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Summary

A total of 356 finishing pigs (DNA; 241 × 600; initially 196.3 ± 2.43 lb) were used in a 44-d growth trial to evaluate nutritional strategies to reduce growth rate of pigs beyond 200 lb body weight. A total of 3 diets were manufactured (control, Lys-deficient, and corn) and arranged into 4 nutritional strategies. In stage 1 (d 0 to 28), pens received one of two dietary treatments (control or Lys-deficient). Then on d 28, pens of pigs previously fed the control diet were separated into 2 groups, one fed the control diet and the other the corn diet. Pens of pigs previously fed the Lys-deficient diet were separated into 2 groups, one fed the Lys-deficient diet and the other the corn diet. The control diet contained 13.0% CP and 0.70% standardized ileal digestible (SID) Lys; the Lys-deficient diet contained 10.3% CP and 0.50% SID Lys; and the corn diet contained 8.1% CP and 0.18% SID Lys. There were 9 to 10 pigs per pen and 9 pens per treatment. Pens were assigned to 1 of the 4 nutritional strategies in a randomized complete block design with initial weight as a blocking factor. In stage one (d 0 to 28), pigs fed the Lys-deficient diet had decreased ($P < 0.001$) ADG, F/G, and d 28 BW compared to pigs fed the control diet. There was no evidence of difference in ADFI between control and Lys-deficient diet. In stage 2 (d 28 to 44), pigs fed the corn diet had decreased ($P < 0.05$) ADG and poorer ($P < 0.05$) F/G compared to pigs fed the control or Lys-deficient diets. Pigs fed the Lys-deficient diet in both stages had decreased ($P < 0.05$) ADG and poorer ($P < 0.05$) F/G compared to pigs fed the control diet in both stages. For the overall period (d 0 to 44), pigs fed the Lys-deficient diet (stage 1) then corn diet (stage 2) had decreased ($P < 0.05$) ADG and final BW, and poorer ($P < 0.05$) F/G compared to the three other treatments. There was no evidence of difference for ADG, F/G, and final BW between pigs fed the Lys-deficient diet in both stages and pigs fed the control diet (stage 1) then corn diet (stage 2). Pigs of these two treatments had decreased ($P < 0.05$) ADG, F/G, and final BW, compared to pigs fed the control diet in both stages. For carcass characteristics, there was no evidence of difference in carcass yield between treatments. Pigs fed the Lys-deficient diet (stage 1) then corn diet (stage 2) had decreased ($P < 0.05$) HCW, percentage lean, and loin depth, and increased ($P < 0.05$) backfat compared to pigs fed the control diet in both stages. There was no evidence of difference in backfat, loin depth and percentage lean between pigs fed the Lys-deficient and corn diet in stage 2. In summary, low dietary Lys levels reduced the growth rate of pigs beyond 200 lb, which resulted in up to 26 lb difference

in final BW. These results allow producers to have flexible strategies to slow growth-rate and try to maintain ideal marketing weights to cope with the reduced capacity of processing plants.

Introduction

The US pork industry experienced a substantial reduction in the ability to process market pigs due to plant closures attributed to the 2020 COVID-19 pandemic. With the reduced ability for processors to accept delivery of market animals, animals grow beyond their intended market weight which makes them too large for the infrastructure of the facility. Therefore, producers were forced to utilize a variety of strategies to reduce the growth rate of pigs. Incorporating strategies that could reduce growth rate to prevent animals from becoming too large is exceptionally important for this situation. To our knowledge, there was little information in the literature regarding strategies to limit growth rates of heavy weight pigs. Therefore, our objective was to evaluate nutritional strategies to reduce growth rate of pigs beyond 200-lb body weight.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. The facility was totally enclosed and environmentally regulated, containing 36 pens. Each pen was equipped with a two-hole dry single-sided feeder (Farmweld, Teutopolis, IL) and a 1-cup waterer. Pigs were stocked at a floor space of approximately 7.0 ft² per pig. Pens were equipped with adjustable gates to allow space allowances per pig to be maintained if a pig died or was removed from a pen during the experiment. Pens were located over a completely slatted concrete floor with a 4-ft pit underneath for manure storage. A robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) was used to deliver and record daily feed additions to each individual pen.

