

## Effects of different standardized ileal digestible lysine: net energy proportion in growing and finishing pigs

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### Abstract

This experiment was performed to evaluate the optimal proportion of dietary standardized ileal digestible lysine (SID Lys) to net energy (NE) proportion in growing to finishing pigs. A total of seventy-two pigs were used at phase 1 (initial body weight 37.23 ± 0.23 kilogram, for 42 d) and at phase 2 (initial body weight 54.16 ± 0.20 kilogram, for 77 d). They were arbitrarily assigned to three treatments groups consisting of four duplicates per treatment (six pigs in duplicates, respectively). Diet treatments were as follows: CON = basal diets (phase 1, crude protein (CP): 19.1%; SID Lys: 0.94%; SID Lys: NE proportion: 0.91 g/MJ / phase 2, CP: 17.0%; SID Lys: 0.84%; SID Lys: NE proportion: 0.79 g/MJ), TRT1 (phase 1, CP: 18.0%; SID Lys: 0.92%; SID Lys: NE proportion: 0.89 g/MJ / phase 2, CP: 15.8%; SID Lys: 0.8%; SID Lys: NE proportion: 0.75 g/MJ), TRT2 (phase 1, CP: 17.3%; SID Lys: 0.82%; SID Lys: NE proportion: 0.79 g/MJ / phase 2, CP: 14.8%; SID Lys: 0.7%; SID Lys: NE proportion: 0.65 g/MJ). In phase 1 and 2, growth performance did not meaningfully be affected when SID Lys: NE proportion decreased with reducing CP content. In phase 2, the nitrogen digestibility of CON group in 11 week was higher ( $p < 0.05$ ) than other treatments. Also, marbling and firmness scores of TRT2 group diets increased ( $p < 0.05$ ) compared with those of CON group, but dissimilarities of other meat qualities did not be detected among treatments. In conclusion, introduction of NE system can reduce negative problems introduced when dietary CP decreased. Also, 0.79 and 0.65 g/MJ of SID Lys: NE proportion is the optimal Lys: NE proportion to achieve improved pork quality without impairing the growth performance in growing-finishing pigs, respectively.

**Keywords:** Digestibility, Growth performance, Meat quality, SID lysine: net energy

## INTRODUCTION

Participants in the pig industry had added excess nutrition in diet over their requirements because

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#### Competing interests

The authors declare no conflict of interest.

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Not applicable.

#### Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

#### Authors' contributions

Conceptualization: Lee JH, Lee SD, Kim IH, Cho JH.

Data curation: Lee JH, Lee SD, Yun W, Oh HJ, An JS.

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#### Ethics approval and consent to participate

All manuals were used in the experiment were accepted from animal management and use commission of Chungbuk National University.

they want to achieve the improving growth. Notably, the nitrogen of these excessive nutrients can result in environmental pollution by excretion into feces and urine [1]. For solving these problems, researchers have studied on effects of low protein in the diet, which caused the positive impact and negative impact on pigs. Some researches had shown that low crude protein in diet did not influence growth performance, but meaningfully reduced N emission by 10% and odor gas such as ammonia and volatility fatty acids [2,3]. However, pigs fed the low protein diets had more body fat than pigs fed the high protein diets in carcass. The introduction of net energy (NE) system has been used as a method to fulfil satisfied growth, carcass traits and meat quality by several researchers in the last few years [4,5]. Some research reported that the reported optimum proportion of standardized digestible lysine (Lys): NE proportion for growing-finishing pigs (27 to 100 kg) is from 0.85 to 0.70 g /MJ, but other research showed that standardized digestible Lys: NE proportion for growing-finishing pigs (27 to 100 kg) is from 1.11 to 0.78 g/MJ [6,7]. Difference discovered between these studies can be attributed to the various reasons such as type of feedstuffs, the dietary crude protein (CP) and NE content, the age and genotype of the pigs used [8]. Therefore, we carried out the investigation on the effects of different Lys: NE proportion with reducing crude protein in growing-finishing pigs.

