RESEARCH ARTICLE

J Anim Sci Technol 2025;67(1):96-105
https://doi.org/10.5187/jast.2023.e118

JAST
Journal of Animal Science and Technology
pISSN 2672-0191 eISSN 2055-0391

Effects of increasing dietary lysine and energy levels on growth efficiency, nutrient absorption, and meat carcass traits in growing-finishing pigs

Sarbani Biswas, De Xin Dang, Sungbo Cho, Dae-Kyung Kang, In Ho Kim*

Department of Animal Resource and Science, Dankook University, Cheonan 31116, Korea

Received: Jun 30, 2023
Revised: Oct 21, 2023
Accepted: Oct 26, 2023

***Corresponding author**
In Ho Kim
Department of Animal Resource and Science, Dankook University, Cheonan 31116, Korea.
Tel: +82-41-550-3652
E-mail: inhokim@dankook.ac.kr

ORCID
Sarbani Biswas
https://orcid.org/0000-0001-9762-807X
De Xin Dang
https://orcid.org/0000-0002-9672-8922
Sungbo Cho
https://orcid.org/0000-0002-2593-2758
Dae-Kyung Kang
https://orcid.org/0000-0001-9241-1250
In Ho Kim
https://orcid.org/0000-0001-6652-2504

Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
This research was supported by Basic Science Research Program through

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 standardized ileal digestible (SID). SID levels have been suggested as the most effective approach for incorporation

the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-RS-2023-00275307). This research was supported by Basic Science Research Capacity Enhancement Project through Korea Basic Science Institute (National Research Facilities and Equipment Center) grant funded by the Ministry of Education (Grant No. 2019R1A6C1010033).

Acknowledgements
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: Biswas S, Dang DX, Cho S, Kang DK, Kim IH.
Data curation: Biswas S, Dang DX.
Formal analysis: Biswas S, Dang DX.
Methodology: Biswas S, Dang DX, Cho S, Kang DK, Kim IH.
Software: Biswas S, Dang DX.
Validation: Kim IH.
Investigation: Cho S, Kang DK, Kim IH.
Writing - original draft: Biswas S, Dang DX.
Writing - review & editing: Biswas S, Dang DX, Cho S, Kang DK, Kim IH.

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

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, 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 (BW; 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 [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].

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

	Grower (initial to week 8)			Finisher (week 8 to week 16)		
	CON[2)]	TRT1	TRT2	CON	TRT1	TRT2
Ingredients (%)	100.00	100.00	100.00	100.00	100.00	100.00
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[3)]	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
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

1)A growing-to-finish feeding regimen designed to either meet or beyond the NRC's [21] suggested standards including superdose level of phytase (FTU/kg).

2)CON, basal diet; TRT1, basal diet + 0.05% SID lysine; TRT2, basal diet + 0.05% lysine SID + 0.084 MJ/kg net energy.

3)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 $FeSO_4 \cdot 7H_2O$).

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

https://doi.org/10.5187/jast.2023.e118

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℃ 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 average daily gain (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℃ 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 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). BFT (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 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,

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

	CON[1)]	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	1,320	1,302	1,308	5.61	0.434
Week 8	2,188	2,180	2,170	11.56	0.660
Week 12	2,613	2,648	2,626	18.50	0.763
Week 16	,2939	2,944	2,946	20.92	0.985
Overall	2,265	2,268	2,262	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)] CON, basal diet; TRT1, basal diet + 0.05% SID lysine; TRT2, basal diet + 0.05% lysine SID + 0.084 MJ/kg NE.

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

SID, standardized ileal digestible; NE, net energy; ADG, average daily gain; ADFI, average daily feed intake.

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) [19]. Another study by Rodrguez-Sanchez et al. [29] 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 [30]. However, pigs provided lysine-deficient diets showed poorer feed efficiency, but ADG and

 https://doi.org/10.5187/jast.2023.e118

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

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

SID, standardized ileal digestible; NE, net energy.

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

Items	CON[1)]	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)]CON, basal diet; TRT1, basal diet + 0.05% SID lysine; TRT2, basal diet + 0.05% lysine SID + 0.084 MJ/kg NE.

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

SID, standardized ileal digestible; NE, net energy; BFT, backfat thickness; LMP, lean meat percentage.

