EFFECT OF DIET COMPLEXITY AND PHASE FEEDING ON GROWTH PERFORMANCE, DIARRHEA INCIDENCE AND DIET ECONOMICS IN NURSERY PIGS

Lenitta A. Lopez[1] and Rommel C. Sulabo[1]

ABSTRACT

Thirty-two newly-weaned pigs (8.89 ± 0.73 kg; PIC L337×C24) were used to determine the interactive effects of diet complexity and phase feeding on growth performance, diarrhea incidence, and economic return in nursery pigs. Pigs were randomly allotted to 1 of 4 treatments in a 2 × 2 factorial arrangement using a randomized complete block design. Treatment factors were nursery diet complexity (Complex vs. Semi-complex) and nursery phase feeding program (2- vs. 3-phase). Each treatment had 8 replications. Results showed no significant interaction for all growth and diarrhea parameters measured. Overall (d 0 to 42), pigs fed the complex diets had greater (*P*=0.04) ADFI compared with those fed semi-complex diets; however, no significant differences were observed for ADG, G:F, final BW and diarrhea incidence. Increasing the number of phases in the nursery feeding program did not have any significant effect on growth performance and diarrhea incidence. Overall, the most cost-effective feeding program was the 3-phase, semi-complex treatment, which had the least feed cost per kg gain and greatest margin over feed cost among all the treatments. In conclusion, reducing the complexity of the nursery diets and employing a 3-phase nursery feeding program may be the most cost-effective strategy in maximizing economic return.

Key words: diet complexity, phase feeding, growth performance, nursery pigs

INTRODUCTION

Developing a cost-effective nursery feeding program that will maximize growth and reduce the incidence of post-weaning diarrhea is an important aspect of commercial pig production. Complexity pertains to designing the diet with an effort of increasing diet digestibility and palatability either by increasing the concentration of digestible nutrients or using specialty feed ingredients (Menegat *et al*., 2019). Increasing the complexity of nursery diets has a positive effect on piglets early post-weaning (Whang *et al*., 2000; Sulabo *et al*., 2010); however, growth and efficiency improvements from greater diet complexity decrease as piglets increase in age (Dritz *et al*., 1996; Wolter *et al*., 2003). These suggest that diet complexity may only be important in the earlier phases after weaning, and it can be reduced

[1]Institute of Animal Science, College of Agriculture and Food Science, University of the Philippines Los Baños, College, Laguna 4031 Philippines (email: rcsulabo@up.edu.ph).

in later phases to take advantage of the greater ability of pigs to digest nutrients. Therefore, the economics of feeding complex diets to nursery pigs should be evaluated.

In the nursery, a phase feeding strategy is the use of multiple diets, each diet fed for a relatively short period of time, to match the changing nutrient requirements and digestive capabilities of pigs (Menegat *et al.*, 2019). It also allows adjustment of the diet for economic reasons without affecting growth performance. In a phase feeding program, feeding complex diets for a longer period may be an unnecessary expense whereas feeding for a shorter period may negatively affect post-weaning feed intake and growth. However, there is no information available on the interaction of diet complexity and phase feeding in nursery pigs. Therefore, the objective of the study was to determine the interactive effects of diet complexity and phase feeding on growth performance, diarrhea incidence, and economic return in nursery pigs.

MATERIALS AND METHODS

A total of 32 newly-weaned pigs (initial BW=8.89 ± 0.73 kg; PIC L337 × C24) were used in a 42-d growth assay. Pigs were blocked by initial weight and sex and were randomly allotted to 1 of 4 treatments in a 2 × 2 factorial arrangement using a randomized complete block design. Treatment factors were nursery diet complexity (Complex vs. Semi-complex) and nursery phase feeding program (2- vs. 3-phases). Treatments were: 1) Complex, 2-phase, 2) Complex, 3-phase, 3) Semi-complex, 2-phase, and 4) Semi-complex, 3-phase (Table 1). Each treatment had 8 replications (pens) with 1 pig per pen. Each individual pig in each pen was provided *ad libitum* access to feed and water.