## MATERIALS AND METHODS

All manuals used in the experiment were accepted from animal management and use commission of Chungbuk National University.

### Animals and facilities

In phase 1, seventy-two crossbred [(Landrace × Yorkshire) × Duroc] growing pigs weighted 37.23 ± 0.23 kilogram (85-d age) were applied in an experimental period of 42 days at Chungbuk National University research farm. Pigs were arbitrarily assigned to 3 treatment groups consisting of four duplicates per treatment with six pigs (three barrows and three gilts) in duplicates, respectively. In phase 2, seventy-two crossbred [(Landrace × Yorkshire) × Duroc] finishing pigs weighted 54.16 ± 0.20 kilogram (110-d age) were divided again randomly to 3 dietary treatments consisting of four duplicates per treatment with six pigs (three barrows and three gilts) in duplicates, respectively and the experiment lasted 77 days. All pigs were raised in the room where it is possible to control temperature and humidity. Respective pen was fitted out feeder and a teat drinker which made from stainless steel on one side, and pigs were offered feed and water freely. Body weights (BW) of pigs were measured at the initial and final experiment period in phase 1 and initial, middle (d 42) and final (d 77) experiment period in phase 2. Feed exhaustion were noted according to a pen for this experiment to settle the average daily gain (ADG), average daily feed intake (ADFI), and gain: feed ratio (G:F).

### Dietary treatments

In phase 1, the diets (Table 1) were designed to hold 191, 180, and 173 g/kg CP, and standardized ileal digestible lysine (SID Lys): NE proportions of 0.91, 0.89, and 0.79 g/MJ NE. In phase 2, the diets (Table 1) were mixed to have 170, 158, and 148 g/kg CP, and 0.79, 0.75, and 0.65 g/MJ NE. Dietary CP and lysine content in CON diets were set in NRC [1]. Treatments reduced the dietary CP content by 1% and 2%, respectively. All diets in phase 1 and phase 2 were designed to hold 10.38 MJ/kg of NE based on NRC [1]. NE figures used for ingredient (corn, soybean meal, wheat, etc) were 11.43, 8.75, 6.99, and 30.40 MJ/kg, respectively. Dietary NE levels were calculated in accordance with method of [9] and were established on chemical evaluation of diet raw material

**Table 1.** Compositions of growing-finishing pig diets for phase 1 and phase 2 (as-fed basis)

Item	Phase 1 <sup>1)</sup>			Phase 2 <sup>2)</sup>		
	CON	TRT1	TRT2	CON	TRT1	TRT2
Ingredients (g/kg)						
Corn	440.1	412.6	461.3	454.9	479.4	508.0
Wheat	111.5	150.0	150.0	150.0	150.0	150.0
Soybean meal (48%)	231.0	226.0	173.0	173.4	166.5	139.0
Milk product	30.0	30.0	30.0	30.0	30.0	30.0
DDGS	80.0	80.0	80.0	80.0	80.0	80.0
Rice bran	10.0	20.0	20.0	20.0	20.0	20.0
Tallow	32.3	23.3	19.3	28.5	15.5	12.8
Molasses	30.0	30.0	30.0	30.0	30.0	30.0
Dicalcium phosphate	0.25	0.25	0.30	0.25	0.25	0.25
Limestone	16.8	14.0	14.0	17.3	13.3	13.5
Salt	3.0	3.0	3.0	3.0	3.0	3.0
Choline chloride	0.8	0.8	0.8	0.8	0.8	0.8
L-Lysine (98.5%)	8.3	3.9	10.0	5.7	5.2	6.4
DL-Methionine (99%)	0.5	0.6	1.4	0.6	0.4	0.5
L-Threonine (99%)	0.2	0.3	1.2	0.3	0.4	0.5
Vitamin premix <sup>3)</sup>	2.0	2.0	2.0	2.0	2.0	2.0
Trace mineral premix <sup>4)</sup>	1.0	1.0	1.0	1.0	1.0	1.0
Calculated composition <sup>5)</sup>						
NE (MJ/kg)	10.38	10.38	10.38	10.38	10.38	10.38
Crude protein (%)	19.1	18.0	17.3	17.0	15.8	14.8
Crude fat (%)	6.49	5.75	5.46	6.36	5.15	4.94
SID Lys (%)	0.94	0.92	0.82	0.84	0.80	0.70
Ca (%)	0.8	0.7	0.7	0.81	0.66	0.66
Total P (%)	0.63	0.66	0.65	0.63	0.63	0.62
SID Lys:NE ratio (g/MJ)	0.91	0.89	0.79	0.79	0.75	0.65

