Strategy to blend leftover finisher feed to nursery pigs in a wean-to-finish production system[1]

Fangzhou Wu,[*,2] Kyle F. Coble,[†,3] Chad W. Hastad,[†] Mike D. Tokach,[*] Jason C. Woodworth,[*] Joel M. DeRouchey,[*] Steve S. Dritz,[‡] and Robert D. Goodband[*]

*Department of Animal Sciences and Industry, College of Agriculture, Kansas State University, Manhattan, KS 66506; †New Fashion Pork, Jackson, MN 56143; and ‡Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506

ABSTRACT: In wean-to-finish pig production, leftover finisher feed from the previous group is commonly blended with nursery diets as weanling pigs enter the facility. Two experiments were conducted to evaluate feeding the last finisher diet to nursery pigs. The timing (phase) and dose were evaluated. Each experiment used 1,260 pigs from two commercial research rooms with 21 pigs per pen and 30 pens per room (15 pens per treatment). Pigs were fed commercial nursery diets in a five-phase feeding program, and phase changes were based on a feed budget. In experiment 1, pens of pigs (initially 5.83 kg) were blocked by body weight, gender, and room and allotted to one of four treatments. Treatments included standard nursery diets throughout (control) or standard diets with 2.5 kg/pig of the last finisher feed blended at the beginning of phase 2, 3, or 4. Growth responses during the intermediate periods were promptly decreased ($P < 0.05$) once the finisher feed was introduced regardless of phase in which it was blended. However, during the overall nursery period, blending the finisher diet into phase 2 decreased ($P < 0.05$) average daily gain (ADG) and average daily feed intake (ADFI), but did not affect gain:feed ratio (G:F), compared with control pigs or those that had blended diet in phase 4 with blending of phase 3 diet intermediate. In experiment 2, weaned pigs were fed common phase 1 and 2 diets before the start of the experiment. At the beginning of phase 3, pens of pigs (initially 10.6 kg) were blocked by body weight and room and allotted to one of four treatments. Treatments consisted of a dose-titration of blending increasing amounts of finisher feed (0, 1.25, 2.50, and 3.75 kg/pig) into the phase 3 nursery diet. Overall, blending increasing amounts of the last finisher feed with phase 3 nursery diet decreased ADG (linear, $P = 0.050$) and tended to decrease (linear, $P < 0.07$) ADFI and final body weight. However, there was no evidence for difference in overall G:F. In conclusion, blending finisher feed into the early nursery diets decreased overall ADG and ADFI; however, pigs greater than 11 kg had improved ability to compensate for the negative effects of blending the last finisher feed on overall growth performance. Nevertheless, increasing the amounts of finisher feed fed to 11-kg pigs from 0 to 3.75 kg/pig resulted in a linear decrease in overall ADG and ADFI. Economic analysis indicated no change in income-over-feed-cost due to the timing and dose of blending finisher feed into nursery diets.

Key words: finisher feed, growth, nursery pig, wean-to-finish

[1]Contribution number 19-049-J from the Kansas Agricultural Experiment Station, Manhattan, KS 66506–0210. Appreciation is expressed to New Fashion Pork (Jackson, MN) for use of research facilities and Doug Garry, Dylan Smith, and Zach Post for technical support.

[2]Corresponding author: fangzhou@ksu.edu
[3]Present address: JBS S.A., Greeley, CO 80634
Received October 5, 2018.
Accepted December 19, 2018.

Transl. Anim. Sci. 2019.3:409–418
doi: 10.1093/tas/txy143

INTRODUCTION

In a wean-to-finish pig production, one of the challenges in feed management is to determine what to do with feed remaining in the bin at the end of the finishing phase after pigs have been marketed. The precision of budgeting finisher feed based on predicted feed intake and closeout dates is not perfect. Thus, there is often feed remaining in the bins that must be removed and transported to another site or fed to the next group of pigs. However, in a wean-to-finish barn, the next group happens to be weanling pigs. One strategy is to remove the feed. However, this is time consuming and expensive if the feed is disposed. If the feed is transferred to another group of pigs, this poses a biosecurity risk. Thus, a common strategy is to blend leftover finisher feed into the later stage nursery diets, which requires prolonged feed storage and may result in tandem blending of the early nursery phase diets. Therefore, information regarding the timing and maximum dose of the last finisher feed blended into nursery diets is needed to quantify and mitigate its negative effects. To address this problem, two experiments were designed to replicate a commercial production scenario where up to 7.5 metric tons of the last finisher diet was left in the bins at a 2,000-head barn; thus, up to 3.75 kg per pig of the last finisher feed would have to be fed to each nursery pig in the subsequent turn. Therefore, the objective of this study was to determine the effects of feeding finisher feed blended into different phases of nursery diet (experiment 1), and the dose effect of increasing the quantity of finisher feed blended (experiment 2), on nursery pig growth performance and production economics.

MATERIALS AND METHODS

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these studies. The studies were conducted at New Fashion Pork's nursery research facility located in southwest Minnesota. Both of the experiments used two adjoining research rooms. Each room was equipped with 30 pens (2.59 × 5.56 m) that contained a three-hole dry self-feeder and a cup waterer to allow ad libitum access to feed and water. Diets were manufactured at the New Fashion Pork feed mill located in Worthington, MN.