A total of 356 pigs (241 × 600, DNA; Columbus, NE; initially 196.3 lb) were used. Treatments were fed in two stages and the trial was 44 days in length. At the initiation of the study, pens of pigs were weighed and allotted to one of four treatment strategies in a randomized complete block design with average pen weight serving as the blocking factor. Pigs were housed in mixed gender pens with 9 to 10 pigs per pen and 9 pens per treatment. A total of 3 diets were manufactured (control, Lys-deficient and corn). In Stage 1 (day 0 to 28), pens received one of two dietary treatments (control or Lys-deficient). On day 28, pens of pigs were divided into four late finishing nutritional strategies which were fed from day 28 to 44. Pens previously fed the control diet were divided into two groups, one half continued on the control diet and the other half switched to the corn diet. Pens previously fed the Lys-deficient diet were divided into two groups, one half remained on the Lys-deficient diet and the other half switched to the corn diet. The treatment structure is shown in Figure 1. The control diet contained 13.0% CP and 0.70% standardized ileal digestible (SID) Lys; Lys-deficient diet contained 10.3% CP and 0.50% SID Lys; corn diet contained 8.1% CP, 0.18% SID Lys and was 98% corn with remaining portion of the diet being vitamins and minerals (Table 1). All diets met the vitamin and mineral requirements of the pigs with the only deficiency being amino acid levels.

Pigs were weighed approximately every 7 days from d 0 to 44 of the trial to determine ADG, ADFI, and F/G. On d 28, one or two of the heaviest pigs in each pen were selected and marketed. These pigs were included in the d 0 to 28 growth performance data but not in carcass data. On the last day of the trial, final pen weights were taken, and the remaining pigs were tagged with RFID ear tags and transported to a USDA-inspected packing plant (Triumph Foods, St. Joseph, MO) for carcass data collection. Carcass measurements included hot carcass weight (HCW), loin depth, backfat, and percentage lean.

For the economic analysis, feed cost, feed cost per lb of gain, revenue per pig, and IOFC were calculated on a per pig placed basis. Corn was valued at \$125/ton, soybean meal at \$300/ton, L-lysine at \$0.80/lb, DL-methionine at \$1.50/lb, L-threonine at \$1.25/lb, and L-tryptophan at \$9/lb. Feed cost per pig was calculated by multiplying the feed cost per lb by ADFI and by the number of days in each phase, then adding up the values of each phase. Feed cost per lb of gain was calculated by dividing the feed cost per pig by the overall weight gain per pig. Revenue was obtained by multiplying carcass gain by using either the current market value (\$0.30/lb; current) or a more typical market value (\$0.65/lb; standard). The IOFC was calculated by subtracting the feed cost per pig from revenue per pig.

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R program (version 3.5.2)¹ with pen considered the experimental unit, initial BW as blocking factor, and treatment as fixed effect. In stage 1, data were analyzed as two treatments (control or Lys-deficient) with 18 pens per treatment. In stage 2, data were analyzed as 4 treatments with 9 pens per treatment. All results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

In stage one (d 0 to 28), pigs fed the Lys-deficient diet had decreased ($P < 0.001$) ADG, F/G, d 28 BW, Lys intake per day, and Lys intake per kg of gain compared to pigs fed the control diet (Table 2). Day 28 BW was approximately 10 lb lighter for pigs fed the Lys-deficient diet compared to pigs fed the control diet. There was no evidence of difference in ADFI observed ($P = 0.832$). During week 4 (d 21 to 28), pigs experienced heat stress, which contributed to the reduced ADG and ADFI compared to other periods (Figure 3 and 4).

In stage 2 (d 28 to 44), pigs fed the corn diet had decreased ($P < 0.05$) ADG, Lys intake per day, and Lys intake per kg of gain, and poorer ($P < 0.05$) F/G compared to pigs fed the control or Lys-deficient diets in stage 2. Pigs fed the Lys-deficient diet in both stages had decreased ($P < 0.05$) ADG, Lys intake per day, and Lys intake per kg of gain, and poorer ($P < 0.05$) F/G compared to pigs fed the control diet in both stages.