<sup>1)</sup>CON (CP: 19.1%, SID Lys: 0.94%, NE: 10.38 MJ/kg, SID Lys: NE: 0.91 g/MJ); TRT1 (CP: 18.0%, SID Lys: 0.92%, NE: 10.38 MJ/kg, SID Lys: NE: 0.89 g/MJ); TRT2 (CP: 17.3%, SID Lys: 0.82%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ).

<sup>2)</sup>CON (CP: 17.0%, SID Lys: 0.84%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ); TRT1 (CP: 15.8%, SID Lys: 0.80%, NE: 10.38 MJ/kg, SID Lys: NE: 0.75 g/MJ); TRT2 (CP: 14.8%, SID Lys: 0.70%, NE: 10.38 MJ/kg, SID Lys: NE: 0.65 g/MJ).

<sup>3)</sup>Provided per kg of complete diet: vitamin A, 4,000 IU; vitamin D<sub>3</sub>, 800 IU; vitamin E, 171 IU; vitamin K, 2 mg; riboflavin, 4 mg; niacin, 20 mg; thiamine, 4 mg; d-pantothenic, 11 mg; choline, 166 mg; biotin, 0.08 mg; and vitamin B<sub>12</sub>, 16 µg.

<sup>4)</sup>Provided per kg of complete diet: Cu (as CuSO<sub>4</sub> · 5H<sub>2</sub>O), 15 mg; Fe (as FeSO<sub>4</sub> · 7H<sub>2</sub>O), 80 mg; Zn (as ZnSO<sub>4</sub>), 56 mg; Mn (MnO<sub>2</sub>), 74 mg; I (as KI), 0.3 mg; Co (as CoSO<sub>4</sub> · 5H<sub>2</sub>O), 0.5 mg; and Se (as Na<sub>2</sub>SeO<sub>3</sub> · 5H<sub>2</sub>O), 0.4 mg.

<sup>5)</sup>Calculated value.

DDGS, dried distillers grains with solubles; NE, net energy; SID Lys, standardized ileal digestible lysine; CP, crude protein.

for CP, ether extract (EE) and crude fiber (CF) [10]. Besides the starch content was estimated by manual of [11]. The true NE figure of crystal structure of lysine, methionine, and threonine used on this study was 14.09, 17.31, and 12.30 MJ/kg of DM in each by applying INRA and AFZ figures [12].

The tangible equation applied to the computation of NE was: NE = (0.00294 × MJ/kg Digestible energy) + (1.58 × g/kg ether extract) + (0.47 × g/kg Starch) – (0.97 × g/kg Crude protein) – (0.98 × g/kg Crude fiber).

Other constituents of feed were mixed to satisfy or surpass the nutrient demand [1] for 30–50 kg of BW growing pigs and 50 to 110 kg of finishing pigs and fed a coarse form.

### Sampling and measurements

The apparent total tract digestibility (ATTD) of gross energy (GE), dry matter (DM) and nitrogen (N) were settled into usage of chromic oxide (2 g/kg) as an inactive maker [13]. Pigs were supplied feed containing chromic oxide on 35 and 70 days in phase 1 and 2 respectively. Fresh feces were gathered into respective pen (phase 1 for 41 day; phase 2 from 41 to 76 day), and these samples were saved in a refrigerator at  $-20^{\circ}\text{C}$  until analysis. All diets and feces samples were evaluated for DM and N following the procedures outlined [10]. N and GE were settled with a Kjeltac 2300 nitrogen analyzer (Foss Tecator AB, Hoeganaes, Sweden) and Parr 6100 oxygen bomb calorimeter (Parr Instrument, Moline, IL). Chromium was analyzed via UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan) following the manuals described by [14].