During each of the experiments, feed additions to each pen were delivered and recorded by a robotic feeding system (FEEDPro; Feedlogic Corp., Willmar, MN). Pens of pigs were weighed and feed disappearance measured every 7 days to determine average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (G:F).

Experiment 1

A total of 1,260 weaned pigs [initially 5.8 kg; PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] were used. Pens of pigs (21 pigs per pen, 30 pens of barrows, and 30 pens of gilts) were blocked by initial pen weight, gender, and room. Within blocks, pens were allotted randomly to 1 of 4 treatments with 15 replications per treatment. Pigs were fed commercial nursery diets in a five-phase feeding program (Table 1) with phase changes made by using a prescribed feed budget (Table 2). Treatments consisted of a standard five-phase nursery diet program (control) and the standard program with 2.5 kg/pig of a last finisher diet blended in phase 2, 3, or 4 diets. The finisher feed did not contain ractopamine. In the blended diets, feed delivery followed the sequence of 1.25 kg/pig of the finisher diet, then a 50:50% blend of the finisher and standard diet, and ended with the remaining allocation of the budgeted nursery diet.

Experiment 2

A total of 1,260 pigs [initially 10.6 kg; PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] were used. Before the start of the experiment, newly weaned pigs were placed into pens with 21 pigs per pen and 30 pens per room. Barrows and gilts were mixed in a pen with a constant sex ratio balanced across pens. Pigs were fed commercial nursery diets in a five-phase feeding program (Table 3) with phases 1 and 2 fed during the pretreatment period. Phase changes were made again by using a feed budget (Table 4). At the beginning of phase 3 (day 0 of the experiment), pens of pigs were blocked by pen weight

Table 1. Composition of experimental diets (as-fed basis; experiment 1)[1]

Items	Phase 2	Phase 3	Phase 4	Phase 5	Finisher
Ingredients, %					
Corn	43.14	39.27	37.07	38.39	79.00
Soybean meal (48% crude protein)	23.75	27.05	32.60	29.30	14.75
Corn distiller's dried grains with solubles	7.50	15.00	20.00	25.00	—
Whey permeate	4.58	2.91	—	—	—
Steamed-rolled oats	3.93	2.49	—	—	—
Corn gluten meal	0.95	0.60	—	—	—
Yeast protein meal[2]	2.24	1.43	—	—	—
Enzymatically treated soy product[3]	1.65	1.05	—	—	—
Limestone	0.85	1.05	1.05	1.28	0.70
Monocalcium phosphate (22% P)	0.84	0.83	0.60	0.65	0.15
Sodium chloride	0.35	0.38	0.26	0.31	0.53
Vitamin and mineral premix	0.08[4]	0.10[4]	0.154	0.15[4]	0.10[5]
L-lysine HCl	0.55	0.55	0.46	0.49	0.35
L-threonine	0.20	0.18	0.12	0.12	0.12
L-tryptophan	0.07	0.07	0.05	0.05	0.02
DL-methionine	0.07	0.10	0.17	0.14	0.08
L-valine	0.09	0.06	—	—	—
L-isoleucine	0.04	0.03	—	—	—
Choline chloride	0.01	—	—	—	—
Beef tallow	1.95	2.95	4.45	3.60	3.85
Vegetable oil	0.88	0.56	—	—	—
Phytase[6]	0.04	0.04	0.02	0.02	—
AV-E Digest[7]	5.00	2.50	2.50	—	—
XFE Liquid Energy[8]	—	—	0.50	0.50	0.25
Tri-basic copper chloride	0.01	0.04	—	—	—
Zinc oxide	0.32	0.21	—	—	—
Other additives	0.91	0.58	—	—	0.10
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Standardized ileal digestible amino acids, %					
Lysine	1.40	1.40	1.41	1.32	0.81
Isoleucine:lysine	57	58	62	62	56
Methionine and cysteine:lysine	58	58	58	58	60
Threonine:lysine	63	63	62	62	66
Tryptophan:lysine	20	20	20	20	18
Valine:lysine	67	67	68	68	66
Total lysine, %	1.56	1.56	1.58	1.48	0.89
Crude protein, %	22.10	22.78	24.18	22.84	12.45
Net energy, kcal/kg	2,295	2,385	2,469	2,491	2,712
Ca, %	0.78	0.78	0.75	0.75	0.37
P, %	0.71	0.71	0.68	0.68	0.34
Available P, %	0.43	0.43	0.45	0.45	0.19

[1]Phase 1 diet formulation is not available.

[2]ProPlex DY (ADM Animal Nutrition, Quincy, IL).

[3]HP 300 (Hamlet Protein, Inc., Findlay, OH).