Diets were formulated (Table 2 and 3) with varying levels of lactose, specialty protein ingredients and soybean meal during each of the nursery phases to create the levels of diet complexity. The specialty feed ingredients used in the diets were chosen for their higher concentration of digestible nutrients or the lower concentration of anti-nutritional factors compared with soybean meal. For the complex Phase 1 diet (C1), it was formulated to contain 12% lactose from whey permeate, 10% enzyme-treated soybean meal, 3% soy protein concentrate, 5% spray-dried animal plasma and 1.25% spray-dried blood cells. A maximum restriction was set for soybean meal at 10% of the diet. For the semi-complex Phase 1 diet (SC1), it was formulated to contain less lactose (8% from whey permeate) and a lower concentration of specialty protein sources (5% enzyme-treated soybean meal, 3% soy protein concentrate, 2.5% spray-dried animal plasma, and no spray-dried blood cells).

Table 1. Experimental treatments[1].

<table>
<tr><th>Phase</th><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Pig age (d)</td><td>28 to 34</td><td>35 to 49</td><td>50 to 70</td></tr>
<tr><td>Study period (d)</td><td>0 to 6</td><td>7 to 21</td><td>22 to 42</td></tr>
<tr><td>Treatment 1</td><td>C1</td><td colspan="2">C2</td></tr>
<tr><td>Treatment 2</td><td>C1</td><td>C2</td><td>S3</td></tr>
<tr><td>Treatment 3</td><td>SC1</td><td colspan="2">SC2</td></tr>
<tr><td>Treatment 4</td><td>SC1</td><td>SC2</td><td>S3</td></tr>
</table>

[1]C1: Complex 1 diet, SC1: Semi-complex 1 diet, C2: Complex 2 diet, SC2: Semi-complex 1 diet

Table 2. Ingredient composition (as-fed basis) of phase 1, 2, and 3 diets.

Item	Phase 1		Phase 2		Phase 3 (S3)
	Semi-complex (SC1)	Complex (C1)	Semi-complex (SC2)	Complex (C2)	
Ingredient, %					
Corn, yellow	47.44	48.20	49.38	48.95	62.07
Blood cells, spray-dried	--	1.25	--	--	--
Hydrolyzed peptone	--	--	3.00	5.00	--
Plasma, spray-dried	2.50	5.00	--	--	--
Soybean meal	24.48	10.00	34.00	20.00	32.56
Soybean meal, enzyme-treated	5.00	10.00	--	5.00	--
Soy protein concentrate	3.00	3.00	--	3.00	--
Whey permeate	9.41	14.12	4.71	9.41	--
Coconut oil	3.65	3.54	4.13	4.12	1.06
L-Lysine	0.31	0.23	0.30	0.29	0.22
DL-methionine	0.19	0.19	0.18	0.19	0.08
L-threonine	0.09	0.06	0.12	0.10	0.05
L-tryptophan	0.01	--	0.01	0.02	--
Monocalcium phosphate	1.17	0.83	1.44	1.16	1.17
Limestone	1.11	1.94	1.09	1.12	1.35
Vitamin premix[1]	0.03	0.03	0.03	0.03	0.03
Mineral premix[1]	0.10	0.10	0.10	0.10	0.10
Choline chloride, 60%	0.35	0.35	0.35	0.35	0.35
Salt	0.30	0.30	0.30	0.30	0.30
Zinc oxide, 72% Zn	0.30	0.30	0.30	0.30	0.30
CTC 20% premix	0.20	0.20	0.20	0.20	0.20
Tiamulin 10% premix	0.04	0.04	0.04	0.04	0.04
Acidifier	0.20	0.20	0.20	0.20	--
Antimold	0.05	0.05	0.05	0.05	0.05
Mycotoxin binder	0.05	0.05	0.05	0.05	0.05
Antioxidant	0.01	0.01	0.01	0.01	0.01
Phytase	0.01	0.01	0.01	0.01	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00

[1]Provided the following quantities of vitamins and micro minerals per kgof complete diet: Vitamin A, 11,128 IU; vitamin D3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.42 mg; thiamin, 0.24 mg; riboflavin, 6.58 mg; pyridoxine, 0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid, 23.5 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

Table 3. Calculated and analyzed composition (as-fed basis) of phase 1, 2, and 3 diets.