The ATTD of DM and N were determined to use the following second-hand equations:

Computation equation of apparent total tract digestibility =  $\{1 - [(NCf \times CCd) / (NCd \times CCf)]\} \times 100$ ,

NCf = nutrient content of feces (% DM),

NCd = nutrient content of diet (% DM),

CCf = chromium content of feces (% DM),

CCd = chromium content of diets (% DM).

At the final study period, all of pigs were killed in a regional slaughterhouse. Hot carcass weight was immediately settled after slaughter, and fat back, muscular percentage, TBARS, meat color and muscle meat proportion were measured into usage of a real-time ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark). After refrigerating at  $2^{\circ}\text{C}$  for 24 h, longissimus muscle sample was removed to 2.54 cm between 10th and 11th rib (pigs' right side). Sensory evaluation including marbling, intramuscular fat, color and firmness scores) were determined by described manuals of [15]. Drip loss was evaluated by the proportion of the initial weight applying 2 g of meat sample in accordance with the manual of [16]. Replicate pH figure of respective sample was determined into usage of a glass-electrode pH meter (WTW pH 340-A, Wtw Measurement Systems, Ft. Myers, FL, USA). Water holding capacity (WHC) was determined via the instruction of [17]. *Longissimus* muscle area (LMA) was determined through finding the longissimus muscle exterior at the 10th rib, which also employed the digitizing area-line sensor. The final rib of backfat thickness which determined at the median of separated corpse were revised by usage of regression assay for the average final BW before being gathered using the equation suggested by [15].

### Statistical analysis

In this experiments, all data were analyzed by ANOVA applying the General Linear Models (GLM) procedures of SAS (SAS Institute, 2008), with the pen as the experimental unit. Dissimilarities between dietary treatment were settled using Duncan's multiple range tests. All consequences were presented in the table as means, standard error (SE) and *p*-values of  $< 0.05$ . A *p*-values were meant statistically significant.

## RESULTS

### Growth performance and nutrient digestibility

In phase 1, growth performance including ADG, ADFI, and G:F ratio did not show meaningful dissimilarities between the treatments (Table 2). In common with growth performance, digestibility of DM, N, and GE did not show dissimilarities among the treatments on day 42. In phase 2, each

period (0 to 42 day; 42 to 77 day) and the whole period (0 to 77 day), there were nothing to change on BW, ADG, ADFI and G: F ratio among treatments (Table 3). At 43 and 77 day, no dissimilarities in the ATTD of DM and energy were checked between treatments (Table 4). On the other hand, the CON group had a greater N digestibility ( $p < 0.05$ ) than that of TRT2 group.

### Meat quality

There were no dissimilarities among dietary treatments on hot carcass traits (HCW), pH value, drip loss percentage, WHC, TBARS concentration, LMA, and backfat thickness (Table 5). In Minolta color parameter, lightness ( $L^*$ ) of TRT2 group was analogous to that of CON and TRT1 group. Redness ( $a^*$ ) was meaningfully decreased ( $p < 0.05$ ) when SID Lys: NE proportion decreased. The color of TRT2 group was meaningfully increased ( $p < 0.05$ ) compared with that of CON group but was analogous to that of TRT1 group. The marbling and firmness scores improved ( $p < 0.05$ ) when SID Lys: NE proportion decreased.

