TITLE PAGE

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Abstract

This study was executed to estimate the impacts of increasing dietary standardized ileal digestible (SID) lysine and net energy levels on growth, nutrient absorption, and meat carcass traits in growing-finishing pigs. In total, 90 pigs [(Yorkshire × Landrace) × Duroc] were erratically dispensed to 3 treatments (6 replicate/treatment) with 5 pigs (3 barrows and 2 gilts) per pen, and their average primary body weight was 20.51± 0.02 kg. The trial period was 16 weeks (growing stage, initial to week 8; finishing stage, week 8 to week 16). The dietary treatments used included control (CON) as the basal diet, TRT1 (basal diet + 0.05% SID lysine), and TRT2 (basal diet + 0.05% SID lysine + 0.084 MJ/kg net energy) for both the growing and finishing stages. Both the TRT1 and TRT2 group diets improved (p = 0.033) average daily gain (ADG) at week 12 and tended to enhance (p = 0.088) body weight at week 12 and ADG at the overall period compared to the CON group. Moreover, pigs in the TRT2 group had higher backfat thickness (p = 0.034) at week 12 in comparison to the TRT1 and CON diets. Nevertheless, no treatment effect was found (p > 0.05) in nutrient absorption or carcass grade among the dietary treatments. Hence, incorporating the increasing level of 0.05% SID lysine and 0.084 MJ/kg net energy into the pig diet during the growing and finishing stages can be considered a suitable approach for enhancing both growth efficiency and carcass backfat thickness in pigs.

Keywords: carcass traits, energy, growing-finishing pig, lysine, performance

INTRODUCTION

Pig farmers should improve their understanding of the correlation between swine production efficiency and nutritional accessibility to modify feeding strategies and diet compositions to optimize profitability in the swine industry. Lysine is an essential amino acid in the diet that cannot be synthesized by pigs, so the level of lysine in the diet could impact growth performance and nutrient digestion [1, 2]. The lysine requirement of animals can be more accurately assessed by measuring the SID. Standardized ileal digestible levels have been suggested as the most effective approach for incorporation in routine feed formulations, ensuring optimal nutrition for animals [3]. The animal diet is the source of energy for the growth of pigs; thus, the amount of energy in the pig diet is crucial to the development of swine. The net energy represents the actual available energy to the animals for management and production. The efficiency of pigs can be predicted more accurately by the net energy system than by metabolizable energy and digestible energy [4]. Low-energy diets are associated with reduced energy consumption because pigs may consume less energy if there is a decrease in the concentration of energy in their diet [5]. Hence, net energy is considered the best way to assess how much energy is consumed and how it affects a pig's performance, but net energy is hard to quantify, and very few values are convenient for various waste elements [6]. However, feed is the largest expense of swine production, and energy is the most expensive ingredient [7, 8]. Therefore, special attention should be paid to lysine contents and energy levels when formulating feed components.

According to reports, improving nutritional lysine contents and/or the amount of energy had positive effects on the growth efficiency of pigs [9, 10]. As mentioned by Main et al. [1], feeding pigs with high SID lysine contents improved growth performance. The growth efficiency of growing-finishing pigs showed a positive response to the increase in dietary net energy levels [11], and the changes in dietary net energy levels have no discernible impact on the performance or carcass composition of pigs [12]. Several studies have employed the implementation of the net energy system as a strategy for achieving growth, carcass features, and quality of meat over the past few years [13, 14]. The mechanism for the potential additional benefit of feeding above generally accepted net energy and lysine requirements in improving pig growth performance may involve enhanced nutrient utilization and metabolic efficiency, possibly through the stimulation of protein synthesis [15]. However, employing a low-lysine diet was not effective in enhancing the intramuscular fat content or improving the eating quality of pork muscle in finishing pigs with high slaughter weights [16]. Similarly, the utilization of a low-energy diet and the subdivision of the growing-finishing phase based on dietary protein levels did not yield any significant effects on growth performance or carcass characteristics [17]. To achieve a noticeable impact on growth performance and nutrient digestibility, a greater range of dietary energy levels may be necessary, especially when accounting for digestible nutrient concentration [18]. Altering the diet to ensure sufficient dietary lysine and net energy content can be the paramount factor in optimizing muscle development, as the lysine and net energy needs undergo significant changes during this period [19]. The disparities observed among these studies can be attributed to a multitude of factors, including the types of feed ingredients employed, variations in dietary lysine and net energy concentrations, and differences in the age and genetic makeup of the pigs utilized [20].