[4]Provided per kilogram of premix: 3,933,333 IU vitamin A; 266,667 IU vitamin D_3; 440,920 IU vitamin D; 26,455 IU vitamin E; 1,609 mg vitamin K; 5,512 mg riboflavin; 13,228 mg pantothenic acid; 17,637 mg niacin; 16,169 mcg vitamin B_{12}; 39,683 ppm Mn; 111,700 ppm Fe; 132,276 ppm Zn; 220,460 ppm Cu; 558 ppm I; and 441 ppm Se.

[5]Provided per kilogram of premix: 4,739,890 IU vitamin A; 250,000 IU vitamin D_3; 485,012 IU vitamin D; 33,069 IU vitamin E; 2,094 mg vitamin K; 4,409 mg riboflavin; 15,432 mg pantothenic acid; 22,046 mg niacin; 16,535 mcg vitamin B_{12}; 59,524 ppm Mn; 143,299 ppm Fe; 198,414 ppm Zn; 330,690 ppm Cu; 441 ppm I; and 661 ppm Se.

[6]Ronozyme HiPhos (DSM Nutritional Products, Inc., Parsippany, NJ).

[7]AV-E Digest (XFE Products, Des Moines, IA).

[8]Liquid Energy (XFE Products, Des Moines, IA).

Table 2. Feed budgets (kilogram per pig) of treatments (experiment 1)

Phase	Control	Blended diets[1]		
		Phase 2	Phase 3	Phase 4
Phase 1	2.48 (2.41)[2]	2.48 (2.37)	2.48 (2.60)	2.48 (2.70)
Phase 2	3.66 (3.72)	1.25 (1.21) last finisher diet, 2.50 (2.25) 50:50% blend, 2.50 (2.28) standard phase 2	3.66 (3.73)	3.66 (3.72)
Phase 3	3.66 (3.70)	3.66 (3.71)	1.25 (1.30) last finisher diet, 2.50 (2.48) 50:50% blend, 2.50 (2.53) standard phase 3	3.66 (3.72)
Phase 4	9.53 (9.33)	9.53 (9.30)	9.53 (9.42)	1.25 (1.30) last finisher diet, 2.50 (2.46) 50:50% blend, 8.28 (8.11) standard phase 4
Phase 5	9.53 (15.22)	7.03 (12.07)	7.03 (11.64)	7.03 (12.25)

[1]Finisher feed was blended with standard nursery diets in different phases; blended diets were delivered in the sequence of finisher feed, 50% finisher and 50% standard blended diet, and standard diet.

[2]Values in the parenthesis indicate the actual amount (kilogram per pig) of diet consumed.

and room. The reason for selecting phase 3 to initiate this experiment was based on findings from experiment 1. Each room contained seven complete blocks and a two-pen incomplete block (two incomplete blocks from the adjoining rooms formed a complete block). Within blocks, pens were allotted randomly to one of four treatments with 15 replications per treatment. Treatments consisted of a dose-titration of blending increasing amounts of the last finisher diet (0, 1.25, 2.50, and 3.75 kg per pig, corresponding to 0, 2.5, 5, and 7.5 metric tons of leftover finisher feed per 2,000-head barn, respectively) into the phase 3 nursery diet. The last finisher diet did not contain ractopamine. When the finisher feed was blended with nursery diet, feed delivery followed the sequence of half of the finisher feed budget, a 50:50% blend the last finisher, and phase 3 nursery diets and ended with the remaining budget of the phase 3 nursery diet.

Chemical Analysis

Nine feed samples (five standard nursery diets, one finisher diet, and three blended diets) from experiment 1 and seven feed samples (five nursery diets, one finisher diet, and one blended diet) from experiment 2 were collected directly from the feed robot delivery outlet. Feed samples were delivered to the Kansas State University Swine Laboratory, stored at −20 °C until they were analyzed for dry matter, crude protein, and mineral content (Ward Laboratories, Inc., Kearney, NE). Standard procedures from Association of Official Analytical Chemists (AOAC; 2006) were followed for analysis of moisture (Method 934.01) and crude protein (Method 990.03). To determine the moisture content, samples were weighed, dried to approximately 90% dry matter at 64 °C, and then mixed and ground through a 1-mm sieve, followed by another drying under 105 °C for 3 h. Crude protein was calculated by multiplying N concentration by 6.25 in which percentage N was determined based on thermal conductivity with combustion method. Calcium (Ca), phosphorous (P), zinc, and copper concentrations were analyzed by iCAP 6000 series ICP Emission Spectrometer (Thermo Electron Corporation, Marietta, OH) using methods outlined by AOAC (2012).