## DISCUSSION

### Growth performance and nutrient digestibility

Generally, diets with low crude protein caused reducing growth rate and feed efficiency compared with diets with high protein [18]. Also, 2% reduction of dietary CP decreased pig's growth performance [19]. However, diets of reducing Lys: NE proportion with low dietary CP did not cause the change of growth performance in growing and finishing phases in the current study (Tables 2 and 3). Results obtained in the current study were in accordance with many former studies, which reported no change in growth performance of pig incepted low protein diet [6,20]. These contradictory results could be explained by the use of different energy system in this experiment. Digestible energy (DE) or metabolic energy (ME) system had been used in almost every previous experiment. However, net energy (NE) used in this study represents more accurate energy content than DE and ME, and is considered independent of the feed intake. Actually, Campbell & Taverner [21] employed iso-energetic feeds with various protein contents and observed no dissimilarity in ADFI. Also, other researcher reported that NE content in diets did not influence the ADFI in finishing pigs [22]

**Table 2.** Effect of reducing SID Lys: NE ratios on growth performance and nutrient digestibility in growing pigs (phase 1)

Items	CON	TRT1	TRT2	SE
Growth performance				
Initial BW (kg)	37.42 <sup>1)</sup>	37.01	37.25	0.61
Final BW (kg)	67.46	66.24	66.37	0.67
ADG (g)	715	696	693	16
ADFI (g)	1,512	1,481	1,519	27
G:F ratio	0.473	0.470	0.456	0.012
Nutrient digestibility (%)				
Dry matter	74.94	74.55	75.78	0.43
Nitrogen	67.58	69.09	70.06	0.82
Gross energy	73.28	72.85	72.79	0.43

<sup>1)</sup>Each mean represents 4 pens with 6 pigs each per treatment. CON (CP: 19.1%, SID Lys: 0.94%, NE: 10.38 MJ/kg, SID Lys: NE: 0.91 g/MJ); TRT1 (CP: 18.0%, SID Lys: 0.92%, NE: 10.38 MJ/kg, SID Lys: NE: 0.89 g/MJ); TRT2 (CP: 17.3%, SID Lys: 0.82%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ).

SE, standard error; BW, body weights; ADG, average daily gain; ADFI, average daily feed intake; G:F, gain to feed; CP, crude protein; SID Lys, standardized ileal digestible lysine; NE, net energy.

**Table 3. Effect of reducing SID Lys: NE ratios on growth performance in finishing pigs (phase 2)**

Items	CON	TRT1	TRT2	SE
Initial BW (kg)	54.31 <sup>1)</sup>	54.19	53.99	1.42
42 d BW (kg)	88.12	87.58	86.96	1.28
Final BW (kg)	119.06	118.35	117.80	1.13
0–42 day				
ADG (g)	805	795	785	33
ADFI (g)	2,120	2,202	2,131	71
G:F ratio	0.380	0.361	0.368	0.011
42–77 day				
ADG (g)	884	879	881	37
ADFI (g)	2,732	2,676	2,652	98
G:F ratio	0.324	0.328	0.332	0.019
0–77 day				
ADG (g)	841	833	829	26
ADFI (g)	2,398	2,418	2,368	65
G:F ratio	0.351	0.345	0.350	0.011

<sup>1)</sup>Each mean represents 4 pens with 6 pigs each per treatment. CON (CP: 17.0%, SID Lys: 0.84%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ); TRT1 (CP: 15.8%, SID Lys: 0.80%, NE: 10.38 MJ/kg, SID Lys: NE: 0.75 g/MJ); TRT2 (CP: 14.8%, SID Lys: 0.70%, NE: 10.38 MJ/kg, SID Lys: NE: 0.65 g/MJ).

SE, standard error; BW, body weights; ADG, average daily gain; ADFI, average daily feed intake; G:F, gain to feed; CP, crude protein; SID Lys, standardized ileal digestible lysine; NE, net energy.

