (%)	0.68	0.67	0.67	0.73
Tryptophan (%)	0.27	0.26	0.26	0.25
Calcium (%)	1.01	1.01	1.01	1.01
Phosphorus (%)	0.7	0.69	0.69	0.68

Note: Control: lysine 0.8%; $Lys_{+0.1}$: additional 0.1% lysine, $Lys_{+0.2}$: additional 0.2% lysine, $Lys_{+0.3}$: additional 0.3% lysine, DCP: dicalci phosphate, ME: metabolizable energy, CP: crude protein, *: supplemented for need of methionine+cysteine, **: vitamin premix and micro mineral premix.

and FCR (P<0.05). The daily BWG in the control treatment was 14.9 g/bird/day, which increased gradually with lysine added to the diet at levels of 0.1, 0.2, and 0.3% and peaked at 0.3% lysine (16.38 g/bird/day). The addition of lysine to the diet at 0.2% (FCR at 3.95) and 0.3% (FCR at 3.81), also significantly improved the feeding efficiency on Noi broilers and 0.1% (FCR at 4.12) as opposed to the lysine level in the diet in the control treatment (FCR at 4.22).

Effects of levels of dietary lysine on nutrient apparent digestibility of Noi chickens

The apparent digestibility of CP, Ca, P, and AA of Noi broilers at 56–84 days of age is shown in Table 4. The findings showed that the apparent CP digestibility in the treatments differed significantly (P<0.01) compared to the control with no addition of lysine (0.8% lysine). In particular, the control treatment had a lower apparent digestibility of CP (64.02%) than the others with lysine addition at levels of 0.1, 0.2, and 0.3% (68.00, 69.58, and 68.72%, respectively). The apparent digestibility of indispensable AAs (glycine, histidine, leucine, lysine, and valine) and the dispensable AAs and the average AA digestibility improved when lysine was added at 0.1, 0.2, and 0.3% to the diet. However, apparent digestibility of P, Ca, arginine, cysteine, methionine, phenylalanine, and threonine was not affected when lysine was added to the diet (P>0.05).

Effects of lysine levels in the diets on carcass composition and internal organ ratio of Noi broilers

Table 5, presents the carcass composition and the chicken internal organ ratio at 84 days of age. As shown, the weight of breast meat (BM) of the male and female chickens in the control treatment (70.75 g and 75.25 g/bird, respectively) was significantly lower than the figures for those being fed 0.3% lysine supplemented diets (90 g/bird for males and 102 g/bird for females). In addition, the dressing ratio of male chicken, which was 64.82% in the control treatment, increased gradually through the experimental treatments with $Lys_{+0.1}$ (66.81%), $Lys_{+0.2}$ (67.9%), and $Lys_{+0.3}$ (69.54%). The latter showed significant differences compared with the control treatment. The results also indicated that the breast yield of female chickens (12.36% in the control treatment) tended to increase when adding lysine, especially with 0.2% and 0.3% lysine added (13.88% and 13.86%, respectively). Finally, the BM yield of males registered an increase from 11.51% in the control treatment to 13.67% with an addition of 0.3% lysine. No differences were found in internal organ ratios in all treatments.

Table 3. Effect of lysine levels of diets on Noi boiler growth and FCR

Terms	Treatments				P/SEM
	Control	$Lys_{+0.1}$	$Lys_{+0.2}$	$Lys_{+0.3}$	
Initial BW (g/bird)	496	498	510	513	0.074/4.93
Daily feed intake (g/bird)	62.83	64.25	62.38	62.5	0.609/1.08
Daily BWG (g)	14.90^{b}	15.59^{ab}	15.78^{ab}	16.38^{a}	0.005/0.23
FCR (g of feed/g of BWG)	4.22^{a}	4.12^{a}	3.95^{b}	3.81^{b}	0.000/0.04
Final BW (g/bird)	914^{c}	935^{bc}	952^{ab}	972^{a}	0.001/7.84

Note: FCR: feed conversion ratio; BW: bodyweight; BWG: bodyweight gain; $Lys_{+0.1}$: 0.1% additional lysine in the diet; $Lys_{+0.2}$: 0.2% additional lysine in the diet; $Lys_{+0.3}$: 0.3% additional lysine in the diet.