Economic Analysis

Calculation of economics were based on a gain value of $1.32 per kg body weight (BW) and feed prices of $0.574, $0.495, $0.429, $0.327, $0.292, and $0.190 per kg of nursery phase 1, 2, 3, 4, 5, and last finisher diets, respectively. Feed prices consisted of costs for ingredients excluding manufacturing and delivery costs. Economic response variables included and were calculated using the following equations:

$$\text{Feed cost} = \text{diet cost} \times \text{feed consumption};$$

$$\text{Gain value} = \text{total BW gain} \times \$1.32/\text{kg};$$

$$\text{Feed cost per kg of gain} = \text{feed cost}/(\text{ADG} \times \text{period length, d});$$

$$\text{Income-over-feed-cost} = \text{gain value} - \text{feed cost}$$

Statistical Analysis

All data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. The statistical models for experiment 1 included the fixed effect of treatment (blending phases) and the random effects

Table 3. Composition of experimental diets (as-fed basis; experiment 2)[1]

Items	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Finisher
Ingredients, %						
Corn	41.47	44.45	40.13	44.75	45.53	80.77
Soybean meal (48% crude protein)	16.30	23.05	26.00	29.20	27.15	14.90
Corn DDGS[2]	5.00	7.50	15.00	16.75	20.00	—
Spray dried whey	5.50	—	—	—	—	—
Whey permeate	5.82	4.37	2.91	—	—	—
Steamed-rolled oats	4.99	3.74	2.49	—	—	—
Corn gluten meal	1.20	0.90	0.60	—	—	—
Yeast protein meal[3]	2.85	2.14	1.43	—	—	—
Enzymatically treated soy product[4]	2.10	1.58	1.05	—	—	—
Limestone	0.67	0.84	0.10	—	1.30	0.88
Monocalcium phosphate (22% P)	0.45	0.68	—	0.15	1.03	0.40
Sodium chloride	0.38	0.38	—	0.03	0.34	0.43
Vitamin and mineral premix[5]	0.30[5]	0.30[5]	0.30[5]	0.15[5]	0.15[5]	0.10[6]
Nursery mineral premix	—	—	2.50	2.50	—	—
L-lysine HCl	0.56	0.57	0.22	0.18	0.54	0.28
L-threonine	0.20	0.22	0.20	0.17	0.17	0.11
L-tryptophan	0.07	0.06	0.06	0.04	0.03	0.03
DL-methionine	0.14	0.14	0.16	0.22	0.21	0.05
L-valine	0.12	0.09	0.06	0.06	0.08	—
L-isoleucine	0.05	0.04	0.03	—	—	—
Choline chloride	0.04	0.01	—	—	—	—
Phytase[7]	—	—	—	—	0.07	—
Protease[8]	—	—	—	0.05	0.05	—
AV-E Digest[9]	7.50	5.00	2.50	2.50	—	—
XFE Liquid Energy[10]	0.75	—	—	0.75	0.75	0.75
Choice white grease	0.85	1.90	2.90	2.50	2.60	1.20
Vegetable oil	1.12	0.84	0.56	—	—	—
Tri-basic copper chloride	0.01	0.03	0.01	—	—	—
Zinc oxide	0.41	0.31	0.21	—	—	—
Other additives	1.15	0.86	0.58	—	—	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Standardized ileal digestible amino acids, %						
Lysine	1.35	1.40	1.40	1.38	1.32	0.74
Isoleucine:lysine	0.58	0.57	0.58	0.57	0.56	0.57
Methionine and Cysteine:lysine	0.62	0.58	0.58	0.58	0.58	0.56
Threonine:lysine	0.63	0.63	0.63	0.62	0.62	0.66
Tryptophan:lysine	0.20	0.19	0.19	0.19	0.18	0.20
Valine:lysine	0.69	0.67	0.66	0.67	0.68	0.65
Total lysine, %	1.51	1.56	1.56	1.55	1.47	0.82
Crude protein, %	21.30	22.27	22.94	22.99	21.73	12.74
Net energy, kcal/kg	2,412	2,443	2,476	2,535	2,535	2,601
Ca, %	0.70	0.71	0.73	0.79	0.77	0.46
P, %	0.64	0.65	0.66	0.68	0.67	0.40
Available P, %	0.45	0.43	0.43	0.45	0.45	0.24

[1]Phases 1 and 2 diets were fed before the start of experiment.

[2]Distiller's dried grains with solubles.

[3]ProPlex DY (ADM Animal Nutrition, Quincy, IL).

[4]HP 300 (Hamlet Protein, Inc., Findlay, OH).

[5]Provided per kilogram of premix: 3,933,333 IU vitamin A; 266,667 IU vitamin D_3; 440,920 IU vitamin D; 26,455 IU vitamin E; 1,609 mg vitamin K; 5,512 mg riboflavin; 13,228 mg pantothenic acid; 17,637 mg niacin; 16,169 mcg vitamin B_{12}; 39,683 ppm Mn; 111,700 ppm Fe; 132,276 ppm Zn; 220,460 ppm Cu; 558 ppm I; and 441 ppm Se.

[6]Provided per kilogram of premix: 4,739,890 IU vitamin A; 250,000 IU vitamin D_3; 485,012 IU vitamin D; 33,069 IU vitamin E; 2,094 mg vitamin K; 4,409 mg riboflavin; 15,432 mg pantothenic acid; 22,046 mg niacin; 16,535 mcg vitamin B_{12}; 59,524 ppm Mn; 143,299 ppm Fe; 198,414 ppm Zn; 330,690 ppm Cu; 441 ppm I; and 661 ppm Se.

[7]Ronozyme HiPhos (DSM Nutritional Products, Inc., Parsippany, NJ).

[8]CIBENZA® DP100 (Novus International, Saint Charles, MO).