Therefore, our experiment targeted assessing the outcomes of increasing dietary levels of SID lysine and net energy on growth, nutrient absorption, and carcass traits of growing-finishing pigs, as well as evaluating the appropriate dietary strategy.

MATERIAL AND METHODS

The Animal Care and Use Committee of Dankook University, Cheonan, Republic of Korea, authorized the research protocol (DK-2-2002) for our current experiment.

Experimental design and diets

Ninety pigs [(Yorkshire × Landrace) × Duroc] were arbitrarily distributed into three categories depending on their primary body weight (20.51 ± 0.02 kg). Every treatment consisted of six repetition pens, each containing five mixed-sex (3 barrows and 2 gilts) pigs. The trial period was 16 weeks, which included the growing stage (initial to week 8) and the finishing stage (week 8 to week 16). During the growing and finishing phases, the three dietary treatments were CON (basal diet), TRT1 (basal diet + 0.05% SID lysine), and TRT2 (basal diet + 0.05% lysine SID + 0.084 MJ/kg net energy). All of the pig's diets were prepared according to the National Research Council's [21] (Table 1). The determination of dietary net energy levels followed the procedure outlined by Noblet et al. [22] and was determined through chemical assessment of the protein content (CP), ether extract (EE), and crude fiber (CF) in the raw materials used for the diet, as outlined by AOAC [23]. The actual net energy values for the crystal structures of lysine, methionine, and threonine utilized in this study were derived through the application of INRA and AFZ data [24]. Before receiving the experimental diet, pigs were provided with a basal diet for 10 days to adapt to the experimental diet.

All of the pigs were kept in a space that was preserved clean and had a slatted plastic floor, mechanical aeration, and environmental controls. The desired room temperature and humidity were set at 25°C and 60%, respectively. For the pigs' unlimited access to feed and water, stainless steel self-feeders and nipple drinkers were provided for each enclosure.

Sample collection and measurement

To estimate the ADG, each pig was weighed at initial, 4, 8, 12, and 16 weeks. The amount of feed left in each pen was evaluated every day to assess the average daily feed intake (ADFI). The gain-to-feed ratio (G: F) was measured using ADG and ADFI values.

To assess the diet's retention of dry matter (DM), nitrogen, and energy, 0.2% Cr_2O_3 was utilized as a non-digestible indicator one week earlier fecal assembly. During weeks 4, 8, 12, and 16, two pigs were erratically chosen from every pen for taking fecal specimens through the rectal massage technique. Following a per-pen pooling of the specimens, the chosen specimens were stored at -20°C in a freezer until analysis. All excreta were dried (60℃) using a drier oven for 72 hours. The excreta specimens were ground into powder form to pass through a sieve that was 1 mm in diameter. Feed and fecal specimens were examined for DM, nitrogen, and energy by using the technique given by the Association of Official Analytical Chemists [25]. The combustion heat in the specimen was measured using a Parr 6100 bomb calorimeter to determine energy. The specimens' chromium was evaluated utilizing atomic absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan). The calculation of apparent total tract digestibility (ATTD) of nutrients was determined using the procedure described by Biswas et al. [26].

