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Growth performance and nutrient digestibility of growing-finishing pigs under different energy concentrations

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Abstract

Two experiments were conducted to examine the effects of the difference in energy concentration in diets on performance and nutrient digestibility of growing-finishing pigs. The experimental diets were as follows: 1) a normal energy level corn-soybean meal-based diet (CON) and 2) high-energy diet compared with the CON (HE). Pigs had free access to their feed and water *ad labium* for 6 weeks during each experimental period. In experiment 1, 60 growing pigs (initial body weight [BW] of 23.85 kg) were randomly allotted to 2 treatment groups with 5 replications (6 pigs·pen^{-1}). In experiment 2, 48 finishing pigs (initial BW = 65.13 kg) were randomly assigned to 2 treatment groups with 6 replications (4 pigs·pen^{-1}). The growth performance was measured at the beginning and end of each period. The apparent total tract digestibility (ATTD) was determined by chromium oxide as an indigestible marker during the last 7 days of each experiment. In experiment 1, the dietary treatments did not affect the growth performance and ATTD of energy and nutrients. In experiment 2, no differences in growth performance were observed for pigs fed CON and HE throughout the experimental period. Additionally, dietary treatments did not affect the ATTD. In conclusion, the high energy content in diets for the growing-finishing period had no effect on the growth performance or digestibility, indicating that a wide range of energy content changes in diets would be required to affect the performance and digestibility of grower-finisher pigs. It is also necessary to understand the characteristics of components used to adjust the dietary energy concentration.

Keywords: apparent digestibility, feed ingredient, growing-finishing pigs, high-energy diet

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Introduction

Energy derived from organic matter (carbohydrates, lipids, and proteins) in animal diets is an essential component for maintenance and functioning of biological processes and represents the single largest cost of swine diet (Noblet et al., 1994; Kil et al., 2013b; Shurson et al., 2015). Many studies have been conducted to find alternatives to alleviate price fluctuation of conventional energy sources and thus promote stability within the swine industry (Park et al., 2016; Clarke et al., 2018). A swine diet should be formulated to meet the energy and nutrient requirements of each growth stage, considering the characteristics of each ingredient and stage as feed ingredients have various nutritional compositions that impart different properties to feed sources (Liu, 2011; Shurson et al., 2015; Velayudhan et al., 2015). Thus, it is difficult to design the feed with a single ingredient or alternative materials and to meet the dietary energy requirements for cost-effective pork production.

Another important aspect related to energy level in the swine diet is that the concentration of dietary energy influences the voluntary feed intake (VFI) of pigs. In the growing and finishing periods, VFI is one of the most important factors for pork production because it determines the level of ingestion of materials closely related to swine maintenance and growth (Nyachoti et al., 2004; Li and Patience, 2017). Previous studies have demonstrated that feed intake in pigs increased because of decreased energy density in diet; conversely, other studies have reported decreased feed intake when high-energy diets are fed to growing-finishing pigs (Noblet and van Milgen, 2004; Beaulieu et al., 2009; Lei et al., 2018; Liu et al., 2018). These results are related to the physiological regulation that adjusts feed intake to maintain homeostasis, and this regulation allows pigs to consume feed until they meet their energy requirement (Nyachoti et al., 2004; Kil et al., 2013b; Li and Patience, 2017). It is also a generally accepted fact that supplementation of dietary fat improves growth performance during the growing and finishing stages (Pettigrew and Moser, 1991). However, there is still considerable controversy regarding the effect of dietary energy content on growth performance (body weight gain, feed or energy intake, and feed efficiency) as well as the nutrient digestibility of growing-finishing pigs (De la Llata et al., 2001; Lee et al., 2015; Clarke et al., 2018). Therefore, the objective of these experiments was to identify the effects of different dietary energy concentrations on growth performance and digestibility of growing-finishing pigs.

Materials and Methods

The Institutional Animal Care and Use Committee of Chungnam National University reviewed and approved all experimental protocols used in this research. Two experiments were conducted at the Animal Research Center of Chungnam National University.