Item	Phase 1		Phase 2		Phase 3 (S3)
	Semi-complex (SC1)	Complex (C1)	Semi-complex (SC2)	Complex (C2)	
Calculated, %					
DM	87.10	87.66	86.73	87.30	86.22
ME, kcal/kg	3,400.00	3,400.00	3,400.00	3,400.00	3,300.00
SID Lys, %[1]	1.48	1.48	1.37	1.37	1.15
Lactose	8.00	12.00	4.00	8.00	--
NDF	7.78	6.86	8.29	7.60	9.28
Ca	0.93	0.93	0.93	0.93	0.93
Available P	0.44	0.44	0.44	0.44	0.42
Analyzed, %					
DM	90.98	90.03	90.64	90.75	90.30
CP (N × 6.25)	23.19	23.29	22.37	22.37	20.19
Crude fat	4.61	6.26	5.74	6.89	3.24
Crude fiber	2.09	2.94	2.03	2.35	2.83
Ash	6.47	6.24	5.59	6.02	5.70
Ca	1.02	0.87	1.03	0.94	0.91
Total P	0.89	0.82	0.88	0.84	0.75

[1]SID: Standardized ileal digestible.

There was no maximum restriction set for soybean meal, which resulted in greater inclusion (24.5%) compared with the C1 diet. Both Phase 1 diets were formulated to contain 3,400 kcal ME/kg and 1.48% standardized ileal digestible (SID) Lys. All other nutrients were formulated to meet or exceed (NRC, 2012) requirements for 8 to 10 kg pigs.

For the complex Phase 2 diet (C2), it was formulated to contain 8% lactose from whey permeate, 5% enzyme-treated soybean meal, 3% soy protein concentrate and 5% hydrolyzed peptone. A maximum restriction was set for soybean meal at 20% of the diet. The semi-complex Phase 2 diet (SC2) was formulated to contain less lactose (4% from whey permeate) and contained less specialty protein ingredients (only 3% hydrolyzed peptone). There was no maximum restriction set for soybean meal, which resulted in greater inclusion (34%) compared with the C2 diet. Both Phase 2 diets were formulated to contain 3,400 kcal ME/kg and 1.37% SID Lys. All other nutrients were formulated to meet or exceed (NRC, 2012) requirements for 10 to 20 kg pigs. The Phase 3 diet (S3) was a corn-soybean meal diet formulated to contain 3,300 kcal ME/kg and 1.15% SID Lys. It contained no lactose and specialty protein ingredients. All other nutrients were formulated to meet or exceed (NRC, 2012) requirements for 20 to 40 kg pigs.

For the 2-phase feeding program, Phase 1 was from d 0 to 6 and Phase 2 was from d 7 to 42. For the 3-phase feeding program, Phase 1, 2 and 3 were from d 0 to 6, d 7 to 21 and d 22 to 42, respectively. All vaccination schedules and other management practices, such as bathing, cleaning of pens and other sanitary procedures were applied similarly in all groups throughout the whole duration of the study.

Pigs and feeders were weighed at d 0, 6, 21, and 42 post-weaning. At the conclusion of the experiment, data were summarized and ADG, ADFI, and G:F were calculated for each treatment and the overall period. The diarrhea score of each pen was assessed visually twice a day (0800 and 1600 h) by at least 2 independent evaluators, with the score ranging from 1 to 5 (1 = normal feces, 2 = moist feces, 3 = mild diarrhea, 4 = severe diarrhea, and 5 = watery diarrhea). Diarrhea days were calculated for each treatment by counting pig days with a diarrhea score of 3 or greater. The frequency of diarrhea was also obtained by dividing the pig days with diarrhea score of ≥ 3 by the entire period multiplied by 100.

Total live weight gain and feed intake data for each treatment were used to compute for economic analysis. Feed cost was based on the prevailing prices of individual ingredients at the start of the trial. Feed cost per pig, value of gain per pig, feed cost per kg gain, and margin over feed cost were calculated for each treatment. Feed cost per pig was calculated by multiplying diet cost with total feed consumed for the period. The value of gain per pig was calculated by multiplying total weight gain in the period with the prevailing live weight price. Feed cost per kg gain was calculated by dividing feed cost per pig by total weight gain per pig. And finally, the margin over feed cost was calculated by subtracting feed cost per pig from the value of gain per pig.