[9]AV-E Digest (XFE Products, Des Moines, IA).

[10]Liquid Energy (XFE Products, Des Moines, IA).

of weight block, gender, and room. Means were reported as least-squares means and separated by the PDIFF option. For experiment 2, the statistical models included the fixed effect of treatment (finisher feed amount) and the random effects of weight block and room. Contrasts were used to determine the linear and quadratic effects of increasing finisher feed dose. Results were considered significant at $P < 0.05$ and marginally significant at $0.05 < P < 0.10$.

RESULTS

Diet Analysis: Experiments 1 and 2

As expected, the finisher diet contained lower crude protein, Ca, and P concentrations than nursery diets (Table 5). Nutrient concentrations in blended diets approximated the average between the finisher diet and the corresponding nursery diet phase, indicating that diets were properly blended.

Experiment 1

From day 0 to 7, there were no differences in growth performance as expected ($P > 0.16$; Table 6) because all pigs received standard phase 1 diet. From day 7 to 14 (phase 2 diets), pigs that received finisher feed blended into the phase 2 diet had decreased ($P < 0.01$) ADG, ADFI, G:F, and day 14 BW compared with pigs in other treatment groups. From day 14 to 21, blending finisher feed into the phase 3 diet resulted in decreased ($P < 0.01$) ADG and G:F compared with other treatments, but no differences in ADFI were observed. BWs of pigs fed the finisher diet blended into phase 2 or phase 3 were lower ($P < 0.05$) than pigs from control and phase 4 blending treatments on day 21.

Table 4. Feed budgets (kilogram per pig) of treatments (experiment 2)

	Finisher feed budget[1], kg/pig			
Phase	0	1.25	2.50	3.75
Phase 1	-	-	2.48 (2.54)[2]	-
Phase 2	-	-	2.00 (1.78)	-
Phase 3	3.74 (3.93)	0.63 (0.74) last finisher diet, 1.25 (1.36) 50:50% blend, 3.12 (3.21) standard phase 3	1.25 (1.37) last finisher diet, 2.50 (2.71) 50:50% blend, 2.50 (2.59) standard phase 3	1.87 (1.99) last finisher diet, 3.74 (3.90) 50:50% blend, 1.87 (1.02) standard phase 3
Phase 4	9.53 (10.11)	9.53 (9.65)	9.53 (9.74)	9.53 (9.82)
Phase 5	9.53 (7.67)	8.28 (7.33)	7.03 (4.57)	5.78 (4.01)

[1]The budgeted amount of finisher diet was blended into phase 3 nursery diet; blended diets were delivered in the sequence of finisher feed, 50% finisher and 50% standard blended diet, and standard diet.

[2]Values in the parenthesis indicate the actual amount (kilogram per pig) of diet consumed.

Table 5. Analyzed nutrient composition of experimental diets[1]

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Finisher	50% Phase 2: 50% finisher blend	50% Phase 3: 50% finisher blend	50% Phase 4: 50% finisher blend
Experiment 1									
Dry matter, %	89.2	89.6	89.1	88.5	87.2	87.8	88.5	88.7	87.7
Crude protein, %	22.3	23.8	23.8	24.5	19.1	13.6	19.2	18.5	18.8
Ca, %	1.02	1.01	0.95	0.96	0.87	0.62	0.80	0.87	0.79
P, %	0.71	0.88	0.70	0.70	0.52	0.31	0.53	0.54	0.49
Zinc, ppm	2,335	3,466	1,733	151	117	114	1,529	821	137
Copper, ppm	88	209	246	186	141	155	219	184	185
Experiment 2									
Dry matter, %	90.0	90.8	90.1	88.4	88.7	88.5	—	89.4	—
Crude protein, %	20.2	21.8	23.3	23.4	23.0	14.5	—	18.8	—
Ca, %	0.97	1.12	1.03	0.73	1.01	1.18	—	1.06	—
P, %	0.54	0.55	0.63	0.64	0.69	0.45	—	0.53	—
Zinc, ppm	2,605	2,169	2,260	265	169	123	—	847	—
Copper, ppm	100	216	215	98	155	135	—	135	—

[1]Multiple samples of each diet were collected, blended and subsampled, and analyzed (Ward Laboratories, Inc., Kearney, NE).

Table 6. Effects of blending finisher feed into different phases of nursery diets on growth performance (experiment 1)[1]