**Table 4. Effect of reducing SID Lys: NE ratios on nutrient digestibility in finishing pigs (phase 2)**

Items (%)	CON	TRT1	TRT2	SE
42 day				
Dry matter	80.39 <sup>1)</sup>	79.79	78.39	0.98
Nitrogen	77.37	77.45	77.23	0.94
Gross energy	78.44	77.34	77.13	1.22
77 day				
Dry matter	79.51	79.40	77.01	0.95
Nitrogen	79.78 <sup>a</sup>	77.79 <sup>ab</sup>	76.22 <sup>b</sup>	1.03
Gross energy	76.68	76.24	74.87	1.15

<sup>1)</sup>Each mean represents 4 pens with 6 pigs each per treatment. CON (CP: 17.0%, SID Lys: 0.84%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ); TRT1 (CP: 15.8%, SID Lys: 0.80%, NE: 10.38 MJ/kg, SID Lys: NE: 0.75 g/MJ); TRT2 (CP: 14.8%, SID Lys: 0.70%, NE: 10.38 MJ/kg, SID Lys: NE: 0.65 g/MJ).

<sup>a,b</sup>Within a row, mean with different superscript differ ( $p < 0.05$ ).

SE, standard error; CP, crude protein; SID Lys, standardized ileal digestible lysine; NE, net energy.

and NE content with low CP did not cause influence on whole daily feed intake in growing pigs [4]. For nutrient digestibility, He et al. [23] showed that 6% reduction of dietary CP indicated the highest ileal digestibility of CP and amino acid (AA). This notion was also supported by a number of published studies [24,25]. In the current study, ATTD of N in TRT2 group were lower ( $p < 0.05$ ) than those of CON group at the last of phase 2, and there was also a trend in reduction of ATTD of N in TRT1 group (Table 4). This finding was different from that in other previous studies, so it need that more research is required. However, a reduction of dietary CP did not necessarily cause influence on the pigs' growth in our study. Therefore, introduction of NE system with 2% dietary CP can alleviate the established negative effect from reducing dietary CP in the nutritional strategy.

**Table 5.** Effect of reducing SID Lys: NE ratios on meat quality in finishing pigs (phase 2)

Items	CON	TRT1	TRT2	SE
HCW (kg)	90.2 <sup>1</sup>	90.9	91.3	0.50
pH value	5.71	5.75	5.72	0.01
Drip loss (%)				
1 day	6.74	6.62	6.70	0.54
3 day	7.89	6.62	7.88	0.68
5 day	10.08	9.48	10.05	0.77
WHC (%)	40.39	38.01	39.14	2.27
Minolta color				
Lightness (L*)	51.44 <sup>b</sup>	54.41 <sup>a</sup>	53.70 <sup>ab</sup>	0.82
Redness (a*)	18.21 <sup>a</sup>	17.14 <sup>b</sup>	17.18 <sup>b</sup>	0.26
Yellowness (b*)	6.79	7.86	7.36	0.33
Sensory evaluation				
Color	2.68 <sup>a</sup>	2.34 <sup>b</sup>	2.60 <sup>a</sup>	0.08
Marbling	1.22 <sup>c</sup>	1.94 <sup>b</sup>	2.20 <sup>a</sup>	0.06
Firmness	1.98 <sup>b</sup>	2.40 <sup>a</sup>	2.58 <sup>a</sup>	0.08
TBARS (mg MA/kg)				
0 day	0.019	0.018	0.020	0.001
5 day	0.071	0.070	0.071	0.001
10 day	0.186	0.184	0.184	0.004
LMA (cm <sup>2</sup> )	41.64	37.36	38.74	3.28
Backfat thickness (mm)	19.6	20.3	20.6	0.31

<sup>1</sup>Each mean represents 4 pens with 6 pigs each per treatment. CON (CP: 17.0%, SID Lys: 0.84%, NE: 10.38 MJ/kg, SID Lys: NE: 0.79 g/MJ); TRT1 (CP: 15.8%, SID Lys: 0.80%, NE: 10.38 MJ/kg, SID Lys: NE: 0.75 g/MJ); TRT2 (CP: 14.8%, SID Lys: 0.70%, NE: 10.38 MJ/kg, SID Lys: NE: 0.65 g/MJ).

<sup>a,b</sup>Within a row, mean with different superscript differ ( $p < 0.05$ ).