Table 4. Effects of dietary lysine levels on nutrient apparent digestibility of Noi broilers

Terms	Treatments				P/SEM
	Control	$Lys_{+0.1}$	$Lys_{+0.2}$	$Lys_{+0.3}$	
CP digestibility	64.02^{b}	68.00^{a}	69.58^{a}	68.72^{a}	0.000/0.63
Calcium digestibility	47.64	46.41	49.62	48.92	0.486/1.52
Phosphorus digestibility	45.48	47.81	48.67	47.93	0.700/1.98
Indispensable AA digestibility, %					
Arginine	86.47	84.96	88.95	88.17	0.052/0.96
Cystine	68.79	71.54	71.07	73.77	0.680/2.85
Glycine	64.58^{b}	78.57^{a}	73.92^{a}	78.98^{a}	0.000/1.64
Histidine	82.57^{b}	83.80^{b}	86.47^{ab}	88.91^{a}	0.004/1.03
Isoleucine	66.90^{b}	82.45^{a}	80.27^{a}	80.24^{a}	0.000/1.12
Leucine	78.72^{b}	86.40^{a}	84.06^{a}	85.36^{a}	0.000/0.85
Lysine	83.26^{b}	86.74^{ab}	86.99^{a}	87.77^{a}	0.016/0.88
Methionine	89.68	89.37	88.43	90.74	0.271/0.78
Phenylalanine	83.37	87.04	86.85	85.16	0.193/1.26
Threonine	78.8	81.85	80.69	80.77	0.260/1.03
Valine	62.56^{b}	65.29^{b}	78.66^{a}	75.48^{a}	0.000/1.18
Dispensable AA digestibility					
Alanine	63.69^{b}	68.33^{ab}	67.32^{ab}	72.05^{a}	0.029/1.66
Aspartic	60.43^{c}	74.14^{b}	79.43^{a}	75.46^{ab}	0.000/1.19
Glutamic	70.36^{c}	80.13^{b}	86.97^{a}	83.45^{ab}	0.000/1.10
Serine	75.76^{b}	86.92^{a}	81.98^{ab}	90.80^{a}	0.002/2.11
Tyrosine	69.51^{b}	75.72^{ab}	84.23^{a}	84.71^{a}	0.004/2.59
Overall AA digestibility	73.96^{c}	79.81^{b}	81.35^{ab}	82.49^{a}	0.000/0.48

Note: Control: lysine 0.8% in the diet; CP: crude protein; $Lys_{+0.1}$: 0.1% additional lysine in the diet; $Lys_{+0.2}$: 0.2% additional lysine in the diet; $Lys_{+0.3}$: 0.3% additional lysine in the diet

Table 5. Carcass composition and internal organ ratio of Noi broilers at 84 days old