		Blended diets[2]				
	Control	Phase 2	Phase 3	Phase 4	SEM	*P*-value
BW, kg						
Day 0	5.8	5.8	5.8	5.8	0.05	0.984
Day 7	7.0	7.1	7.0	7.0	0.07	0.979
Day 14	9.8[a]	9.4[b]	9.9[a]	9.9[a]	0.13	0.001
Day 21	12.7[a]	12.2[b]	12.3[b]	12.8[a]	0.16	0.001
Day 28	16.2[a]	15.5[b]	15.5[b]	16.0[a]	0.17	0.001
Day 35	20.8[a]	19.8[c]	20.1[bc]	20.6[ab]	0.22	0.003
Day 47	30.0[a]	29.1[b]	29.4[ab]	29.9[a]	0.26	0.017
Day 0 to 7						
ADG, g	174	176	169	171	8.5	0.880
ADFI, g	174	164	171	179	6.4	0.368
G:F, g/kg	1,026	1,097	1,004	947	54.5	0.161
Day 7 to 14						
ADG, g	398[a]	329[b]	405[a]	415[a]	11.9	0.001
ADFI, g	448[a]	412[b]	446[a]	459[a]	13.1	0.002
G:F, g/kg	886[a]	804[b]	907[a]	905[a]	13.7	0.001
Day 14 to 21						
ADG, g	414[a]	402[a]	346[b]	409[a]	10.9	0.001
ADFI, g	560	556	556	559	10.9	0.991
G:F, g/kg	741[a]	722[a]	622[b]	733[a]	15.8	0.001
Day 21 to 28						
ADG, g	498[a]	475[ab]	467[b]	454[b]	8.1	0.003
ADFI, g	655[ab]	653[ab]	631[b]	673[a]	9.3	0.018
G:F, g/kg	762[a]	728[b]	741[ab]	674[c]	9.9	0.001
Day 28 to 35						
ADG, g	648[a]	616[b]	648[a]	647[a]	10.5	0.067
ADFI, g	884	868	884	913	15.7	0.235
G:F, g/kg	734	712	735	709	10.3	0.146
Day 35 to 47						
ADG, g	769	768	780	776	8.3	0.644
ADFI, g	1,298[a]	1,246[b]	1,254[b]	1,276[ab]	15.6	0.048
G:F, g/kg	594[c]	616[ab]	623[a]	608[b]	4.3	0.001
Day 0 to 47						
ADG, g	514[a]	493[b]	502[ab]	509[a]	5.4	0.031
ADFI, g	736[a]	711[b]	720[ab]	738[a]	8.3	0.045
G:F, g/kg	699	693	698	690	3.6	0.132

[1]A total of 1,260 weaned pigs [PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] were used in a 47-d growth trial with 21 pigs per pen and 15 replications (pen) per treatment. Growth responses include ADG, ADFI, and G:F.

[2]Approximately 2.5 kg/pig of finisher feed was blended with standard nursery diets at the beginning of different phases (as feed budgets presented in Table 2).

[abc]Means with different superscripts within a row differ ($P < 0.05$).

Between day 21 and 28, the switch from the phase 3 to phase 4 budgets occurred in the majority of the pens. During this period, ADG for pigs fed finisher feed blended into the phase 3 or phase 4 diets was lower ($P < 0.05$) than that of pigs from control with phase 2 blending treatment intermediate. No evidence for differences in ADG among pigs from control and phase 2 blending treatment was observed. Pigs with finisher feed blended into the phase 3 diet had decreased ($P = 0.002$) ADFI compared with pigs from the phase 4 blending treatment with pigs from the control and phase 2 blending treatments having intermediate ADFI. Pigs receiving finisher feed blended into the phase 4 diet had poorer ($P < 0.01$) G:F than pigs from other treatments. Also, G:F of pigs from phase 2 blending treatment was lower ($P = 0.025$) than that of pigs from the control, but was not different from pigs from the phase 3 blending treatment. On day 28, BW of pigs fed finisher feed blended into the phase 2 or phase 3 diets was lower ($P < 0.05$) than those from control and phase 4 blending treatments.

From day 28 to 35, the majority of the pens were fed their phase 4 budgets with the diet change from phase 4 to 5 occurring at the end of this week. A marginal treatment effect ($P = 0.067$) was observed for ADG with pigs that had received finisher feed blended into the phase 2 diet having decreased ($P < 0.05$) ADG compared with pigs from other treatment groups. However, no evidence of differences in ADFI and G:F was observed. On day 35, BW of pigs that received finisher feed blended during phase 2 was decreased ($P < 0.01$) compared with those from control and phase 4 blending treatments, but was not different from pigs from phase 3 blending treatment. Pigs that received finisher feed blended into the phase 3 diet also had lower ($P = 0.013$) BW than pigs fed the control treatment. Pigs fed the last finisher diet blended into the phase 4 diet had similar BW compared with control pigs on day 35.

From day 35 to 47, all pigs were fed a standard phase 5 diet. ADG was similar among treatments. Pigs fed finisher feed blended into the phase 2 or phase 3 diets had decreased ($P < 0.05$) ADFI compared with control pigs, but they were not different from pigs from phase 4 blending treatment. G:F increased ($P < 0.01$) in pigs that previously had finisher feed blended into their diets compared with the control. Pigs from phase 3 blending treatment also had better ($P = 0.020$) G:F than pigs from phase 4 blending treatment.

Overall, blending finisher diet during phase 2 resulted in decreased ($P < 0.05$) ADG, ADFI, and final BW, but did not affect G:F compared with control pigs or pigs that had finisher diet blended into the nursery phase 4. No evidence for differences in growth performance were observed among pigs from control, phase 3 blending, and phase 4 blending treatments.