Samples of all experimental diets were collected and properly labeled for subsequent analyses. At the end of the experiment, all diet samples were analyzed in triplicates for DM (method 930.15; AOAC, 2007), CP (method 990.03; AOAC, 2007), crude fat (method 920.39; AOAC, 2007), crude fiber (method 978.10; AOAC, 2007), and ash (method 942.05; AOAC, 2007). Diet samples were analyzed for Ca and P using an atomic absorption spectrophotometer (methods 4.8.03 and 3.4.11, respectively; AOAC, 2007).

Data were analyzed using the MIXED procedure (SAS Institute Inc., Cary, NC) of SAS with replicate as the experimental unit. The model included the main effect of diet complexity and phase feeding and their interaction as fixed effects and block as the random effect. Least squares means were calculated for each independent variable. When the interaction was a significant source of variation, differences between treatments were determined using the PDIFF option of SAS and adjusted using the Tukey-Kramer test. Statistical significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

There was no significant interaction for all growth response parameters measured (Table 4). From d 0 to 6, pigs fed the C1 diet had improved ($P<0.02$) ADG, ADFI, G:F and d 6 BW compared with those fed the SC1 diet. However, diet complexity had no significant effect on growth performance in later phases (d 7 to 21, d 0 to 21 and d 22 to 42). Overall (d 0 to 42), pigs fed the complex diets had greater ($P<0.04$) ADFI compared with those fed semi-complex diets; however, no significant differences were observed for ADG, G:F, and BW at d 21 and 42. Likewise, increasing the number of diet phases in the nursery feeding program had no significant effect on overall growth performance.

The results of the present experiment agree with previous studies that evaluated the effects of diet complexity on weanling pigs (Whang *et al*., 2000; Wolter *et al*., 2003; Collins *et al*., 2017). Those studies reported marked improvements in early post-weaning ADG,

Table 4. Effect of diet complexity and phase feeding on nursery pig performance (main effects)[1].

Item	Phase Feeding		Diet complexity		SEM	*P*-value		
	2-phase	3-phase	Semi-complex	Complex		P	D	P × D
BW, kg								
d 0	8.89	8.89	8.86	8.92	0.26	1.00	0.41	0.94
d 6	9.36	8.91	8.76[b]	9.52[a]	0.32	0.15	0.02	0.32
d 21	15.09	14.41	14.28	15.22	0.59	0.36	0.21	0.82
d 42	30.89	29.34	29.17	31.06	1.03	0.23	0.15	0.74
d 0 to 6								
ADG, kg	0.079	0.004	- 0.017[b]	0.100[a]	0.03	0.08	0.009	0.23
ADFI, kg	0.293	0.254	0.227[b]	0.320[a]	0.02	0.18	0.02	0.37
G:F, kg	0.270	0.020	-0.070	0.310	0.12	0.38	0.01	0.18
d 7 to 21								
ADG, kg	0.381	0.367	0.368	0.379	0.03	0.72	0.78	0.79
ADFI, kg	0.528	0.521	0.483	0.566	0.04	0.89	0.08	0.98
G:F, kg	0.740	0.710	0.770	0.680	0.04	0.64	0.12	0.95
d 0 to 21								
ADG, kg	0.295	0.263	0.258	0.299	0.02	0.34	0.22	0.83
ADFI, kg	0.461	0.445	0.410[b]	0.496[a]	0.03	0.68	0.03	0.87
G:F, kg	0.630	0.600	0.620	0.610	0.03	0.59	0.76	0.62

Table 4. Continued....

Item	Phase Feeding		Diet complexity		SEM	*P*-value		
	2-phase	3-phase	Semi-complex	Complex		P	D	P × D
d 22 to 42								
ADG, kg	0.752	0.711	0.709	0.754	0.02	0.25	0.21	0.73
ADFI, kg	1.352	1.289	1.247	1.395	0.06	0.45	0.08	0.19
G:F, kg	0.570	0.550	0.580	0.540	0.02	0.43	0.11	0.07
d 0 to 42								
ADG, kg	0.524	0.487	0.484	0.527	0.02	0.23	0.16	0.75
ADFI, kg	0.909	0.867	0.828[b]	0.945[a]	0.04	0.47	0.04	0.29
G:F, kg	0.580	0.560	0.580	0.560	0.01	0.24	0.10	0.12

[1]Data are least square means of 8 replicates per treatment.