Terms	Sex	Treatments				P/SEM
		Control	$Lys_{+0.1}$	$Lys_{+0.2}$	$Lys_{+0.3}$	
Live weight (g/bird)	Female	865	940	883	948	0.266/33.6
	Male	1,003	1,043	1,008	1,068	0.640/40.3
Carcass weight (g/bird)	Female	573	633	583	649	0.093/22.5
	Male	650	696	684	743	0.310/33.1
Breast weight (g/bird)	Female	70.75^{b}	82.00^{ab}	81.00^{ab}	90.00^{a}	0.026/3.76
	Male	75.25^{b}	91.00^{ab}	86.50^{ab}	102^{a}	0.043/5.71
Thigh weight (g/bird)	Female	126	151	132	149	0.103/7.76
	Male	147	155	154	173	0.191/7.96
Dressing (%)	Female	66.26	67.4	66.08	68.48	0.262/0.91
	Male	64.82^{b}	66.81^{ab}	67.90^{ab}	69.54^{a}	0.049/1.06
Yield (% of carcass weight)						
Breast	Female	12.36^{b}	12.93^{ab}	13.88^{a}	13.86^{a}	0.016/0.33
	Male	11.51^{b}	13.09^{ab}	12.63^{ab}	13.67^{a}	0.028/0.44
Thigh	Female	21.9	23.8	22.66	22.91	0.369/0.73
	Male	22.63	22.25	22.44	23.22	0.622/0.54
Heart	Female	0.453	0.444	0.411	0.416	0.795/0.04
	Male	0.466	0.438	0.439	0.469	0.775/0.03
Liver	Female	2.071	2.821	1.863	1.949	0.553/0.51
	Male	2.029	2.331	1.98	2.245	0.067/0.09
Gizzard	Female	2.368	2.295	2.79	2.474	0.572/0.26
	Male	2.332	2.045	2.517	2.012	0.197/0.18
Spleen	Female	0.285	0.191	0.209	0.178	0.406/0.05
	Male	0.192	0.184	0.135	0.184	0.751/0.04

Note: Control: 0.8% additional lysine in the diet; $Lys_{+0.1}$: 0.1% additional lysine; $Lys_{+0.2}$: 0.2% additional lysine; $Lys_{+0.3}$: 0.3% additional lysine

Discussion

The FI was similar among the treatments because they were raised in the same temperature, humidity, care, and the same ME and CP in the feed. Although broilers can regulate FI when a balanced diet is deficient with lysine, methionine, and tryptophan (Picard *et al*., 1993), the amount of lysine added to the diet was high compared to the actual need. The results are consistent with Lam Thai Hung (2019), who reported that when lysine is added at the levels of 0.9, 1.0, and 1.1% to the H'mong chicken diet at 1-28 days old with similar ME, no difference in FI was observed. Similarly, in the results of Hung and Ngu (2017), the raising of Ac chickens at 1–4 weeks of age with lysine supplementation at levels of 1.00, 1.05, 1.10, 1.15, and 1.20% and ME 2,900 kcal/kg of feed manifested no differences in FI with 99.17, 104.6, 111.9, 104.5, and 103.9 g/bird/week, respectively. Furthermore, adding lysine at a rate of 11 g/kg to the diet of Cobb chickens at 7–28 days of age resulted in FI of 1,476 g/bird, marginally higher than the figure for 10 g/kg diet (1,473 g/bird) (Selle *et al*., 2007).

The treatment $Lys_{+0.3}$ showed an increase in BWG at 16.38 g/bird/day as opposed to 14.9 g/bird/day in the control treatment. This was because lysine is the first limiting AA in the chicken diet, which is used as the basis for calculating the remaining AAs in the diet (Mack *et al*., 1999; Baker *et al*., 2002). Therefore, with extra lysine, the diet AAs were better balanced, thereby facilitating chicken absorption. Along with improved efficiency of the use of feed in the di*et al*so came better FCR. In particular, the FCR of Noi broilers, when supplemented with 0.2% and 0.3% lysine, showed 3.95 and 3.81 g of feed/g of BWG, respectively. This finding was lower than that in the control treatment and the treatment $Lys_{+0.1}$ with the FCR of 4.22 and 4.12 g of feed/g of BWG, respectively.

The results are also consistent with those of Hung and Ngu (2017), who reported that adding 1.1% lysine to the Ac chicken diet led to higher BWG than did a 1.0% addition (52.4 g/bird/week versus 43.6 g/bird/week, respectively). This study also was similar to the conclusion of Hickling *et al.* (1990) that lysine supplementation, which exceeded 118% of NRC standard to the diet of a 1–6 week-old Ross x Arbor Acres chickens, resulted in BWG reaching 2,240 g/bird and FCR reaching 1.79. This result improved when comparing with lysine addition according to the NRC standard with BWG of 2,227 g/bird and FCR of 1.81 g. Similarly, adding 11 g/kg lysine gave rise to a higher BWG of 899 g/bird and a lower FCR of 1.64, compared with BWG of 823 g/bird and FCR 1.79 when adding 10 g/kg to the diet of Cobb chickens at 7–28 days old (Selle *et al*., 2007). Also, when lysine at 0.9, 1.0, and 1.1% was added to the diet of Arbor Acres chickens at 22–42 days of age, the figure for BWG at the final stage was 2,756, 2,735, and 2,722 g/bird (Tang *et al*., 2007).