For the overall period (d 0 to 44), there was no evidence of difference in ADFI between all treatments ($P = 0.22$). Pigs fed the Lys-deficient diet (stage 1) then corn diet (stage 2) had decreased ($P < 0.05$) ADG, final BW, and Lys intake per day, and poorer

¹ R Core Team. 2018. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

($P < 0.05$) F/G compared to the three other treatments, and were approximately 26 lb lighter than pigs fed the control diet in both stages (Figure 2). There was no evidence of difference between pigs fed the Lys-deficient diet in both stages and pigs fed the control diet (stage 1) then the corn diet (stage 2) in ADG, F/G, and final BW. Pigs fed these two treatments had poorer ($P < 0.05$) ADG and F/G, and final BW (approximately 15 to 16 lb lighter), compared to pigs fed the control diet in both stages (Figure 2). All pigs fed the Lys-deficient diet in stage 1 had decreased ($P < 0.05$) overall Lys intake per kg of gain compared to pigs fed the control diet in stage 1. There was no evidence of difference in removal and mortality (data not shown). Weekly performance results are shown in Figures 3, 4, and 5.

For carcass characteristics, there was no evidence of difference in carcass yield between all treatments. Pigs fed the Lys-deficient diet (stage 1) then the corn diet (stage 2) had decreased ($P < 0.05$) HCW, percentage lean, and loin depth, and increased ($P < 0.05$) backfat compared to pigs fed the control diet in both stages. There was no evidence of difference in backfat, loin depth, and percentage lean between pigs fed the Lys-deficient and the corn diet in stage 2.

For economics, revenue was determined using either the current market value (\$0.30/lb; current) or a more typical market value (\$0.65/lb; standard). Pigs fed the Lys-deficient diet (stage 1) then the corn diet (stage 2) had increased ($P < 0.05$) feed cost per lb of gain, decreased ($P < 0.05$) IOFC (standard pricing) per pig placed, and decreased ($P < 0.05$) revenue, using either the current or standard pricing model compared to all other treatments (Table 3). Pigs fed the corn diets in stage 2 had decreased ($P < 0.05$) IOFC (current pricing) per pig placed compared to pigs fed the control or Lys-deficient diet in both stages, and decreased ($P < 0.05$) feed cost and IOFC (current) per pig placed compared to pigs fed the control diet in both stages. There was no evidence of difference in all economic criteria between pigs fed the control diet (stage 1) then corn diet (stage 2) and pigs fed the Lys-deficient diet in both stages. Even though pigs fed the control diet in both stages had greater revenue and IOFC, if these pigs can't be processed on time and exceed the acceptable BW, they would generate little or no revenue. In this case, the Lys-deficient or corn diets that have lower total feed cost might be more economical.

In summary, these data suggest that feeding pigs a Lys-deficient diet for 28 d then a virtually all corn diet for 16 d result in 26 lb lighter final BW compared to pigs fed a control diet for 44 d. Feeding pigs a Lys-deficient diet for 44 d or a control diet (28 d) then the corn diet (16 d) resulted in 15 to 16 lb lighter final BW compared to pigs fed the control diet for 44 d. These results allow producers to have flexible strategies to control the growth rate of late finishing pigs so as not to exceed ideal marketing weights if reduced pork processing plant capacity is occurring.

Table 1. Composition of experimental diets (as-fed basis)¹

Items	Control	Lys-deficient	Corn ³
Ingredients, %			
Corn	86.41	92.99	98.22
Soybean meal	11.53	5.00	--
Limestone, ground	0.89	0.88	0.86
Monocalcium phosphate	0.26	0.36	0.43
Salt	0.35	0.35	0.35
L-Lysine-HCl	0.30	0.25	--
Methionine hydroxy analog, dry	0.01	--	--
L-Threonine	0.09	0.03	--
L-Tryptophan	0.02	0.01	--
Vitamin premix with phytase	0.08	0.08	0.08
Trace mineral premix	0.08	0.08	0.08
Total	100	100	100
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lysine	0.70	0.50	0.18
Isoleucine:lysine	60	62	124
Leucine:lysine	156	187	452
Methionine:lysine	30	34	81
Methionine and cysteine:lysine	58	68	163
Threonine:lysine	65	61	117
Tryptophan:lysine	18.6	15.9	25.9
Valine:lysine	70	77	168
Lysine:net energy, g/Mcal	2.73	1.93	0.69
Net energy, kcal/lb	1,163	1,179	1,190
Crude protein, %	13.0	10.3	8.1
Calcium, %	0.47	0.46	0.45
STTD P, ² %	0.24	0.24	0.24
Proximate analysis, ³ %			
Dry matter	88.7	88.7	88.9
Crude protein	12.6	10.2	8.1

¹Experimental diets were fed for 44 days with two stages. Stage 1 was from d 0 to 28 and stage 2 was from d 28 to 44.