Experimental design, animals, and diets

In experiment 1, 60 growing pigs (Landrace × Yorkshire × Duroc; average initial body weight [BW] of 23.85 kg) were used in this experiment for 6 weeks. The growing pigs were randomly assigned to 2 treatments with 6 pigs per pen (5 replicated pens/treatment) in a completely randomized design. All pigs were allowed free access to fresh water and their diets throughout the entire experimental period and housed in an environmentally controlled room. The dietary treatments were a control diet (normal energy level) based on corn and soybean meal (CON; 3,48 $Mcal \cdot kg^{-1}$ metabolizable energy [ME]) and high-energy level diet compared with CON (HE; 3,63 $Mcal \cdot kg^{-1}$ ME). Diets were formulated to meet or exceed the energy and nutrient requirements of grower period recommended by the National Research Council (NRC, 2012).

In experiment 2, 48 finishing pigs (Landrace × Yorkshire × Duroc) with an average initial BW of 65.13 kg was used for 6 weeks. Pigs were housed in groups in an environmentally controlled room and each pen was equipped with feeder and waterer, respectively. All pigs randomly assigned to 1 of 2 treatments with 4 pigs per pen (6 replicated pens·treatment^{-1}) in a completely randomized design. The dietary treatments were similar to those described in experiment 1: 1) a normal energy level diet based on corn and soybean meal (CON; 3,53 Mcal·kg ME^{-1}); 2) high-energy level diet compared with CON (HE; 3,68 Mcal·kg^{-1} ME). Dietary treatments were formulated according to the nutritional value of ingredients as described by NRC (2012), and all diets were formulated to meet or exceed the energy and nutrient requirements of finishing pigs (Table 1). All pigs were allowed free access to fresh water and their diets throughout the entire experimental period.

Measurements, sample collection, and analysis

The initial and final BW of pigs was individually weighed and recorded at the start and end of each period. The amount of feed provided per pen was weighed and recorded during the growing-finishing period, and those remains were weighed and recorded at the end of each stage. Average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G : F) for each pen were calculated and summarized within treatment and stage of growth.

The apparent total tract digestibility (ATTD) of nutrient was determined by chromium oxide (Cr_2O_3; 0.25%) as an index compound during the last 7 days of each experiment: after a four-day adjustment period, fecal samples from randomly selected one pig per pen were collected twice daily by rectal palpation for the last 3 days. The collected samples (diets and feces) from each experiment were pooled and stored at - 20℃ for later analysis. All of the samples were dried in a forced-air drying oven at 60℃ and ground through a cyclone mill (Foss Tecator Sycltec 1093, HillerØd, Denmark) before start analysis. Diet and fecal samples were analyzed for dry matter and crude protein according to the procedures described by the Association of Official Analytical Chemists (AOAC, 2007), and for gross energy using a bomb calorimeter (Parr 1281 Bomb Calorimeter, Parr Instrument Co., Moline, USA), using benzoic acid as a calibration standard. The chromium content in the samples was measured using an absorption spectrophotometer (Hitachi Z-5000 Absorption Spectrophotometer, Hitachi High-Technologies Co., Tokyo, Japan) based on the report by Williams et al. (1962) and ATTD was calculated based on the index method (Adeola, 2001).

Statistical analysis

In experiments 1 and 2, data were analyzed using the General Linear Model Procedure of SAS (SAS Institute Inc., Cary, USA) in a completely randomized design. Pig was the experimental unit. The statistical model for the performance and digestibility included effects of dietary treatments as the fixed effect. Results are given as mean ± standard error of the mean. Statistical significance and tendency were considered at $p < 0.05$ and $0.05 \leq p < 0.10$, respectively.

Table 1. Ingredient and calculated energy and nutrient composition of the experimental diets (as-fed basis).

Items	Treatments			
	Growing pigs		Finishing pigs	
	CON	HE	CON	HE
Ingredient (%)				
Corn	34.60	31.11	38.46	34.97
Soybean meal (44% CP)	29.95	29.95	20.38	20.38
Wheat	14.75	14.75	16.75	16.75
Wheat bran	1.07	1.07	3.00	3.00
Molasses	4.00	4.00	4.00	4.00
Rice	8.00	8.00	9.00	9.00
Beef tallow	4.59	8.08	6.10	9.59
Limestone	0.00	0.00	0.52	0.52
Dicalcium phosphate	1.05	1.05	0.57	0.57
Salt	0.30	0.30	0.30	0.30
Vitamin-mineral premix[z]	1.47	1.47	0.75	0.75
$_{L}$-Lysine-HCl	0.17	0.17	0.16	0.16
$_{DL}$-Methionine	0.05	0.05	0.01	0.01
Calculated energy and nutrient composition				
ME ($Mcal \cdot kg^{-1}$)	3.48	3.63	3.53	3.68
Crude protein (%)	19.51	19.23	16.20	15.91
Ether extract (%)	7.90	11.24	9.13	12.47
Crude fiber (%)	19.51	19.23	16.20	15.91
SID lysine (%)	1.02	1.01	0.78	0.78
SID Met + Cys (%)	0.56	0.55	0.45	0.44
Calcium (%)	0.68	0.68	0.52	0.52
Bioavailable phosphorus (%)	0.36	0.35	0.26	0.25

