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Influence of different phase feeding programs in piglets with different weaning weights

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Weaning is a stressful experience for pigs. When piglets are weaned, they are subjected to social stress, immunological stress and nutritional stress (Kim *et al.* 2012; Johnson and Lay Jr 2017). Consequently weaning is generally associated with a growth check and increased risk of diarrhea (Kim *et al.* 2012; Pluske 2013).

Weaning weight (WW) is an important factor that influences the growth of piglets in the post-weaning period (Cabrera *et al.* 2010; Cámara *et al.* 2016). Practically, however, the weights of piglets vary greatly at weaning. Vieira *et al.* (2015) reported that piglets with heavier WW showed better average daily feed intake (ADFI) and average daily gain (ADG) than the lighter ones. When lighter body weight (BW) pigs are raised with heavier ones in the same pen, they are in inferior position in competition for feed, therefore, they will perform better in pens with less BW difference (Douglas *et al.* 2014). Phase feeding is a useful strategy to meet pigs' requirement more precisely (Moore *et al*. 2016). Therefore, we hypothesized that different WW pigs benefit from the different phase feeding programs including meeting the nutrients requirements and reducing the post-weaning diarrhea. However, there is a scarcity of information on the effects of WW and phase feeding programs in weaning piglets. The objective of this experiment was to investigate the effects of WW and phase feeding program on growth performance, nutrient digestibility, and fecal score in weaning pigs.

All animal care and handling procedures used in this study were approved by the Animal Care and Use Committee of Dankook University (Cheonan, South Korea).

Animals, housing, and experimental design: A total of 144 weaning pigs ([Yorkshire × Landrace] × Duroc) with the age of 28±1 d were used in a 42-day feeding study. The experiment was a 2 × 2 factorial arrangement with two levels of WW (heavier WW (7.97 kg) or lighter WW (5.94 kg) and two phase feeding programs (two-phase feeding program: fed diet 2 from days 1 to 14 and diet 3 from days 15 to 42 or three-phase feeding program: fed diet 1 from days 1 to 7, followed by diet 2 (days 8 to 21) and diet 3 (days 22 to 42). Pigs were randomly stratified based on initial BW and sex (6 replicate pens with 3 borrows and 3 gilts per pen). The composition of experimental diet is presented in Table 1. Over the 42-day experimental period,

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

Items	Diet 1	Diet 2	Diet 3
Ingredients (%)			
Extruded corn	11.15	34.92	45.10
Extruded oat	10.00	-	-
Soybean meal (48% CP)	8.00	20.00	29.50
Biscuit meal	-	5.00	9.00
Fermented soybean meal	7.80	8.20	-
Fish meal (66% CP)	5.00	4.00	2.50
Plasma powder	6.50	-	-
Soy oil	4.05	4.77	3.00
Lactose	10.00	6.00	-
Whey powder	16.50	10.00	6.25
Milk product	12.60	2.00	2.00
Sugar	4.00	2.00	-
L-lysine-HCL (78%)	0.12	0.25	0.16
DL-Methionine (50%)	0.26	0.15	0.10
L-Threonine (89%)	0.77	0.08	-
Monocalcium phosphate	1.25	1.00	0.60
Vitamin premix[1]	0.10	0.10	0.10
Trace mineral premix[2]	0.20	0.20	0.20
Limestone	1.25	0.98	1.14
Salt	0.25	0.25	0.25
Choline chloride (25%)	0.20	0.10	0.10
Calculated compositions (%)			
Metabolizable Energy (kcal/kg)	3,500	3,450	3,400
Crude protein	21.00	19.70	19.00
Lysine	1.60	1.50	1.30
Methionine	0.60	0.58	0.51
Calcium	0.95	0.90	0.85
Total Phosphorus	0.80	0.75	0.65

[1]Provided per kilogram of complete diet: 11,025 IU vitamin A, 1,103 IU vitamin D_3, 44 IU vitamin E, 4.4 mg vitamin K, 8.3 mg riboflavin, 50 mg niacin, 4 mg thiamine, 29 mg d-pantothenic acid, 166 mg choline, 33 µg vitamin B_{12}, [2]Provided per kilogram of complete diet: 12 mg Cu (as $CuSO4•5H_2O$); 85 mg Zn (as $ZnSO_4$); 8 mg Mn (as MnO_2); 0.28 mg I (as KI); 0.15 mg Se (as $Na_2SeO_3•5H_2O$).