²STTD P = standardized total tract digestible phosphorus.

³A representative sample of each diet was collected from the feeders of each treatment, homogenized, and analyzed for proximate nutrients (Ward Laboratories, Inc., Kearney, NE).

Table 2. Effect of nutritional strategies to reduce growth rate of pigs beyond 200 lb body weight^{1,2}

Stage 1 (d 0 to 28):	Control ³		Lys-deficient		SEM	Probability, <i>P</i> <
Stage 2 (d 28 to 44):	Control	Corn	Lys-deficient	Corn		Control vs. Lys-deficient
d 0 to 28 (stage 1)						
ADG, lb	1.84		1.56		≤ 0.035 ⁴	< 0.001
ADFI, lb	6.11		6.13		0.062	0.832
F/G	3.33		3.94		0.037	< 0.001
Lys intake, g/d	19.4		13.9		≤ 0.200 ⁴	< 0.001
Lys intake, g/kg gain	23.3		19.7		≤ 0.295 ⁴	< 0.001
d 0 BW, lb	196.4		196.2		2.43	0.672
d 28 BW, lb (pre-topping)	248.0		239.8		2.69	< 0.001
d 28 to 44 (stage 2)						
ADG, lb	1.90 ^a	1.05 ^c	1.57 ^b	0.98 ^c	0.071	--
ADFI, lb	5.72 ^a	5.34 ^{ab}	5.42 ^{ab}	4.99 ^b	0.129	--
F/G	3.08 ^b	5.21 ^a	3.48 ^b	5.18 ^a	≤ 0.308 ⁴	--
Lys intake, g/d	18.2 ^a	4.4 ^c	12.3 ^b	4.1 ^c	≤ 0.420 ⁴	--
Lys intake, g/kg gain	21.6 ^a	9.5 ^c	17.4 ^b	9.4 ^c	≤ 1.17 ⁴	--
d 28 BW, lb (post-topping)	245.2 ^a	245.1 ^a	234.6 ^b	234.7 ^b	3.39	--
d 44 BW, lb	276.3 ^a	262.2 ^b	259.7 ^b	250.3 ^c	≤ 4.36 ⁴	--
d 0 to 44 (overall)						
ADG, lb	1.89 ^a	1.57 ^b	1.58 ^b	1.35 ^c	0.039	--
ADFI, lb	5.99	5.87	5.93	5.74	0.087	--
F/G	3.19 ^c	3.74 ^b	3.75 ^b	4.26 ^a	0.055	--
Lys intake, g/d	19.0 ^a	14.7 ^b	13.5 ^c	10.8 ^d	0.216	--
Lys intake, g/kg gain	22.3 ^a	20.7 ^b	18.8 ^c	17.6 ^c	0.328	--
Carcass characteristics						
HCW, lb	206.2 ^a	196.0 ^b	192.8 ^{bc}	186.2 ^c	≤ 3.03 ⁴	--
Carcass yield, %	74.8	74.2	74.2	74.1	≤ 0.213 ⁴	--
Backfat depth, in ⁵	0.547 ^b	0.598 ^a	0.603 ^a	0.622 ^a	≤ 0.013 ⁴	--
Loin depth, in ⁵	2.44 ^a	2.33 ^b	2.36 ^{ab}	2.29 ^b	≤ 0.024 ⁴	--
Lean, % ⁵	55.5 ^a	54.5 ^b	54.6 ^b	54.0 ^b	≤ 0.199 ⁴	--

^{a,b,c,d} Means within a row with different superscripts differ (*P* < 0.05).

¹A total of 356 pigs (initially 196.3 lb) were used with 10 pigs per pen and 9 replicates per treatment. Stage 1 was from d 0 to 28. Stage 2 was from d 28 to 44. On d 28, one or two heaviest pigs in each pen were selected and marketed as standard farm marketing protocol. These heavy pigs were included in the d 0 to 28 growth performance data and d 28 pre-topping BW, but not in d 28 post-topping BW and carcass data.

²BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.

HCW = hot carcass weight

³SID lysine (%) was 0.70 for the control diet, 0.50 for the Lys-deficient diet, and 0.18 for the corn diet.

⁴Heterogenous residual variance.

⁵Adjusted using HCW as covariate.