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

Items	CON[1)]	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)]CON, basal diet; TRT1, basal diet + 0.05% SID lysine; TRT2, basal diet + 0.05% lysine SID + 0.084 MJ/kg NE.

SID, standardized ileal digestible; NE, net energy; BFT, backfat thickness.

feed intake were unaffected in different dietary lysine concentrations [31]. 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) [32]. 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 [33]. 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 BW 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 [34]. In a previous study, the apparent DM and nitrogen absorption of growing pigs were not impacted by variations in nutritional lysine levels [35]. As mentioned by Yang et al. [30], 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 [36]. 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 [37]. 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 [30]. As the finishing pigs' energy intake increased, the proportion of external fat, intracellular backfat, and thickness fat increased linearly [38]. 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) [39]. 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 [40]. It has been reported that the lipid deposition level was not affected by the contents of dietary amino acids [41]. 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

 https://doi.org/10.5187/jast.2023.e118

amount of energy [33]. An improved carcass BFT indicates an enhancement of the accumulation of adipose tissue [42]. 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 BW 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.

REFERENCES

1. Main RG, Dritz SS, Tokach MD, Goodband RD, Nelssen JL. Determining an optimum lysine: calorie ratio for barrows and gilts in a commercial finishing facility. J Anim Sci. 2008;86:2190-207. https://doi.org/10.2527/jas.2007-0408
2. Wang L, Hu Q, Wang L, Shi H, Lai C, Zhang S. Predicting the growth performance of growing-finishing pigs based on net energy and digestible lysine intake using multiple regression and artificial neural networks models. J Anim Sci Biotechnol. 2022;13:57. https://doi.org/10.1186/s40104-022-00707-1
3. Stein HH, Pedersen C, Wirt AR, Bohlke RA. Additivity of values for apparent and standardized ileal digestibility of amino acids in mixed diets fed to growing pigs. J Anim Sci. 2005;83:2387-95. https://doi.org/10.2527/2005.83102387x
4. Velayudhan DE, Kim IH, Nyachoti CM. Characterization of dietary energy in swine feed and feed ingredients: a review of recent research results. Asian-Australas J Anim Sci. 2015;28:1-13. https://doi.org/10.5713/ajas.14.0001R
5. Campbell RG, Taverner MR. The effects of dietary fibre, source of fat and dietary energy concentration on the voluntary food intake and performance of growing pigs. Anim Sci. 1986;43:327-33. https://doi.org/10.1017/S0003356100002518
6. Noblet J. Recent developments in net energy. Research for swine. Adv Pork Prod. 2007;18:149-56.
7. Niemi JK, Sevón-Aimonen ML, Pietola K, Stalder KJ. The value of precision feeding technologies for grow–finish swine. Livest Sci. 2010;129:13-23. https://doi.org/10.1016/j.livsci.2009.12.006
8. Shurson GC, Zijlstra RT, Kerr BJ, Stein HH. Feeding biofuels co-products to pigs. In: Makkar HPS, editor. Biofuel co-products as livestock feed: opportunities and challenge. Rome: Food and Agriculture Organization of the United Nations; 2012. p. 175-207.
9. Prandini A, Sigolo S, Morlacchini M, Grilli E, Fiorentini L. Microencapsulated lysine and low-protein diets: effects on performance, carcass characteristics and nitrogen excretion in heavy growing–finishing pigs. J Anim Sci. 2013;91:4226-34. https://doi.org/10.2527/jas.2013-6412
10. Kim JS, Ingale SL, Lee SH, Kim KH, Kim JS, Lee JH, et al. Effects of energy levels of diet and β-mannanase supplementation on growth performance, apparent total tract digestibility and blood metabolites in growing pigs. Anim Feed Sci Technol. 2013;186:64-70. https://doi.org/10.1016/j.anifeedsci.2013.08.008
11. Quiniou N, Noblet J. Effect of the dietary net energy concentration on feed intake and performance of growing-finishing pigs housed individually. J Anim Sci. 2012;90:4362-72. https://doi.org/10.2527/jas.2011-4004