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all pigs were raised in an environmentally controlled room with slatted plastic flooring and a mechanical ventilation system. The room temperature was maintained at 32°C for the first week, and then gradually reduced by 1°C a week. Each pen was equipped with a one-sided self-feeder and a nipple drinker to allow the pig *ad libitum* access to feed and water throughout the experiment.

Experimental procedures and sampling: Pigs were weighed individually and feed consumption was measured on a pen basis at the beginning, day 14 and end of the experiment to determine ADG and ADFI. Gain:feed ratio (G:F) was calculated accordingly.

From d 8 to 14 and 36 to 42, chromium oxide was added to the diet at 0.2% as an indigestible marker for determination of the apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N), and gross energy (GE, Fenton and Fenton, 1979). On d 14 and 42, fresh fecal samples were collected from each pen via rectal massage. Then fecal samples from each pen were pooled and stored at –20°C until the analysis. Before chemical analysis, fecal samples were thawed, dried in an oven (60°C) for 72 h and ground to pass through a 1-mm sieve. Feed and fecal samples were analyzed for DM (method 930.15; AOAC, 2007), N (method 984.13; AOAC, 2007) by an N analyzer (Kjectec 2300 N Analyzer; Foss Tecator AB, Höganäs, Sweden), and GE by an oxygen bomb calorimeter (Parr Instrument Co., Moline, IL). Chromium was analyzed using UV absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan) according to the method described by Williams *et al.* (1962). The ATTD of nutrients was calculated using the following formula:

$$ATTD\ (\%) = \{1 - [(Nf \times Cd) / (Nd \times Cf)]\} \times 100$$

where Nf is nutrient concentration in the feces (% DM), Nd is nutrient concentration in the diet (% DM), Cd is chromium concentration in the diet (% DM), and Cf is chromium concentration in the feces (% DM).

Subjective fecal score was recorded for clinical signs of diarrhea at 0800 h each morning throughout the experiment by a single blinded observer, using the 5-grade scoring system described by O'Shea *et al.* (2014). Briefly, 1 = well-firmed feces; 2 = slightly soft feces; 3 = soft and partially formed feces; 4 = loose and semi-liquid feces (diarrhea); 5 = watery and mucus-like feces (severe diarrhea).

Statistical analyses: Experimental data were analyzed as a completely randomized 2 × 2 design using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Pen was the experimental unit for all data analysis. The data were tested for the main effects of weaning weight, phase feeding program, and their interaction. Variability in the data was expressed as the standard error of means. The level of significant difference was set at $P < 0.05$.

RESULTS AND DISCUSSION

Growth performance: The effects of WW and phase feeding program on growth performance are shown in Table 2. The heavier WW pigs were significantly heavier than their lighter counterparts throughout the experiment

Table 2 The effects of weaning weight and phase feeding program on the performance of pigs for 42 days after weaning[1]

Item	Weaning weight[1]					P-value		
	Heavy		Light					
	Phase feeding program[2]							
	Two	Three	Two	Three	SEM[3]	Weaning weight	Phase feeding program	Interaction
				Body weight (kg)				
Day 1	7.97	7.97	5.95	5.93	0.29	<0.001	0.964	0.968
Day 14	13.26	13.11	10.64	10.43	0.48	<0.001	0.707	0.959
Day 42	27.84	28.15	23.20	23.87	0.69	<0.001	0.487	0.798
Days 1 to 14								
Average daily gain (g/d)	378	367	335	322	17.08	0.019	0.493	0.950
Average daily feed intake (g/d)	445	444	444	445	3.73	1.000	1.000	0.758
Gain:feed (g/g)	0.849	0.826	0.754	0.723	0.04	0.014	0.451	0.909
				Days 15 to 42				
Average daily gain (g/d)	520	537	449	480	9.17	<0.001	0.016	0.428
Average daily feed intake (g/d)	665	677	643	629	4.12	<0.001	0.826	0.004
Gain:feed (g/g)	0.783	0.793	0.698	0.763	0.01	<0.001	0.007	0.042
				Days 1 to 42				
Average daily gain (g/d)	473	480	411	427	10.65	<0.001	0.273	0.666
Average daily feed intake (g/d)	592	599	577	568	3.42	<0.001	0.866	0.021
Gain:feed (g/g)	0.799	0.801	0.712	0.753	0.02	<0.001	0.203	0.243

[1]Weaning weight: heavy, 7.97 kg; light, 5.94 kg.