Table 3. Effect of nutritional strategies to reduce growth rate of pigs beyond 200 lb body weight¹

Stage 1 (d 0 to 28):	Control ²		Lys-deficient		SEM
Stage 2 (d 28 to 44):	Control	Corn	Lys-deficient	Corn	
Economics (per pig placed), \$ ³					
Revenue (current) ⁴	17.28 ^a	14.26 ^b	14.41 ^b	12.30 ^c	0.355
Revenue (standard) ⁵	37.44 ^a	30.90 ^b	31.23 ^b	26.65 ^c	0.769
Feed cost ⁶	20.72 ^a	19.26 ^b	18.61 ^{bc}	17.60 ^c	0.288
Feed cost per lb of gain ⁷	0.27 ^c	0.30 ^b	0.29 ^b	0.32 ^a	0.004
IOFC (current) ⁸	-3.44 ^a	-5.00 ^{bc}	-4.20 ^{ab}	-5.29 ^c	0.232
IOFC (standard)	16.72 ^a	11.64 ^b	12.62 ^b	9.06 ^c	0.584

^{a,b,c} Means within a row with different superscripts differ ($P < 0.05$).

¹ A total of 356 pigs (initially 196.3 lb) were used with 10 pigs per pen and 9 replicates per treatment. Stage 1 was from d 0 to 28. Stage 2 was from d 28 to 44.

² SID lysine (%) was 0.70 for control diet, 0.50 for Lys-deficient diet, and 0.18 for corn diet.

³ Removal rates were similar between all treatments.

⁴ Revenue (current) = $\$0.30 \times (\text{total live weight gain} \times \text{carcass yield})$.

⁵ Revenue (standard) = $\$0.65 \times (\text{total live weight gain} \times \text{carcass yield})$.

⁶ Feed cost per ton: \$169.33 (control diet); \$153.33 (Lys-deficient diet); and \$139.75 (corn diet).

⁷ Feed cost per lb gain = $(\text{total feed cost}) / (\text{total pen gain})$.

⁸ IOFC (income over feed cost) = revenue – feed cost.

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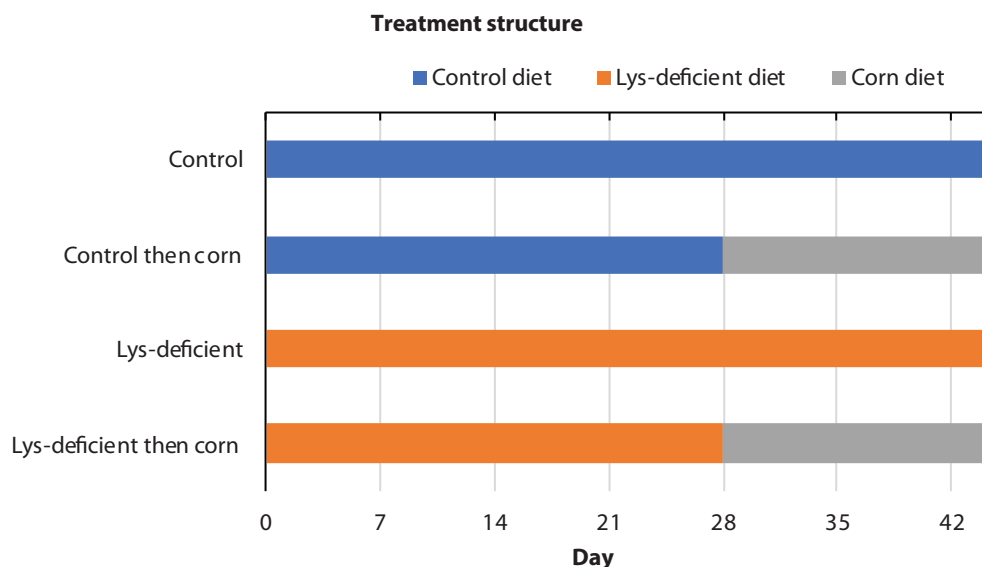


Figure 1. Experimental treatment design. A total of 3 diets were manufactured (control, Lys-deficient, and corn). In Stage 1 (day 0 to 28), pens received one of two dietary treatments (control or Lys-deficient). On day 28, pens of pigs were divided into four late finishing nutritional strategies, which were fed from day 28 to 44. Pens previously fed the control diet were divided into two groups, one half continued on the control diet and the other half switched to the corn diet. Pens previously fed the Lys-deficient diet were divided into two groups, one half remained on the Lys-deficient diet and the other half switched to the corn diet.