At the initial, week 4, 8, 12, and 16, back fat thickness (BFT) and lean meat percentage (LMP) were calculated using pig-log 105 (SFK Technology, Herlev, Denmark) to estimate the BFT and LMP (6.5 cm area on the right and left end frames). Back fat thickness (mm), carcass weight (kg), and carcass grade were also estimated. Pig carcasses were graded as Grade "1+," "1," or "2" depending on the amount of marbling, lean color, and stomach streaking [27]. According to Ha et al. [28], BFT was adjusted to an overall weight of 115 kg.

Statistical analysis

The feeding strategies were used as the classifying variable in a complete block design that was statistically analyzed by a one-way ANOVA. The means were compared to determine if there was any significant difference using Duncan's various comparison analyses. The standard error of means (SEM) represented data variation; a value of $p < 0.05$ was regarded as statistically significant and $p < 0.10$ are regarded as trend.

RESULTS

Growth performance and nutrient digestibility

Pigs in TRT1 and TRT2 treatments exhibited a greater ($p = 0.033$) ADG by week 12 in comparison to those on the CON diet (Table 2). Additionally, BW at week 12 and overall ADG tended to be greater ($p = 0.088$) in the

TRT1 and TRT2 groups in comparison to the CON group. The G: F ratio and ADFI showed no alterations among the treatment group. Furthermore, the different levels of SID lysine and net energy groups showed no differences in the retention of DM, nitrogen, and energy at weeks 4, 8, 12, and 16 (Table 3).

Carcass traits and grade

The dietary TRT2 group improved ($p = 0.034$) BFT at week 12 in comparison to the TRT1 and CON groups. However, the LMP of pigs fed a SID lysine and net energy-included diet did not alter significantly (Table 4). Moreover, feeding approaches did not change considerably on carcass grade among the dietary treatment groups. We observed that the "1%" carcass grade was higher among the treatment groups (Table 5).

DISCUSSION

In a previous study on piglets, enhancing SID lysine levels in dietary treatments enhanced piglets' growth efficiency (ADG and gain-to-feed ratio) [29]. Another study by Rodrguez-Sanchez et al. [30] showed that several feeding regimens with dietary lysine concentrations ranging from 7.0 to 6.0 g/kg lowered ADG devoid of affecting gain-to-feed ratio. The lysine restrictions (20, 30, and 40%) in the grower period resulted in compensatory weight gains and increased feed efficiency [31]. However, pigs provided lysine-deficient diets showed poorer feed efficiency, but ADG and feed intake were unaffected in different dietary lysine concentrations [32]. It is reported that increasing net energy levels from 8.1 to 11.1 MJ/kg in the growing-finishing pig diets improved ADG, ADFI and G: F ratio [11]. In growing-finishing pigs, a reduction in nutritional net energy from the maximal net energy level decreased the G: F ratio [12]. In finishing pigs, the addition of wheat middling reduced the energy content of the diet by 15%, which impeded the ability of the animals to their growth performance (ADG and G: F ratio) [33]. The weaned pig growth rate was not enhanced by increasing energy concentration, although it could boost digestible energy intake, decrease feed intake, and improve feed efficiency [34]. Pig growth performance responded differently to dietary lysine and energy content increases at various growth stages. The cause of this is thought to be because different growth phases required different amounts of energy and had variable lysine concentrations [21]. In our study, the administration of SID lysine and net energy improved ADG and BW in both treatment diets compared to the CON diet in growing-finishing pigs. The elevation in dietary net energy levels provided pigs potential promoting their growth. Furthermore, the biological characteristics of lysine also served to boost growth performance. In our study, the observed significant effects on daily gain and final body weight without significant changes in feed intake or feed conversion (G: F ratio) can be explained by other factors that influence growth performance in pigs. Some factors like nutrient utilization, metabolic efficiency, genetic variability, dietary composition, and individual variability may help explain this phenomenon.