CON, a normal energy level corn-soybean meal-based diet; HE, a high-energy diet compared with CON; CP, crude protein; ME, metabolizable energy; SID, standardized ileal digestible; Met + Cys, methionine + cysteine.

[z] The vitamin-mineral premix provided the following quantities of vitamins and minerals per kilogram of diets: vitamin A, 10,000 IU; thiamin, 0.49 mg as thiamin mononitrate; riboflavin, 1.50 mg; niacin, 10 mg as nicotinic acid; pantothenic acid, 5 mg as calcium pantothenate; pyridoxine, 1 mg as pyridoxine hydrochloride; vitamin B_{12}, 0.01 mg; folic acid, 1 mg; biotin as d-biotin, 0.1 mg; choline, 125 mg as choline-chloride; vitamin D_3, 2,000 IU; vitamin E, 250 IU; vitamin K_3, 0.5 mg; Co, 0.5 mg as cobaltous carbonate; Cu, 3 mg as cupric sulfate; Fe, 20 mg as ferrous sulfate; I, 1.25 mg as calcium iodate; Mg, 10 mg as magnesium oxide; Mn, 60 mg as manganese sulfate; and Zn, 75 mg as zinc sulfate.

Results and Discussion

The effect of energy contents on ADG, ADFI, and G : F during the growing stage (experiment 1) are displayed in Table 2. In experiment 1, the BW of pigs fed a moderate-energy level diet was similar to that of pigs fed HE ($p > 0.10$). Moreover, there were no differences ($p > 0.10$) in ADG, ADFI, and G : F between the CON and HE groups. Furthermore, during the growing period, there were no differences ($p > 0.10$) in dry matter, energy, and crude protein digestibility of pigs between the CON and HE groups (Table 3).

The effect of energy contents on ADG, ADFI, and G : F during the finishing stage (experiment 2) are shown in Table 4. During this stage, there was no significant difference ($p > 0.10$) in the BW of pigs receiving the two dietary treatments. In addition, ADG, ADFI, and G : F of pigs in the CON group were similar ($p > 0.10$) to those in the HE group. The energy concentration of diets did not affect ($p > 0.10$) the ATTD of dry matter, crude protein, and energy during the finishing period (Table 5).

Table 2. Body weight and growth performance of growing pigs fed experimental diets.

Items	Treatments		SEM	p-value
	CON	HE		
Initial BW (0 week; kg)	23.63	24.07	1.66	0.856
Final BW (6 week; kg)	62.90	65.06	2.42	0.545
ADG ($g \cdot d^{-1}$)	935	976	22.94	0.242
ADFI ($g \cdot d^{-1}$)	2,153	2,317	63.51	0.106
G : F ratio ($g \cdot g^{-1}$)	0.44	0.42	0.02	0.481

CON, a normal energy level corn-soybean meal-based diet; HE, a high-energy diet compared with CON; SEM, standard error of means; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G : F ratio, ratio between average daily gain and average daily feed intake.

Table 3. Apparent total tract digestibility of energy and nutrients in growing pigs fed experimental diets.

Items (%)	Treatments		SEM	p-value
	CON	HE		
Dry matter	87.05	89.43	1.52	0.302
Crude protein	85.02	83.93	2.31	0.748
Energy	84.95	85.90	2.00	0.745

CON, a normal energy level corn-soybean meal-based diet; HE, a high-energy diet compared with CON; SEM, standard error of means.

Table 4. Body weight and growth performance of finishing pigs fed experimental diets.

Items	Treatments		SEM	p-value
	CON	HE		
Initial BW (0 week; kg)	63.52	66.73	2.60	0.403
Final BW (6 week; kg)	103.44	105.57	3.23	0.652
ADG ($g \cdot d^{-1}$)	951	925	25.46	0.489
ADFI ($g \cdot d^{-1}$)	3,187	3,168	109.28	0.906
G : F ratio ($g \cdot g^{-1}$)	0.30	0.29	0.01	0.511

CON, a normal energy level corn-soybean meal-based diet; HE, a high-energy diet compared with CON; SEM, standard error of means; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G : F ratio, ratio between average daily gain and average daily feed intake.