Apparent CP digestibility in the treatments supplemented with lysine was significantly higher than that in the control as apparent AA digestibility was improved. Apparent CP digestibility was enhanced with lysine addition because each AA in the diet was better digested. According to Fuller (2004), AA is the smallest unit for protein synthesis; thus, the digestion of proteins in the animal body means AA digestion.

The results of CP apparent digestibility in the present study concurs with that of Mountzouris *et al.* (2010). When apparent ileum digestibility was determined by Cr_2O_3 marker in male Cobb chickens at 29–42 days of age, apparent CP digestibility was 69% when 10 g lysine/kg was included in the diet. However, this result was lower than those reported by Amad *et al.* (2011) and Jamroz *et al.* (2003). As for the former, when determining apparent ileum digestibility by Cr2O3 on Cobb 500 male chickens at 21 days of age with a diet containing lysine 1.43%, apparent CP digestibility was yielded at 76.6%. With the diet containing lysine 1.26%, apparent CP digestibility was 75.3% at 42 days of age. Concerning the study of Jamroz *et al.* (2003), as Cr2O3 was used to determine AND on Hybro HI-YR chickens with a diet containing lysine at

11.68%, apparent CP digestibility was shown at 82.5%. With a diet containing lysine at 10.15%, apparent CP digestibility was at 81.3% at 32 days of age. On the contrary, this result is higher than the that in the study of Garcia *et al*. (2007), which used the Celitmarker to determine apparent ileum digestibility on 308 male Ross chickens at 22–49 days old with a diet containing 1.22% lysine, whose apparent CP digestibility was yielded at 60.7%.

Also indicated in this work is that the addition of 0.1–0.3% lysine did not affect the apparent digestibility of Ca and P. This probably because the digestibility and absorption of P is influenced by the source of P in efficient or inefficient form (Angel *et al*. 2002) and also by interaction with digestion and absorption of Ca (Tamim and Angel, 2003). Meanwhile, the digestibility and absorption of Ca depend on its efficiency; for example, 20–30% was from corn but 60–70% from limestone (Tamim and Angel, 2003; Tamim *et al*., 2004). Besides, digestibility and absorption of Ca and P are also influenced by vitamin D and the parathyroid glands of chickens (Veum, 2010).

Average apparent AA digestibility in the control treatment (73.96%) was significantly lower than that in the treatments (79.81, 81.35, 82.49%) with an extra 0.1, 0.2, and 0.3% lysine, respectively. The addition of lysine limits its deficiency during biosynthesis, which helps improve AA digestibility. The figure of apparent AA digestibility in this study agrees with that of Tao *et al*. (1971), whose result registered an increase from 78.2% to 80.3% in apparent AA digestibility as determined by Cr2O3 when adding 0.25% lysine to the diets of male broilers with BW 1.3–1.8 kg/bird. However, apparent AA digestibility in this study is lower than the findings of Ravindran *et al*. (2005) as the percentage of apparent AA digestibility on male Cobb chickens with diets from various ingredients was 80% at 42 days of age.

Breast meat is an important element related to carcass quality. This study showed that the proportion of BM weight tended to increase significantly with the increasing levels of lysine in the diet. Research by Lohakare *et al*. (2005) showed that AAs in the male Ross chicken diet greatly influenced carcass characteristics. Our findings are consistent with those of Tang *et al*. (2007) conducted on the Arbor Acres chicken with three lysine levels (low, medium, and high), which showed that high levels of lysine in the diet improved BM weight at 56 days of age. Also, the report of Kidd *et al*. (1998) indicated that the BM weight of chickens from 0–50 days old fell with low lysine content in the diet; the yield of BM decreased considerably when reducing lysine from 1.05% to 0.85% (Acar *et al*., 1991).