[2]Treatments were: 1) Complex, 2-phase: Complex 1 diet fed at d 0 to 6, Complex 2 diet fed at d 7 to 42; 2) Complex, 3-phase: Complex 1 diet fed at d 0 to 6; Complex 2 diet fed at d 7 to 21, and Simple 3 diet fed at d 22 to 42; 3) Semi-complex, 2-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet at d 7 to 42; and 4) Semi-complex, 3-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet fed at d 7 to 21; and Simple 3 diet fed at d 22 to 42. P = phase feeding; D = diet complexity.

[a-b]Values within a row lacking a common superscript letter are different ($P \leq 0.05$).

ADFI, and G:F when pigs were fed diets with greater complexity. These can be attributed to the greater digestibility and palatability of specialty protein sources, such as spray-dried animal plasma and blood cells, used in the complex diets (Dritz *et al*., 1996; Sulabo *et al*., 2010). Studies have also shown that the level of lactose in the diet, particularly in earlier nursery phases, plays an important role in increasing post-weaning feed intake and weight gain (Tokach *et al*., 1989; Mahan *et al*., 2004; Cromwell *et al*., 2008). However, the effect of diet complexity on pig growth and efficiency decreases with increasing time post-weaning (Sulabo *et al*., 2010; Collins *et al*., 2017; Koo *et al*., 2017). In addition, Mahan *et al*. (2004) observed positive responses to increasing dietary lactose levels immediately post-weaning, but responses to lactose declined as pigs grew older. These may help explain the lack of significant effects in feeding complex diets in later phases of the nursery period.

The objective of phase feeding is to closely match the nutrient requirements and digestive capabilities of nursery pigs by increasing the number of phases using the most economical diets to achieve optimal performance (Menegat *et al*., 2019). To the best of our knowledge, there has been no published research evaluating the performance effects of nursery feeding programs with either 2- or 3-phases. Most commercial nursery feeding programs in the Philippines have 2-phases: a complex phase 1 diet (usually the creep feed) for 7 to 14 d after weaning, and a less complex phase 2 diet (prestarter feed) ranging from 14 to 35 d. The results of the present experiment suggest that increasing the number of diet phases to more closely match the nutrient requirements of piglets do not significantly affect growth performance. However, with the shorter duration of feeding the more expensive diets, the benefit of the 3-phase feeding program may be more economic in nature.

There was no significant interaction for diarrhea incidence in all phases and the overall period (Table 5). From d 0 to 6, diarrhea incidence was unaffected by diet complexity. However, pigs fed the C2 diet had greater (P=0.05) diarrhea days and frequency of diarrhea at d 7 to 21 compared with pigs fed the SC2 diet. These results were similar to Koo *et al*. (2017) where higher diarrhea scores were observed in pigs fed complex diets compared with those fed less complex diets in later phases in the nursery. A possible reason may be the consumption of a diet high in lactose for an extended period of time, which has been shown to cause osmotic diarrhea due to limited intestinal lactase activity when pigs age (Ekstrom *et al*., 1976). Overall (d 0 to 42), reducing the complexity of the diet did not affect the incidence of post-weaning diarrhea. Likewise, increasing the number of diet phases in the nursery did not significantly affect diarrhea score, diarrhea days and frequency of diarrhea for all feeding phases and the overall period. These suggest that the reduction in the complexity of the semi-complex diet, which included greater inclusion of soybean meal in both SC1 and SC2 diets, and the earlier introduction of simpler diets in the 3-phase feeding program was tolerable to the piglets and did not result in greater diarrhea occurrence in the nursery period. Therefore, this may be an effective strategy in reducing feed costs with the use of less expensive diets fed in longer duration without compromising the growth and health of the piglets.

There was a significant interaction (P<0.01) for feed cost per pig and feed cost per kg gain (Table 6). When fed using the 2-phase feeding program, using the semi-complex diets resulted in a decrease (P<0.01) in feed cost (-₱628/pig) and feed cost per kg gain (-₱25.35) compared with those fed the complex diets. However, reducing diet complexity did not result in a significant decrease in feed cost (-₱170/pig) and feed cost per kg gain (-₱6.01) when using the 3-phase feeding program. Phase feeding or diet complexity did not

Table 5. Effect of diet complexity and phase feeding on diarrhea incidence in nursery pigs (main effects)[1,2].