The growing pigs fed diets containing 0.85% lysine exhibited reduced nitrogen consumption, excretions, and utilization than pigs fed other treatment regimens [35]. In a previous study, the apparent DM and nitrogen absorption of growing pigs were not impacted by variations in nutritional lysine levels [36]. As mentioned by Yang et al. [31], lysine restriction (20, 30, and 40%) linearly reduced the digestibility of DM and gross energy during the grower phase. Similarly, the digestibility of DM was not enhanced by decreasing supplemental lysine or energy content, but nitrogen retention was decreased by a lysine-restricted diet [37]. Pigs between the weights of 13 to 20 kg and 20 to 30 kg of BW which consumed nutritional regimens comprising 14.5 MJ of ME/kg had the highest levels of nitrogen retention [38]. In agreement with our research, Kim et al. [10] found no difference in the digestibility of DM, nitrogen, and energy in different energy levels of growing pig diets. The inconsistency of results might be caused by the amount and quality of lysine and net energy, animal species, and age. More research is needed to assess the proper reason for the insignificant outcomes of digestibility by increasing dietary lysine and net energy levels in the pig diet.

The inclusion of dietary lysine and energy did not effect on carcass parameters in this study. In a prior investigation, it was determined that reducing the levels of dietary protein and lysine in the finishing diet for barrows did not yield sustainable significance in terms of BFT and LMP [14]. Lysine-restricted growing pig diet caused a quadratic impact on dressing percentage, but not on the other carcass parameters [31]. As the finishing pigs' energy intake increased, the proportion of external fat, intracellular backfat, and thickness fat increased linearly [39]. Finishing pigs provided on the increased level of energy diets (3.48 Mcal of metabolizable energy) had fatter carcasses than pigs on the decreased level of energy diets (3.30 Mcal of metabolizable energy) [40]. Pigs administered high net energy diets had higher fat depth in the 10th rib area than pigs provided lower net energy diets, which resulted in a smaller amount of lean meat in the carcasses of live animals [41]. It has been reported that the lipid deposition level was not affected by the contents of dietary amino acids [42]. In comparison to the TRT1 and CON groups, the dietary TRT2 group had a better BFT at week 12 in our trial. As a result, we concluded that increasing dietary SID lysine content was ineffective in improving carcass traits. The maximal amount of body protein synthesis occurred when pigs were fed a high-energy diet. Lipid deposition will require an excessive amount of energy [34]. An improved carcass BFT indicates an enhancement of the accumulation of adipose tissue [43]. Therefore, we considered that the increase in carcass traits in the TRT2 group was related to the increase in dietary net energy levels in this study.

CONCLUSION

The increasing level of 0.05% SID lysine and 0.084 MJ/kg net energy in the diet of growing-finishing pigs improved body weight gain without impairing nutrient uptake. Additionally, pigs fed an increased net energy and SID lysine diet enhanced the carcass BFT. Therefore, the addition of increasing level of 0.05% and SID lysine and 0.084 MJ/kg net energy could be a suitable feed supplement for growing-finishing pigs for better growth and backfat thickness.

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Table 1. Formula and composition of experimental diet (as fed-basis)