[2]Phases feeding program: two-phase feeding program, fed diet 1 from days 1 to 14 then diet 3 from days 15 to 42; three-phase feeding program, fed diet 1 from days 1 to 7, diet 2 from days 8 to 21, then fed diet 3 from days 21 to 42.

[3]Standard error of means

(P<0.05). Body weight, however, was not affected by phase feeding programs and there was no significant interaction between WW and phase feeding program for BW (P>0.05). The heavier WW pigs grew significantly faster, ate more feed and had better G:F than their lighter WW counterparts in all measured periods except days 1 to 14 when ADFI was similar for both groups (P<0.05). From days 15 to 42, pigs in three-phase feeding program grew faster (P<0.05) and had a higher G:F (P<0.05) than those in the two-phase feeding program, although growth performance were not affected by phase feeding during days 1 to 14 and 1 to 42. There were significant interactions between WW and phase feeding during days 15 to 42 for ADFI and G:F and during days 1 to 42 for ADFI (P<0.05).

After weaning, particularly the first 2 weeks post-weaning, the growth rate of piglets is reduced because of the weaning stress (Campbell *et al*. 2013). Numerous experiments have demonstrated that high protein level and highly digestible and palatable ingredients (e. g. lactose, fish meal, plasma powder, and whey) could improve the growth performance of weaning pigs and relieve weaning stresses (Wellock *et al.* 2009; Skinner *et al.* 2014; Zhang *et al.* 2015). Whang *et al.* (2000) reported that a high quality three-phase diets program increased ADG of barrows during days 1 to 42 post weaning compared to a low quality single phase program. In the present experiment, the results showed no advantage of including the high quality diet 1 in the three-phase feeding program. The explanation is probably that the effects of high quality starter diet were hindered by the stress of changing diet on day 7. However, the improved G:F between days 15 and 42 was most noticeable on the three-phase program in lighter pigs (9.3% more efficient in the three-phase feeding program than that of two-phase feeding program). It is also evident that while differences were not significant between days 0 and 42 the G:F of lighter WW pigs on two-phase feeding program was 5.4% worse than those on the three-phase feeding program. These are likely due to the fact that the pigs in two-phase feeding program were changed to diet 3 at 14 days whereas those in the three-phase feeding program remained on diet 2 until 22 days, and diet 3 is deficient in amino acids especially for lighter WW pigs at 14 days. Therefore, the recommendation might be to use a two-phase feeding program but extend use of diet 2 for 21 days.

Our results showed that pigs of heavier WW grew faster and were more feed efficient than those of lighter WW. These results were in line with those of Wolter and Ellis (2001) Main *et al.* (2004). These results may be explained by the more developed digestive tract of pigs with heavier WW, which will help them better deal with the diet transition at weaning.

Apparent total tract nutrient digestibility and diarrhea score: On days 14 and 42, although the ATTD of N was not affected by WW, the ATTD of DM and GE were greater in pigs with heavier WW compared with pigs with lighter WW (P<0.05 Table 3). Feeding phase programs did not affect the ATTD of DM, N, and GE (P>0.05). In addition, there were no interactive effects of WW and phase feeding programs on the ATTD of DM, N, and GE (P>0.05). No influence of WW and phase feeding programs on fecal score was detected throughout the experiment (P>0.05; Table 4).

In the current research, phase-feeding programs did not affect the nutrient digestibility. Otherwise, heavier WW pigs had better ATTD of DM and GE as compared to lighter WW pigs. The small intestine is an important organ in digestion and absorption of nutrients (De Vos *et al.* 2014). However, Michiels *et al.* (2013) found that light birth weight had low small intestine length, weight, and relative weight than normal birth weight. This may explain the higher ATTD of DM and GE observed in heavier WW pigs. Additionally, the increased ATTD of DM and GE may, at least partly, help to explain the observed better growth performance in heavier WW pigs compared with lighter WW pigs.

In general, weaning is associated with diarrhea in post-

Table 3. The effects of weaning weight and phase feeding program on nutrient digestibility of pigs for 42 days after weaning[1]

Items, %	Weaning body weight[1]				SEM[3]	P-value		
	Heavy		Light					
	Phases feeding program[2]							
	Two	Three	Two	Three		Weaning weight	Phase feeding program	Interaction
				d 14				
Dry matter	82.55	83.22	81.24	81.62	0.45	0.039	0.785	0.528
Nitrogen	79.59	80.57	79.36	79.15	0.58	0.165	0.331	0.436
Gross energy	81.52	81.36	80.41	80.02	0.52	0.012	0.623	0.256
				d 42				
Dry matter	82.08	82.61	80.95	81.15	0.36	0.001	0.322	0.653
Nitrogen	79.02	79.39	78.06	78.21	0.63	0.102	0.681	0.859
Gross energy	81.78	81.80	80.38	80.64	0.41	0.004	0.733	0.765

[1]Weaning weight: heavy, 7.97 kg; light, 5.94 kg.