Table 5. Apparent total tract digestibility of energy and nutrients in finishing pigs fed experimental diets.

Items (%)	Treatments		SEM	p-value
	CON	HE		
Dry matter	80.47	78.10	2.77	0.558
Crude protein	74.24	67.79	3.83	0.261
Energy	78.78	76.84	2.93	0.649

CON, a normal energy level corn-soybean meal-based diet; HE, a high-energy diet compared with CON; SEM, standard error of means.

The growth performance of growing-finishing pigs is affected by various factors such as animal, diet, and environment (Nyachoti et al., 2004; Li and Patience, 2017), but this study will focus on the issue related to the impact of different dietary energy content.

In general, during the grower and finisher periods, dietary supplements with 5% or 10% dietary fat have been shown to improve the pigs' growth performance (Pettigrew and Moser, 1991). Liu et al. (2018) observed improved growth performance of pigs when fed with high-energy diet (3.46 to 3.60 ME, Mcal·kg^{-1}) than when fed with low-energy diet (3.32 ME, Mcal·kg^{-1}). Similarly, linear improvements in overall growth performance (especially ADG and G : F) owing to increased dietary energy content were reported by De la Llata et al. (2001) and Lee et al. (2015). They imply that regardless of changes in feed intake, growth performance of pigs may be improved by increasing relative energy intake during energy-dependent periods. These results agree with the data reported by Beaulieu et al. (2009), who observed that as the energy density of the diet increased, energy intake increased, leading to improved growth performance. In the current study, however, there was no difference in feed intake nor final BW, ADG, and G : F. The reason for this contrasting result is not clear, but it seems that growth performance was unaffected by the energy value in diets because all pigs were already receiving enough energy from their diets. Alternatively, if pigs could not ingest enough energy, the VFI or body weight gain, which is one of the most important factors in pork production, could have been adjusted to their capabilities with changes in energy content. Consistent with our results, Quiniou and Noblet (2012) found no beneficial effect on the growth performance of growing-finishing pigs fed diets supplemented with fat sources.

The second hypothesis is there is no difference in the growth performance between the treatment groups during the growing and finishing periods because the difference in dietary energy contents is insufficient to produce a significant difference in the result. As mentioned before, the growth rate may be improved by supplying additional substances that change dietary energy content, even if there is no difference in feed intake. Previous studies that have examined the effect of differences in dietary energy content on growth performance also suggest that a substantial difference in dietary energy concentration is required to affect growth performance in pigs (Quiniou and Noblet, 2012; Lee et al., 2015). These results are in agreement with the growth performance data obtained in the current study.

Usually, the energy concentration of swine diet is regulated by fiber and fat sources. A previous study has demonstrated decreases in nutrient digestibility when the fiber content in the diet increased (Kerr and Shurson, 2013). In contrast, supplementation of diet with dietary fat has been shown to improve nutrient digestibility by affecting the rate of gastric emptying and digesta passage (Valaja and Siljander-Rasi, 2001; Gentilcore et al., 2006). However, in this study, no differences in nutrient digestibility were observed even though the energy content was increased by adjusting the inclusion level of ingredients. This finding is contradictory to the finding of Kil et al. (2013a) who observed an improvement in energy and nutrient digestibility of pigs in the growing-finishing period following supplementation of dietary fat. They also reported that the digestibility increased following the addition of soybean oil, which is more digestible than the fats present in conventional raw materials. The reason for this contrasting result is not clear, but it seems that a fat source, which could have a positive effect on digestibility, had already been added to the control diet in this study; therefore, the difference in fat addition level between the two treatments did not affect the digestibility of growing-finishing pigs. Moreover, previous studies have reported that digestibility of energy or nutrients increases linearly with fat addition levels (Kil et al., 2011; Lee et al., 2015). Thus, further research is needed to accurately determine the effects of fat supplementation.

Conclusion

In conclusion, a high-energy diet for growing and finishing pigs did not affect their final BW, growth performance, and ATTD of energy and nutrients. This implies that it is difficult to alter growth performance and digestibility from differences in the energy or fat addition levels used in the current study. Therefore, further studies are required to predict the accurate growth performance and maintain the efficiency of pork production. It is also necessary to understand the characteristics of components used to adjust the dietary energy concentration.

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