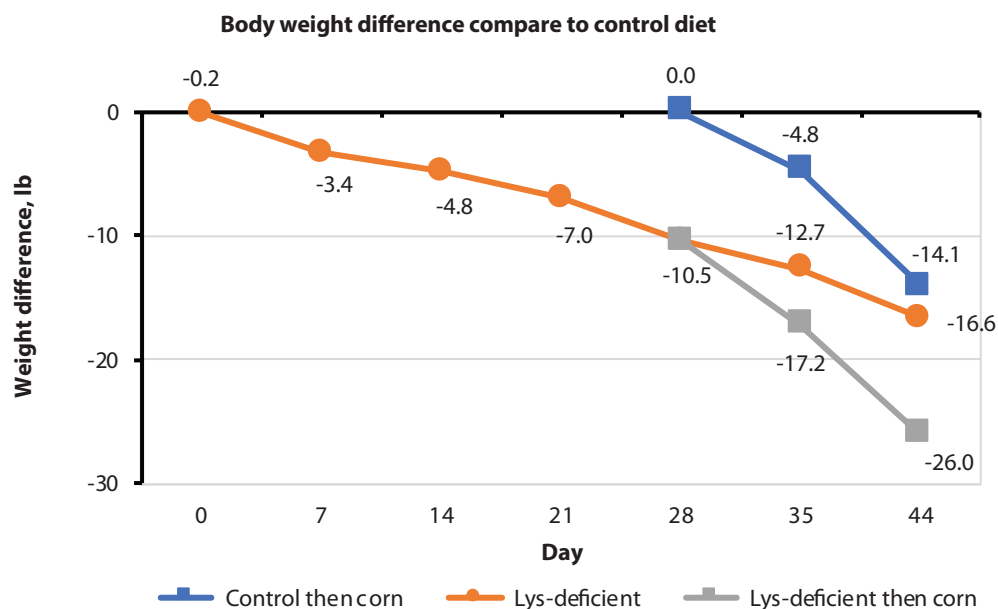


Figure 2. Body weight (BW) difference compared to control diet. The weekly BW differences were calculated by subtracting the BW of pigs fed the control diet from BW of pigs fed other nutritional strategies. Two treatment diets (control and Lys-deficient) were fed to pigs from d 0 to 28. Four nutritional strategies were used from d 28 to 44.

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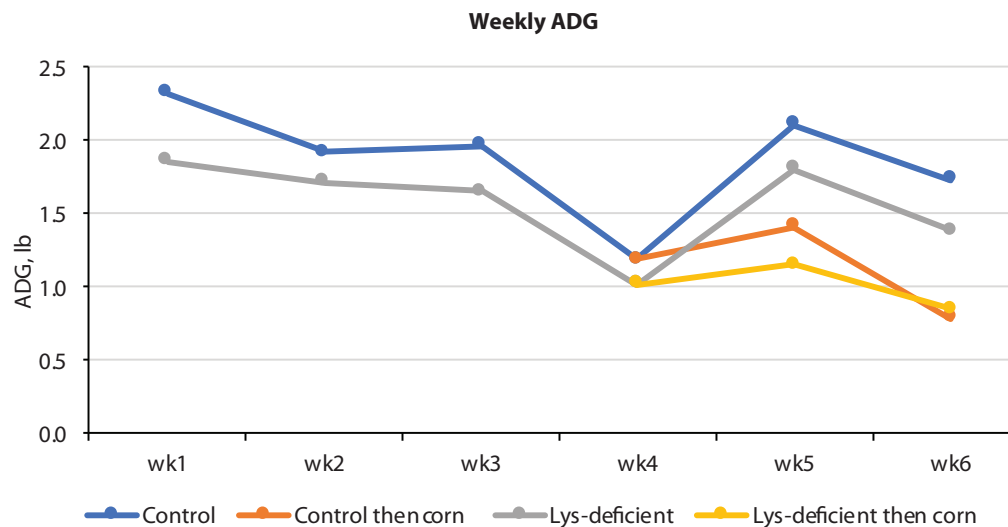


Figure 3. Weekly average daily gain (ADG) of the 4 nutritional strategies. Two treatment diets (control and Lys-deficient) were fed to pigs from week 1 to 4 (d 0 to 28). Four nutritional strategies were used from week 5 to 6 (d 28 to 44).