[2]Phases feeding program: two-phase feeding program, fed diet 1 from days 1 to 14 then diet 3 from days 15 to 42; three-phase feeding program, fed diet 1 from days to 7, diet 2 from days 8 to 21, then fed diet 3 from days 22 to 42.

[3]Standard error of means.

Table 4. The effects of weaning weight and phase feeding program on the fecal scores of pigs for 42 days after weaning1

Item	Weaning weight[2]					P-value		
	Heavy		Light					
	Phase feeding program[3]							
	Two	Three	Two	Three	SEM4	Weaning weight	Phase feeding program	Interaction
days 1 to 7	3.21	3.21	3.18	3.20	0.08	0.674	0.833	0.833
days 8 to 14	3.15	3.14	3.14	3.17	0.05	0.877	0.877	0.877
days 15 to 21	3.12	3.13	3.15	3.14	0.06	0.665	0.665	0.885
days 22 to 27	3.13	3.10	3.10	3.13	0.08	0.913	0.913	0.585
days 28 to 35	3.10	3.12	3.11	3.11	0.04	0.666	0.666	0.666
days 36 to 42	3.12	3.10	3.10	3.11	0.03	1.000	0.627	1.000

[1]Fecal scores were determined using the following fecal scoring system: 1 = hard, dry and well-formed feces; 2 = soft but formed feces; 3 = viscous feces but retain its shape; 4 = fluid and unformed feces; 5 = watery feces.

[2]Weaning weight: heavy, 7.97 kg; light, 5.94 kg.

[3]Phases feeding program: two-phase feeding program, fed diet 1 from days 1 to 14 then diet 3 from days 15 to 42; three-phase feeding program, fed diet 1 from days 1 to 7, diet 2 from days 8 to 21, then fed diet 3 from days 22 to 42.

[4]Standard error of means.

weaning period caused by weaning stresses (Kim *et al.* 2012). Post-weaning diarrhea can be reduced by improving diet quality including using milk product and animal-based protein (Wellock *et al.* 2009). Fecal score indicates the status of diarrhea (Cho *et al.* 2015). Using the scoring system similar to the present study, Peace *et al*. (2011) demonstrated that inclusion of 5% spray-dried porcine plasma reduced fecal score on days 7 and 14. Wellock *et al.* (2009) found that pigs fed high quality diet contained cooked cereal and fish meal and dried skimmed milk powder had lower fecal score within first 2 weeks post-weaning. However, in this study there were no treatment effects on fecal score throughout the experiment. The possible explanation can be the good health status of the pigs used in the trial.

In conclusion, three-phase feeding program increased growth performance during days 15 to 42. Furthermore, heavier WW pigs had better growth performance and ATTD of DM and GE. Both heavy and light WW pigs can be offered a two-phase feeding program but that diet 2 should be extended to 21 days especially for lighter WW pigs.

SUMMARY

This study was conducted to evaluate effects of different phase feeding programs in pigs with different weaning weights (WW). A total of 144 weaning piglets were used in the 2 × 2 factorial arrangement of treatments based on WW (7.95 kg vs. 5.95 kg) and phase feeding program (two vs. three). The heavier WW pigs had better average daily gain (ADG), average daily feed intake (ADFI) and gain:feed ratio (G:F) than their lighter WW counterparts in all periods measured except days 0 to 14 (P<0.05). From days 14 to 42, pigs in the three-phase feeding program exhibited higher ADG and G:F (P<0.05) than those in the two-phase feeding program. On d 14 and 42, although the apparent total tract digestibility (ATTD) of nitrogen was not affected by WW, the ATTD of dry matter and gross energy were greater in pigs with heavier WW compared with those with lighter WW (P<0.05). Feeding phase programs did not affect nutrient digestibility (P>0.05). Fecal score was not affected by WW and phase feeding program throughout the study (P>0.05). In conclusion, three-phase feeding program increased growth performance during days 15 to 42. Heavier WW pigs had better growth performance and nutrient digestibility. Both heavy and light WW pigs can be offered a two-phase feeding program but that diet 2 should be extended to 21 days especially for lighter WW pigs.

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