Blending the last finisher feed into phase 2 or 3 decreased ($P < 0.05$) feed cost relative to control pigs and pigs that received blended diet in phase 4, which can be explained by the slightly decreased overall feed intake and lower cost of the finisher diet (Table 7). The lower final BW also resulted in pigs that received the finisher diet treatment during phase 2 to have lower ($P < 0.05$) gain value than pigs from control and phase 4 blending treatments with blending of phase 3 diet intermediate. No treatment effect was observed for feed cost per kilogram of gain. Income-over-feed-cost was numerically decreased for pigs fed blended diets, and the magnitude is greater when pigs received the blended diet at a younger age; however, no statistically significant difference was detected.

Experiment 2

From day 0 to 14, feeding increasing finisher feed amounts tended to decrease (quadratic, $P < 0.09$) ADG and day 14 BW (Table 8). ADG was unaffected as the last finisher diet quantity increased from 0 to 1.25 kg/pig but decreased thereafter. There was no strong evidence that ADFI was affected by feeding the finisher diet. However, G:F

Table 7. Effects of blending finisher feed into different phases of nursery diets on production economics (experiment 1)[1]

		Blended diets[2]				
Item	Control	Phase 2	Phase 3	Phase 4	SEM	*P*-value
Economics, \$/pig						
Feed cost[3]	12.37[a]	11.74[b]	12.01[b]	12.39[a]	0.134	<0.001
Gain value[4]	31.95[a]	30.64[b]	31.18[ab]	31.64[a]	0.334	0.031
Feed cost/kg gain[5]	0.511	0.509	0.507	0.516	0.0044	0.410
IOFC[6]	19.58	18.89	19.16	19.26	0.261	0.317

IOFC, income-over-feed-cost.

[1]A total of 1,260 weaned pigs [PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] with initial BW of 5.9 kg were used in a 47-d growth trial with 21 pigs per pen and 15 replications (pen) per treatment.

[2]Approximately 2.5 kg/pig of finisher feed was blended with standard nursery diets at the beginning of different phases (as feed budgets presented in Table 2).

[3]Feed cost = diet cost × feed consumption.

[4]Gain value = total BW gain × \$1.32/kg.

[5]Feed cost per kilogram of gain = feed cost/(ADG × period length, d).

[6]IOFC = gain value − feed cost.

[ab]Means with different superscripts within a row differ ($P < 0.05$).

decreased (linear, $P < 0.001$) as more finisher feed was blended into the phase 3 nursery diet.

From day 14 to 28, pigs previously fed increasing finisher diet amounts had increased (linear, $P < 0.05$) ADG and G:F. ADFI was unaffected by the finisher feed quantity fed. Overall (day 0 to 28), blending increasing amounts of finisher feed with phase 3 nursery diet decreased ADG (linear, $P = 0.050$) and tended to decrease ADFI and final BW (linear, $P < 0.07$). However, there were no evidences of any linear or quadratic effects of increasing the quantity of finisher feed on overall G:F.

Feed cost, gain value, and feed cost per kilogram of gain decreased (linear, $P < 0.05$) as the quantity of finisher feed fed in phase 3 increased from 0 to 3.75 kg/pig (Table 9). However, no evidence of statistical differences in income-over-feed-cost was observed among treatments.

DISCUSSION

In a series of two experiments, we evaluated the feeding phase and dose of finisher feed fed to nursery pigs. To the best of our knowledge, this is

Table 8. Effects of blending increasing doses of finisher feed into nursery diets on growth performance (experiment 2)[1]

	Finisher feed budget[2], kg/pig					*P*-value, <	
Item	0	1.25	2.50	3.75	SEM	Linear	Quadratic
BW, kg							
Day 0	10.6	10.6	10.6	10.5	0.18	0.828	0.817
Day 14	16.5	16.6	16.1	15.7	0.25	0.001	0.087
Day 28	25.1	25.3	25.0	24.7	0.35	0.068	0.195
Day 0 to 14							
ADG, g	426	432	395	368	10.9	0.001	0.090
ADFI, g	575	601	566	554	16.2	0.105	0.169
G:F, g/kg	741	722	699	664	9.6	0.001	0.418
Day 14 to 28							
ADG, g	612	620	630	638	12.2	0.029	0.993
ADFI, g	980	994	949	960	23.5	0.175	0.947
G:F, g/kg	624	626	667	667	8.6	0.001	0.934
Day 0 to 28							
ADG, g	518	526	512	502	8.4	0.050	0.216
ADFI, g	777	797	756	755	14.8	0.052	0.367
G:F, g/kg	668	661	678	666	4.7	0.566	0.535

[1]A total of 1,260 weaned pigs [PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] were used in a 28-day growth trial with 21 pigs per pen and 15 replications (pen) per treatment. Growth responses include ADG, ADFI, and G:F.

[2]The budgeted amounts of finisher feed blended into phase 3 nursery diet.