Item	Phase-feeding		Diet Complexity		SEM	*P*-value		
	2-phase	3-phase	Semi-complex	Complex		P	D	P × D
Diarrhea score[3]								
d 0 to 6	2.42	2.29	2.36	2.34	0.13	0.53	0.95	0.10
d 7 to 21	2.28	2.37	2.22	2.43	0.08	0.38	0.06	0.32
d 22 to 42	2.06	1.97	2.04	1.98	0.04	0.06	0.16	0.35
d 0 to 42	2.15	2.14	2.13	2.16	0.05	0.87	0.54	0.72
Diarrhea days[4]								
d 0 to 6	1.20	1.19	1.13	1.26	0.28	0.98	0.74	0.54
d 7 to 21	4.67	5.63	4.13[a]	6.17[b]	0.74	0.34	0.05	0.59
d 22 to 42	1.32	0.56	1.06	0.82	0.36	0.07	0.55	0.34
d 0 to 42	7.16	7.38	6.31	8.22	1.08	0.87	0.17	0.63
Frequency, %[5]								
d 0 to 6	19.9	19.8	18.8	21.0	4.71	0.98	0.74	0.54
d 7 to 21	31.1	37.5	27.5[a]	41.0[b]	4.90	0.34	0.05	0.59
d 22 to 42	6.3	2.7	5.1	3.9	1.73	0.07	0.55	0.34
d 0 to 42	17.0	17.6	15.0	19.6	2.56	0.87	0.17	0.63

[1]Data are least square means of 8 replicates per treatment.

[2]Treatments were: 1) Complex, 2-phase: Complex 1 diet fed at d 0 to 6, Complex 2 diet fed at d 7 to 42; 2) Complex, 3-phase: Complex 1 diet fed at d 0 to 6; Complex 2 diet fed at d 7 to 21, and Simple 3 diet fed at d 22 to 42; 3) Semi-complex, 2-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet at d 7 to 42; and 4) Semi-complex, 3-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet fed at d 7 to 21; and Simple 3 diet fed at d 22 to 42. P = phase feeding; D = diet complexity.

[3]Diarrhea score = 1, normal feces; 2, moist feces; 3, mild diarrhea; 4, severe diarrhea; 5, watery diarrhea.

[4]Diarrhea days = number of pig days ≥3.

[5]Frequency (frequency of diarrhea for each phase and the entire experimental period) = (diarrhea days/total number of days) × 100.

[a-b]Values within a row lacking a common superscript letter are different ($P \leq 0.05$).

Table 6. Diet economics (interactive effects)[1].

Item	Treatment[2]				SEM	*P*-value		
	2-phase Complex	3-phase Complex	2-phase Semi-complex	3-phase Semi-complex		P	D	P × D
Feed cost[3], ₱	1,766^{c}	1,063^{ab}	1,138^{b}	893^{a}	72	<0.01	<0.01	<0.01
Value of gain[4], ₱	2,772	2,538	2,505	2,369	148	0.23	0.16	0.75
Feed cost/kg gain, ₱/ kg BW	76.55^{c}	51.19^{b}	54.30^{b}	45.18^{a}	1.73	<0.01	<0.01	<0.01
Margin over feed cost[5], ₱	1,007	1,474	1,367	1,476	94	<0.01	0.07	0.07

[1]Data are least square means of 8 replicates per treatment.

[2]Treatments were: 1) Complex, 2-phase: Complex 1 diet fed at d 0 to 6, Complex 2 diet fed at d 7 to 42; 2) Complex, 3-phase: Complex 1 diet fed at d 0 to 6; Complex 2 diet fed at d 7 to 21, and Simple 3 diet fed at d 22 to 42; 3) Semi-complex, 2-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet fed at d 7 to 42; and 4) Semi-complex, 3-phase: Semi-complex 1 diet fed at d 0 to 6; Semi-complex 2 diet fed at d 7 to 21; and Simple 3 diet fed at d 22 to 42. P = phase feeding; D = diet complexity.

[3]Feed cost was calculated with the following feed prices: Semi-complex 1: ₱39.39/kg. Complex 1: ₱50.72/kg. Semi-complex 2: ₱32.83/kg. Complex 2: ₱41.83/kg Simple 3: ₱22.67/kg.

[4]Value of gain was determined using live weight price of ₱120/kg.