Conclusion

The addition of lysine to the diet at 0.2–0.3% improved the BWG and FCR of Noi broilers, and the addition of 0.1–0.3% lysine increased the apparent digestibility of CP and overall AA. Still, it did not affect the apparent digestibility of Ca and P of Noi broilers. Moreover, 0.3% lysine added to the diet improved the breast weight and yield of male and female chickens, the dressing of male chickens, and the breast yield of the female chickens increased when supplemented with 0.2% lysine.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

Acar, N., Moran Jr, E.T., Bilgili, S.F., 1991. Live performance and carcass yield of male broilers from two commercial strain crosses receiving rations containing lysine below and above the established requirement between six and eight weeks of age. Poult. Sci. 70, 2315-2321.

Amad, A.A., Männer, K., Wendler, K.R., Neumann, K., Zentek, J., 2011. Effects of a phytogenic feed additive on growth performance and ileal nutrient digestibility in broiler chickens. Poult. Sci. 90, 2811-2816.

Angel, R., Tamim, N.M., Applegate, T.J., Dhandu, A.S., Ellestad, L.E., 2002. Phytic acid chemistry: influence on phytin-phosphorus availability and phytase efficacy. J. Appl. Poult. Res. 11, 471-480.

AOAC, 2000. Official Methods of Analysis of AOAC International: 17th ed. AOAC International, USA.

AOAC, 2006. Official Methods of Analysis. 18th ed. Assoc. Off. Anal. Chem., Gaithersburg, MD.

Araújo, L.F., Junqueira, O.M., Araújo, CS da S., Barbosa, L.C.G.S., Ortolan, J.H., Faria, D.E. de, Stringhini, J.H., 2005. Energy and lysine for broilers from 44 to 55 days of age. Braz. J. Poult. Sci. 7, 237-241.

Baker, D.H., 2003. 13 ideal amino acid patterns for broiler chicks. Amino acids in animal nutrition. 223.

Baker, D.H., Batal, A.B., Parr, T.M., Augspurger, N.R., Parsons, C.M., 2002. Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine, and valine for chicks during the second and third weeks posthatch. Poult. Sci. 81, 485-494.

Corzo, A., Kidd, M.T., Burnham, D.J., Miller, E.R., Branton, S.L., Gonzalez-Esquerra, R., 2005. Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. J. Appl. Poult. Res. 14, 1-9.

Van Duy, N., Moula, N., Do Duc, L., Pham Kim, D., Dao Thi, H., Bui Huu, D., Vu Dinh, T., Farnir, F., 2015. Ho Chicken in Bac Ninh Province (Vietnam): From an indigenous chicken to local poultry breed. Int. J. Poult. Sci. 14, 521-528.

Fuller, M.F., 2004. The encyclopedia of farm animal nutrition. Aberdeen: CABI.

Garcia, V., Catala-Gregori, P., Hernandez, F., Megias, M.D., Madrid, J., 2007. Effect of formic acid and plant extracts on growth, nutrient digestibility, intestine mucosa morphology, and meat yield of broilers. J. Appl. Poult. Res. 16, 555-562.

Hickling, D., Guenter, W., Jackson, M.E., 1990. The effects of dietary methionine and lysine on broiler chicken performance and breast meat yield. Can. J. Anim. Sci. 70, 673-678.

Hung, L.T., Ngu, N.T., 2017. Effects of dietary lysine on growth performance, carcass composition and immunological responses to influenza vaccination in Ac chickens. Int. J. Emerging Technol. Adv. Eng. 7, 421-426.

Jamroz, D., Orda, J., Kamel, C., Wiliczkiewicz, A., Wertelecki, T., Skorupinska, J., 2003. The influence of phytogenic extracts on performance, nutrient digestibility, carcass characteristics, and gut microbial status in broiler chickens. J. Anim. Feed Sci. 12, 583-596.