SE, standard error; HCW, hot carcass weight; WHC, water hold capacity; TBARS, thiobarbituric acid reactive substance; LMA, longissimus muscle area; CP, crude protein; SID Lys, standardized ileal digestible lysine; NE, net energy.

### Meat quality

Meat quality is an important economic trait and decides the preference of meat from customers. The main valuable elements are color, pH, fat composition and drip loss [26,27]. In the current study, reducing Lys: NE proportion with reducing dietary CP does not influence on the ultimate results of HCW, muscle pH value, drip loss percentage or other measures of WHC (Table 5). Results obtained in the current study were in accordance with many former studies [28,29]. Spencer et al. [30] reported that pigs (initial BW = 77 kg) fed diets reduced by 23 g/kg CP (113 g/kg dietary CP concentration compared with 136 g/kg of CON diet), showed increased backfat and a trend to have smaller LMA. Also, Lee et al. [31] also found that LMA was lower in low (12%) dietary CP than in high (16%) and medium (14%) dietary CP. The fatness in carcass increased when pigs fed with low-CP diet. This is because energy expenditure reduced in the catabolism of excess dietary protein [2]. Low protein diets lead to better utilization of energy due to a reduction of urinary energy losses and heat production, and this surplus energy promotes the retention of energy (particularly fat deposition) [6]. Therefore, excess energy is changed to fat, thereby creating a fatter carcass. Besides, a reducing dietary protein level and the following enrichment in carbohydrates or the same fat level with limiting essential amino acid would enable to improve the efficiency of energy utilization, causing increasing fat deposition in carcass [32]. However, in this study, there were no meaningful dissimilarities on backfat thickness and LMA among treatments. The dissimilarities between our

current study may be caused by introduction of NE system. Therefore, the adoption of NE system with 2% dietary CP diets can alleviate the problems that could arise when pigs were consumed diets with low protein. During the past few years, the leaner genotypes were selected, resulting in reduced intramuscular fat (IMF) due to preference of consumer [33]. As time passed, their preference improved on the increasing IMF [34]. In the current study, IMF or marbling and firmness scores of TRT1 and TRT2 groups improved ( $p < 0.05$ ) compared with those of CON group (Table 5). This result in the current study were in accordance with the former studies, which reported the IMF percentage was improved when dietary protein level was decreased by 3 g/kg [18]. IMF was related to hardness, and the intensities of pork decreased IMF increased in beef [35]. Likewise, restricting dietary CP during the growing pig decreased the firmness and tended to raise the IMF content [36]. Thus, this result in the current study indicated that increasing IMF of pork decrease pork's firmness scores. The  $a^*$  figures are colour coordinates indicating a difference from green to red color. An increasing  $a^*$  figures indicates that a sample had more red color and decreasing  $a^*$  figures represents that color tended to be green. The  $b^*$  figures are also colour coordinates, indicating a difference in color from blue to yellow. An increasing  $b^*$  value indicates that a sample had more blue color and decreasing  $a^*$  figures represents that color tended to be yellow [37]. The  $L^*$  indicates a sample with more brightness. In the current results, the  $L^*$  increased, but  $a^*$  decreased when Lys: NE proportion was reduced. Cameron et al. [38] reported that the  $a^*$ ,  $b^*$  and chroma figures of meat obtained from pigs fed a diet holding 0.42 g of lysine/MJ of ME was higher than that from pigs fed diets either 0.80 or 1.17 g of lysine/MJ of ME. Moreover, some studies reported that meat color ( $L^*$ ,  $a^*$ , and  $b^*$ ) increased when dietary CP was decreased [36]. The dissimilarities between our current study and these findings may be generated by different strains of pigs and different analytical methods [39].

## CONCLUSION

The application of NE system can alleviate adverse effect such as reduction of growth and fatness carcass when dietary CP decreased. Also, approximately 0.79 and 0.65 g/MJ of SID Lys: NE proportion is supposed to be the optimum SID Lys: NE proportion to attain improved pork quality without impairing growth performance in growing and finishing pigs, respectively.

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