12. Kerr BJ, Southern LL, Bidner TD, Friesen KG, Easter RA. Influence of dietary protein level, amino acid supplementation, and dietary energy levels on growing-finishing pig performance and carcass composition. J Anim Sci. 2003;81:3075-87. https://doi.org/10.2527/2003.81123075x
13. Yi X, Zhang S, Yang Q, Yin H, Qiao S. Influence of dietary net energy content on performance of growing pigs fed low crude protein diets supplemented with crystalline amino acids. J Swine Health Prod. 2010;18:294-300.
14. Tous N, Lizardo R, Vilà B, Gispert M, Font-i-Furnols M, Esteve-Garcia E. Effect of reducing dietary protein and lysine on growth performance, carcass characteristics, intramuscular fat, and fatty acid profile of finishing barrows. J Anim Sci. 2014;92:129-40. https://doi.org/10.2527/jas.2012-6222
15. Lee JH, Lee SD, Yun W, Oh HJ, An JS, Kim IH, et al. Effects of different standardized ileal digestible lysine: net energy proportion in growing and finishing pigs. J Anim Sci Technol. 2020;62:198-207. https://doi.org/10.5187/jast.2020.62.2.198
16. Park TW, Lee EY, Jung Y, Son YM, Oh SH, Kim DH, et al. Effects of lysine concentration of the diet on growth performance and meat quality in finishing pigs with high slaughter weights. J Anim Sci Technol. 2023;65:1242-53. https://doi.org/10.5187/jast.2023.e49
17. Hong JS, Lee GI, Jin XH, Kim YY. Effect of dietary energy levels and phase feeding by protein levels on growth performance, blood profiles and carcass characteristics in growing-finishing pigs. J Anim Sci Technol. 2016;58:37. https://doi.org/10.1186/s40781-016-0119-z
18. Park S, Choe J, Cho J, Jang KB, Kyoung H, Park KI, et al. Determination of optimal energy system and level for growing pigs. J Anim Sci Technol. 2024;66:514-22. https://doi.org/10.5187/jast.2023.e63
19. Schneider JD, Tokach MD, Dritz SS, Nelssen JL, DeRouchey JM, Goodband RD. Determining the effect of lysine: calorie ratio on growth performance of ten- to twenty-kilogram of body weight nursery pigs of two different genotypes. J Anim Sci. 2010;88:137-46. https://doi.org/10.2527/jas.2008-1204
20. Nam DS, Aherne FX. The effects of lysine:energy ratio on the performance of weanling pigs. J Anim Sci. 1994;72:1247-56. https://doi.org/10.2527/1994.7251247x
21. NRC (National Research Council). Nutrient requirements of swine. 11th rev. ed. Washington, DC: National Academies Press; 2012.
22. Noblet J, Fortune H, Shi XS, Dubois S. Prediction of net energy value of feeds for growing pigs. J Anim Sci. 1994;72:344-54. https://doi.org/10.2527/1994.722344x
23. AOAC (Association of Official Analytical Chemists) International. Official methods of analysis of AOAC International. 18th ed. Gaithersburg, MD: AOAC International; 2005.
24. Sauvant D, Perez JM, Tran G. Tables of composition and nutritional value of feed materials: pig, poultry, cattle, sheep, goats, rabbits, horses and fish. Wageningen: Wageningen Academic; 2004.
25. AOAC (Association of Official Analytical Chemists) International. Official method of analysis of AOAC International. 17th ed. Arlington, VA: AOAC International; 2000.
26. Biswas S, Dang DX, Kim IH. Comparison of the effects of zinc oxide and zinc aspartic acid chelate on the performance of weaning pigs. J Anim Sci Technol. 2024;66:125-34. https://doi.org/10.5187/jast.2023.e39
27. KAPE (Korea Institute for Animal Products Quality Evaluation). Animal products grade system: the pork carcass grading system [Internet]. 2010 [cited 2023 May 7]. http://www.ekape.or.kr/view/eng/system/pork.asp
28. Ha DM, Kim GD, Han JC, Jeong JY, Park MJ, Park BC, et al. Effects of dietary energy level on growth efficiency and carcass quality traits of finishing pigs. J Anim Sci Technol.