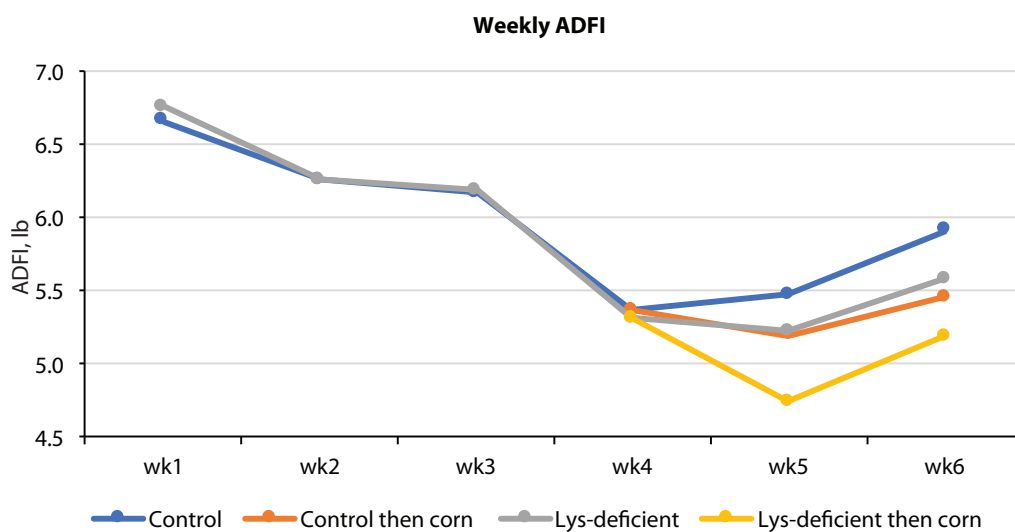


Figure 4. Weekly average daily feed intake (ADFI) of the 4 nutritional strategies. Two treatment diets (control and Lys-deficient) were fed to pigs from week 1 to 4 (d 0 to 28). Four nutritional strategies were used from week 5 to 6 (d 28 to 44).

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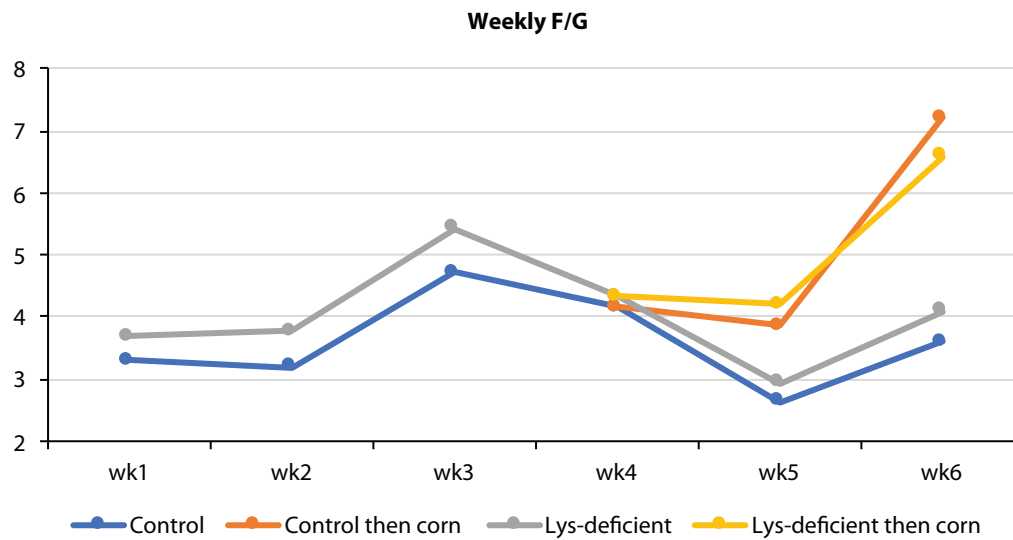


Figure 5. Weekly feed-to-gain ratio (F/G) of the 4 nutritional strategies. Two treatment diets (control and Lys-deficient) were fed to pigs from week 1 to 4 (d 0 to 28). Four nutritional strategies were used from week 5 to 6 (d 28 to 44).