Table 9. Effects of blending increasing doses of finisher feed into nursery diets on production economics (experiment 2)[1]

	Finisher feed budget[2], kg/pig					*P*-value, <	
Item	0	1.25	2.50	3.75	SEM	Linear	Quadratic
Economics, $/pig							
Feed cost[3]	7.23	7.24	6.73	6.40	0.135	0.001	0.113
Gain value[4]	19.19	19.49	18.95	18.59	0.313	0.050	0.215
Feed cost/kg gain[5]	0.499	0.491	0.469	0.454	0.0041	0.001	0.289
IOFC[6]	11.96	12.25	12.22	12.20	0.1983	0.384	0.380

IOFC, income-over-feed-cost.

[1]A total of 1,260 weaned pigs [PIC TR4 × (Fast LW × PIC L02); PIC, Hendersonville, TN, USA; Fast Genetics, Saskatoon, SK, Canada] with initial body weight of 10.6 kg were used in a 28-day growth trial with 21 pigs per pen and 15 replications (pen) per treatment.

[2]The budgeted amounts of finisher feed blended into phase 3 nursery diet.

[3]Feed cost = diet cost × feed consumption.

[4]Gain value = total body weight gain × $1.32/kg.

[5]Feed cost per kilogram of gain = feed cost/(ADG × period length, d).

[6]IOFC = gain value − feed cost.

the first published study that offered a model for wean-to-finish production systems to evaluate the strategy of managing leftover finisher feed.

In experiment 1, blending the finisher diet in phase 2 decreased growth performance immediately and the negative effects persisted during the subsequent periods. The last finisher diet does not contain specialty protein ingredients and is less palatable, which may be responsible for a low ADFI when fed to young pigs. This is supported by many studies (Skinner et al., 2014; Collins et al., 2017; Tekeste et al., 2017) where reducing diet complexity has led to decreased growth performance during the early nursery phase. In addition, the last finisher diet is deficient in amino acids, Ca, and P concentrations for nursery pigs. These diets also contain growth-promoting levels of zinc, copper, and phytase. Lack of these nutrients has been reported to prevent nursery pigs from achieving maximum growth performance (Hill et al., 2000; Nemechek et al., 2018; Wu et al., 2018). It is worth noting that the last finisher feed used in this study did not contain fibrous ingredients, such as distiller's dried grains with solubles and wheat middlings, or ractopamine; otherwise, more severe reduction in nursery growth responses may be expected.

When finisher feed was blended in phase 3 or phase 4, an immediate decrease in growth performance was also observed. However, these pigs were able to maintain or increase feed intake to compensate partly for the negative impact of consuming the finisher diet and, therefore, resumed growth performance to levels similar to the control faster and to a greater degree compared with those receiving the finisher diet during phase 2. Interestingly, pigs that previously received blended diets expressed greater G:F from day 35 to 47 compared with control pigs that never received any finisher feed, which might be a result of the decreased feed intake and compensatory gain.

According to the results from experiment 1, blending 2.5 kg finisher feed per pig into phase 3 nursery diet resulted in no observed impact on overall growth performance. The next question was to determine the maximum amount of the last finisher diet blended with phase 3 (initially 12 kg BW) nursery diets without affecting pig performance. Therefore, the second experiment was designed to characterize the dose–response to increasing the leftover finisher diet quantity. The doses evaluated ranged from 0 to 3.75 kg per pig (corresponding to 0 to 7.5 metric tons per 2,000-head barn) blended into nursery phase 3. On the basis of feed intake, pigs that were budgeted 1.25 kg/pig finisher feed had completed their finisher feed budgets by day 4. These pigs were able to fully compensate for any initial lost gain by day 14, but with a slightly poorer G:F, compared with those that did not receive finisher feed. However, pigs that received 2.50 and 3.75 kg/pig finisher feed completed their finisher feed budgets around days 8 and 11, respectively, and thus had less time for compensatory gain by the end of the first growth period (day 0 to 14).

Pigs that previously received finisher feed had compensatory growth during the second growth period (day 14 to 28), and the degree of compensation linearly related to the quantity of finisher feed fed previously. Compensatory growth after a short period of nutrient deficiency has been widely documented in nursery pigs. Stein and Kil (2006) and Nemechek et al. (2018) both reported that pigs that received early nursery diets with deficient amino acids (or crude protein), but late nursery diets with adequate nutrients, were able to fully compensate for overall ADG with unaffected, or even improved, G:F. Although the mechanism behind compensatory growth is not fully understood, Prince et al. (1983) and Kamalakar et al. (2009) suggested that the magnitude of compensatory gain may be influenced by the degree of amino acid restriction and the length of time that pigs are subjected to the restriction. In this study, pigs that received 2.50 or 3.75 kg/pig finisher feed might have experienced prolonged nutrient deficiency and, therefore, had decreased overall ADG and ADFI compared with those allocated 0 or 1.25 kg/pig finisher feed.

In summary, growth performance of nursery pigs was promptly influenced when fed the last finisher feed blended into nursery diets, and its magnitude of change depended on which phase the finisher feed was blended into. When BW was greater than 11 kg (phase 3 in this study), pigs had improved ability to compensate for the negative effects of feeding finisher feed on overall ADG and ADFI. However, increasing the amounts of finisher feed fed to 11-kg pigs resulted in a linear decrease in overall ADG and ADFI.

Conflict of interest statement. The authors declare no conflict of interest.

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