	Grower (initial to week 8)			Finisher (week 8 to week 16)		
	CON	**TRT1**	**TRT2**	**CON**	**TRT1**	**TRT2**
Ingredients, %						
Corn	64.98	57.35	57.35	69.40	61.64	61.13
Rice	3.00	3.00	3.00	3.00	3.00	3.00
Soybean meal (48% crude protein)	15.26	25.46	25.46	9.66	17.66	17.86
DDGS	5.00	4.00	4.00	6.00	6.00	6.00
Palm kernel meal	2.00	-	-	3.00	2.00	2.00
Tallow	3.20	4.30	4.30	3.00	4.10	4.40
Molasses, cane	2.80	2.50	2.50	2.80	2.50	2.50
Limestone	1.20	1.15	1.15	1.12	1.14	1.14
Monocalcium phosphate	0.62	0.59	0.59	0.50	0.52	0.53
Salt	0.41	0.35	0.35	0.40	0.35	0.35
Methionine, 98%	0.15	0.13	0.13	0.07	0.08	0.08
Lysine, 50%	0.67	0.59	0.59	0.51	0.50	0.50
Threonine, 98.5%	0.16	0.11	0.11	0.11	0.08	0.08
Tryptophane, 20%	0.23	0.15	0.15	0.17	0.17	0.17
Vitamin/Mineral mixture[a]	0.20	0.20	0.20	0.18	0.18	0.18
Vitamin E, 10%	0.02	0.02	0.02	0.01	0.01	0.01
$CuSO_4$	0.03	0.03	0.03	-	-	-
Phytase	0.07	0.07	0.07	0.07	0.07	0.07
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition						
DE, MJ/kg	14.78	14.91	14.91	14.74	14.86	14.86
NE, MJ/kg	10.33	10.33	10.42	10.35	10.37	10.43
SID lysine, g/kg	10.20	10.70	10.70	8.10	8.60	8.60
SID lysine/DE, g/MJ	0.7	0.7	0.7	0.6	0.6	0.6

SID lysine/NE, g/MJ	1.0	1.0	1.0	0.8	0.8	0.8
Analyzed composition, %						
Crude protein	16.36	17.61	17.61	14.46	15.25	15.30
Crude fat	6.83	6.75	6.75	6.77	6.79	7.07
Crude ash	5.09	5.04	5.04	4.70	4.77	4.79
Crude fiber	2.74	2.46	2.46	2.79	2.64	2.64
Calcium	0.77	0.76	0.76	0.71	0.72	0.72
Phosphorus	0.41	0.40	0.40	0.38	0.38	0.38

Abbreviation: DE, digestible energy; NE, net energy; DDGS, distiller's dried grains with soluble; SID, standardized ileal digestible.

[a] Provided per kilogram of complete diet: 4800 IU vitamin A; 1750 IU vitamin D_3; 2.40 mg vitamin K_3; 4.60 mg riboflavin; 1.20 mg vitamin B_6; 13 mg pantothenic acid; 23.50 mg niacin; 0.02 mg biotin; 12.50 mg Mn (as MnO_2); 179 mg Zn (as $ZnSO_4$); 5 mg Cu (as $CuSO_4 \cdot 5H_2O$); 0.50 mg I (as KI); and 0.40 mg Se (as $Na_2SeO_3 \cdot 5H_2O$); 75 mg Fe (as $FeSO_4 \cdot 7H_2O$).

A growing-to-finish feeding regimen designed to either meet or beyond the NRC's (2012) suggested standards including superdose level of phytase (FTU/kg).

Table 2. Effect of increasing dietary SID lysine content and NE level on the growth performance of growing-finishing pigs[1]

	CON	TRT1	TRT2	SEM	*p*-value
Body weight, kg					
Initial	20.53	20.50	20.50	0.34	0.999
Week 4	36.98	37.17	37.41	0.35	0.897
Week 8	58.16	58.91	58.79	0.31	0.615
Week 12	82.34	84.55	84.37	0.46	0.088
Week 16	108.27	110.77	111.24	0.70	0.182
ADG, g					
Week 4	587	595	604	3.64	0.172
Week 8	757	777	764	6.25	0.435
Week 12	864[b]	916[a]	914[a]	9.64	0.033
Week 16	926	936	960	10.74	0.455
Overall	783	806	810	6.95	0.097
ADFI, g					
Week 4	1320	1302	1308	5.61	0.434
Week 8	2188	2180	2170	11.56	0.660
Week 12	2613	2648	2626	18.50	0.763
Week 16	2939	2944	2946	20.92	0.985
Overall	2265	2268	2262	8.88	0.970
Gain to feed ratio					
Week 4	2.24	2.18	2.16	0.01	0.112
Week 8	2.89	2.81	2.84	0.03	0.626
Week 12	3.03	2.89	2.88	0.04	0.322
Week 16	3.18	3.14	3.07	0.04	0.682
Overall	2.89	2.81	2.79	0.03	0.438

[1] Abbreviation: CON (basal diet); TRT1 (basal diet + 0.05% SID lysine); and TRT2 (basal diet + 0.05% lysine SID + 0.084 MJ/kg NE).