 https://doi.org/10.5187/jast.2023.e118

2010;52:191-8. https://doi.org/10.5187/JAST.2010.52.3.191

29. Rodríguez-Sánchez JA, Sanz MA, Blanco M, Serrano MP, Joy M, Latorre MA. The influence of dietary lysine restriction during the finishing period on growth performance and carcass, meat, and fat characteristics of barrows and gilts intended for dry-cured ham production. J Anim Sci. 2011;89:3651-62. https://doi.org/10.2527/jas.2010-3791
30. Yang YX, Jin Z, Yoon SY, Choi JY, Shinde PL, Piao XS, et al. Lysine restriction during grower phase on growth performance, blood metabolites, carcass traits and pork quality in grower finisher pigs. Acta Agric Scand A Anim Sci. 2008;58:14-22. https://doi.org/10.1080/09064700801959908
31. Witte DP, Ellis M, McKeith FK, Wilson ER. Effect of dietary lysine level and environmental temperature during the finishing phase on the intramuscular fat content of pork. J Anim Sci. 2000;78:1272-6. https://doi.org/10.2527/2000.7851272x
32. Hinson RB, Wiegand BR, Ritter MJ, Allee GL, Carr SN. Impact of dietary energy level and ractopamine on growth performance, carcass characteristics, and meat quality of finishing pigs. J Anim Sci. 2011;89:3572-9. https://doi.org/10.2527/jas.2010-3302
33. Oresanya TF, Beaulieu AD, Beltranena E, Patience JF. The effect of dietary energy concentration and total lysine/digestible energy ratio on the growth performance of weaned pigs. Can J Anim Sci. 2007;87:45-55. https://doi.org/10.4141/A05-064
34. Reynolds AM, O'Doherty JV. The effect of amino acid restriction during the grower phase on compensatory growth, carcass composition and nitrogen utilisation in grower–finisher pigs. Livest Sci. 2006;104:112-20. https://doi.org/10.1016/j.livsci.2006.03.012
35. Ren JB, Zhao GY, Li YX, Meng QX. Influence of dietary lysine level on whole-body protein turnover, plasma IGF-I, GH and insulin concentration in growing pigs. Livest Sci. 2007;110:126-32. https://doi.org/10.1016/j.livsci.2006.10.009
36. Jin YH, Oh HK, Piao LG, Jang SK, Choi YH, Heo PS, et al. Effect of dietary lysine restriction and energy density on performance, nutrient digestibility and meat quality in finishing pigs. Asian-Australas J Anim Sci. 2010;23:1213-20. https://doi.org/10.5713/ajas.2010.90585
37. Urynek W, Buraczewska L. Effect of dietary energy concentration and apparent ileal digestible lysine: metabolizable energy ratio on nitrogen balance and growth performance of young pigs. J Anim Sci. 2003;81:1227-36. https://doi.org/10.2527/2003.8151227x
38. Liu ZH, Yang FY, Kong LJ, Lai CH, Piao XS, Gu YH, et al. Effects of dietary energy density on growth, carcass quality and mRNA expression of fatty acid synthase and hormone-sensitive lipase in finishing pigs. Asian-Australas J Anim Sci. 2007;20:1587-93. https://doi.org/10.5713/ajas.2007.1587
39. Apple JK, Maxwell CV, Brown DC, Friesen KG, Musser RE, Johnson ZB, et al. Effects of dietary lysine and energy density on performance and carcass characteristics of finishing pigs fed ractopamine. J Anim Sci. 2004;82:3277-87. https://doi.org/10.2527/2004.82113277x
40. Smith JW 2nd, Tokach MD, O'Quinn PR, Nelssen JL, Goodband RD. Effects of dietary energy density and lysine: calorie ratio on growth performance and carcass characteristics of growing-finishing pigs. J Anim Sci. 1999;77:3007-15. https://doi.org/10.2527/1999.77113007x
41. Eits RM, Kwakkel RP, Verstegen MWA, Stoutjesdijk P, De Greef KH. Protein and lipid deposition rates in male broiler chickens: separate responses to amino acids and protein-free energy. Poult Sci. 2002;81:472-80. https://doi.org/10.1093/ps/81.4.472
42. Dang DX, Kim IH. Effects of adding high-dosing Aspergillus oryzae phytase to corn–wheat–soybean meal-based basal diet on growth performance, nutrient digestibility, faecal gas emission, carcass traits and meat quality in growing-finishing pigs. J Anim Physiol Anim Nutr. 2021;105:1056-62. https://doi.org/10.1111/jpn.13537