[5]Margin over feed cost = value of gain – feed cost during trial.

[a-c]Values within a row lacking a common superscript letter are different ($P \leq 0.05$).

significantly affect the value of gain per pig. For margin over feed cost, the 3-phase feeding program resulted in greater (P<0.01) margin over feed cost (+₱288/pig) compared with those fed the 2-phase feeding program. On the other hand, pigs fed the semi-complex diets tended (*P*=0.07) to have a greater margin over feed cost (+₱181/pig) compared with those fed the complex diets, which was due to the lower cost of the diets. Overall, the most cost-effective feeding program was the 3-phase, semi-complex treatment, which had the least feed cost per kg gain (₱45.18) and greatest margin over feed cost (₱1,476/pig) among all the treatments.

In conclusion, reducing complexity of the nursery diets and employing a 3-phase nursery feeding program may be the most cost-effective strategy in maximizing economic return. Future research may focus on determining the optimal level of reduction in nursery diet complexity that will not compromise growth performance and increase diarrhea occurrence.

REFERENCES

AOAC (Association of Official Analytical Chemists). 2007. *Official Methods of Analysis*. 18th ed. Howitz W and Latimer Jr. GW, ed. Gaithersburg, MD: AOAC Int.

Collins CL, Pluske JR, Morrison RS, McDonald TN, Smits RJ, Henman DJ, Stensland I and Dunshea FR. 2017. Post-weaning and whole-of-life performance of pigs is determined by live weight at weaning and the complexity of the diet fed after weaning. *Anim Nutr* 3:372-379.

Cromwell GL, Allee GL and Mahan DC. 2008. Assessment of lactose level in the mid- to late-nursery phase on performance of weanling pigs. *J Anim Sci* 86:127–133.

Dritz SS, Owen KQ, Nelssen JL, Goodband RD and Tokach MD. 1996. Influences of weaning age and nursery diet complexity on growth performance and carcass characteristics and compositions of high-health status pigs from weaning to 109 kilograms. *J Anim Sci* 74:2975-2984.

Ekstrom KE, Grummer RH and Benevenga NJ. 1976. Effects of a diet containing 40% dried whey on the performance and lactase activities in the small intestine and cecum of Hampshire and Chester White pigs. *J Anim Sci* 42:106–113.

Koo B, Kim JW, de Lange CFM, Hossain MM and Nyachoti CM. 2017. Effects of diet complexity and multicarbohydrase supplementation on growth performance, nutrient digestibility, blood profile, intestinal morphology, and fecal score in newly weaned pigs. *J Anim Sci* 95:4060–4071.

Mahan DC, Fastinger ND and Peters JC. 2004. Effect of diet complexity and dietary lactose levels during three starter phases in postweaning pig performance. *J Anim Sci* 82: 2790-2797.

Menegat MB, Goodband RD, DeRouchey JM, Tokach MD, Woodworth JC and Dritz SS. 2019. *Kansas State University Swine Nutrition Guide: Nursery Phase Feeding Program*. Retrieved on 12 April 2020 from https://www.asi.k-state.edu/research-andextension/swine/swinenutritionguide/nurseryphase feeding.html.

NRC (National Research Council). 2012. *Nutrient Requirements of Swine*. 11th ed. Washington, DC: National Academic Press.

Sulabo RC, Tokach MD, Derouchey JM, Dritz SS, Goodband RD and Nelssen JL. 2010. Influence of feed flavors and nursery diet complexity on preweaning and nursery pig performance. *J Anim Sci* 88:3918-3926.

Tokach MD, Nelssen JL and Allee GL. 1989. Effect of protein and (or) carbohydrate fractions of dried whey on performance and nutrient digestibility of early weaned pigs. *J Anim Sci* 67:1307-1312.

Whang KY, Mckeith FKM, Kim SW and Easter RA. 2000. Effect of starter feeding program on growth performance and gains of body components from weaning to market weight in swine. *J Anim Sci* 78:2885–2895.

Wolter BF, Ellis M, Corrigan BP, Dedecker JM, Curtis SE, Parr EN and Webel DM. 2003. Impact of early postweaning growth rate as affected by diet complexity and space allocation on subsequent growth performance of pigs in a wean-to-finish production system. *J Anim Sci* 81:353–359.