Khoa, D.V.A., Tuoi, N.T.H., Nguyen, N.T., Thuy, N.T.D., Okamoto, S., Kawabe, K., Shimogigri, T., 2019. Some quantitative genetic traits in Vietnamese indigenous Noi chicken from 0 to 28 days old. Biotechnol. Anim. Husb. 35, 141-151.

Kidd, M.T., Kerr, B.J., Halpin, K.M., McWard, G.W., Quarles, C.L., 1998. Lysine levels in starter and grower-finisher diets affect broiler performance and carcass traits. J. Appl. Poult. Res. 7, 351-358.

Lam Thai Hung. 2019. Using efficiency of lysine and metabolizable energy of H'mong broilers from 0 to 28 days of age. J. Anim. Husb. Sci. Tech. 249, 69-74.

Lohakare, J.D., Choi, J.Y., Kim, J.K., Yong, J.S., Shim, Y.H., Hahn, T-W., Chae, B.J., 2005. Effects of dietary combinations of vitamin A, E and methionine on growth performance, meat quality and immunity in commercial broilers. Asian-Australas. J. Anim. Sci. 18, 516-523.

Mack, S., Bercovici, D., De Groote, G., Leclercq, B., Lippens, M., Pack, M., Schutte, J.B., Van Cauwenberghe, S., 1999. Ideal amino acid profile and dietary lysine specification for broiler chickens of 20 to 40 days of age. Br. Poult. Sci. 40, 257-265.

Moran, J.E.T., Bilgili, S.F., 1990. Processing losses, carcass quality, and meat yields of broiler chickens receiving diets marginally de-

ficient to adequate in lysine prior to marketing. Poult. Sci. 69, 702-710.

Mountzouris, K.C., Tsitrsikos, P., Palamidi, I., Arvaniti, A., Mohnl, M., Schatzmayr, G., Fegeros, K., 2010. Effects of probiotic inclusion levels in broiler nutrition on growth performance, nutrient digestibility, plasma immunoglobulins, and cecal microflora composition. Poult. Sci. 89, 58-67.

Picard, M.L., Uzu, G., Dunnington E.A., Siegel, P.B., 1993. Food intake adjustments of chicks: short term reactions to deficiencies in lysine, methionine and tryptophan. Br. Poult. Sci. 34, 737-746.

Ravindran, V., Hew, L.I., Ravindran, G., Bryden, W.L., 2005. Apparent ileal digestibility of amino acids in dietary ingredients for broiler chickens. Anim. Sci. 81, 85-97.

Selle, P.H., Ravindran, V., Ravindran, G., Bryden, W.L., 2007. Effects of dietary lysine and microbial phytase on growth performance and nutrient utilisation of broiler chickens. Asian-Australas. J. Anim. Sci. 20, 1100-1107.

Tamim, N.M., Angel, R., 2003. Phytate phosphorus hydrolysis as influenced by dietary calcium and micro-mineral source in broiler diets. J. Agric. Food Chem. 51, 4687-4693.

Tamim, N.M., Angel, R., Christman, M., 2004. Influence of dietary calcium and phytase on phytate phosphorus hydrolysis in broiler chickens. Poult. Sci. 83, 1358-1367.

Tang, M.Y., Ma, Q.G., Chen, X.D., Ji, C., 2007. Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in Arbor Acres broilers. Asian-Australas. J. Anim. Sci. 20, 1865-1873.

Tao, R., Belzile, R.J., Brisson, G.J., 1971. Amino acid digestibility of rapeseed meal fed to chickens: effects of fat and lysine supplementation. Can. J. Anim. Sci. 51, 705-709.

Veum, T.L., 2010. Phosphorus and calcium nutrition and metabolism. Phosphorus and calcium utilization and requirements in farm animals, 94-111.

Vietnam Animal production, 2020. Animal production statistics in Vietnam, 01/10/2018.