SID, standardized ileal digestible; NE, net energy; ADG, average daily gain; ADFI, average daily feed intake; SEM, standard error of the mean.

[a,b] Means in the equivalent row show the superscripts differ ($p < 0.05$).

Table 3. Effect of increasing dietary SID lysine content and NE level on the apparent nutrient digestibility of growing-finishing pigs[1]

	CON	TRT1	TRT2	SEM	*p*-value
Dry matter, %					
Week 4	80.29	80.73	81.04	0.28	0.574
Week 8	76.91	77.17	77.36	0.19	0.658
Week 12	74.10	74.22	74.44	0.25	0.865
Week 16	70.09	70.24	71.61	0.55	0.486
Nitrogen, %					
Week 4	78.08	79.11	79.44	0.43	0.435
Week 8	74.78	74.91	75.09	0.29	0.919
Week 12	72.13	72.30	72.53	0.28	0.853
Week 16	67.22	67.69	68.18	0.93	0.921
Energy, %					
Week 4	79.15	79.49	80.04	0.53	0.800
Week 8	75.67	76.21	76.59	0.30	0.475
Week 12	73.33	73.50	73.59	0.25	0.917
Week 16	68.74	69.40	69.71	0.59	0.810

[1] Abbreviation: CON (basal diet); TRT1 (basal diet + 0.05% SID lysine); and TRT2 (basal diet + 0.05% lysine SID + 0.084 MJ/kg NE).

SID, standardized ileal digestible; NE, net energy; SEM, standard error of the mean.

Table 4. Effect of increasing dietary SID lysine content and NE level on the carcass traits of growing-finishing pigs[1]

Items	CON	TRT1	TRT2	SEM	*p*-value
BFT, %					
Initial	5.4	5.4	5.5	0.12	0.979
Week 4	8.6	8.9	9.0	0.11	0.327
Week 8	11.9	12.4	12.2	0.11	0.227
Week 12	15.38[b]	15.90[b]	16.03[a]	0.11	0.034
Week 16	17.7	17.8	17.9	0.06	0.503
LMP, %					
Initial	72.8	72.8	72.7	0.19	0.955
Week 4	65.5	65.7	66.0	0.20	0.720
Week 8	58.9	59.1	59.0	0.19	0.913
Week 12	54.8	55.2	55.03	0.21	0.788
Week 16	51.4	51.6	51.7	0.19	0.811

[1] Abbreviation: CON (basal diet); TRT1 (basal diet + 0.05% SID lysine); and TRT2 (basal diet + 0.05% lysine SID + 0.084 MJ/kg NE).

SID, standardized ileal digestible; NE, net energy; BFT, backfat thickness; LMP, lean meat percentage; SEM, standard error of the mean.

Table 5. Effect of increasing dietary SID lysine content and NE level on the carcass grade of growing-finishing pigs[1]

Items	CON	TRT1	TRT2	SEM	*p*- value
Carcass Weight, kg	88.06	89.06	89.33	0.61	0.676
BFT, mm	17.66	19.03	19.36	0.36	0.130
1+, %	33.33	30.00	40.00	-	-
1, %	40.00	36.67	43.33	-	-
2, %	26.67	33.33	16.67	-	-

[1] Abbreviation: CON (basal diet); TRT1 (basal diet + 0.05% SID lysine); and TRT2 (basal diet + 0.05% lysine SID + 0.084 MJ/kg NE).

SID, standardized ileal digestible; NE, net energy; BFT, backfat thickness; SEM, standard error of the mean.