Increasing weaning age improves pig performance in a multisite production system[1]

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ABSTRACT: Two trials were conducted to determine the effects of weaning age on pig performance in a multisite production system. The second trial also evaluated the effects of modifying the nursery feeding program according to weaning age. In Trial 1 (2,272 pigs), treatments included weaning litters at 12, 15, 18, or 21 d of age. In Trial 2 (3,456 pigs), litters were weaned at 15, 16, 18, 19, 21, or 22 d of age and categorized into three treatments (15.5, 18.5, or 21.5 d of age). In Trial 2, pigs in each age group were fed one of two nursery feeding programs. Nursery feeding programs varied in both diet formulation and in the quantity of diets fed containing increased levels of whey and spray-dried animal plasma. Each trial was conducted as a randomized complete block design with four blocks of nursery and finishing sites. All weaning-age treatments were weaned from a 7,300-sow farm on the same day into the same nursery. Each block remained intact as pigs moved from nursery to finishing site. Increasing weaning age (12, 15, 18, or 21 d in Trials 1; and 15.5, 18.5, or 21.5 d in Trial 2) increased (linear, $P < 0.001$) ADG (299, 368, 409, 474 ± 7 g/d; 435, 482, 525 ± 13 g/d) and tended to decrease (linear, $P < 0.09$) mortality (5.25, 2.82, 2.11, 0.54 ± 0.76%; 2.17, 1.56, 1.30 ± 0.36%) in the initial 42 d after weaning. Finishing ADG (722, 728, 736, 768 ± 11 g/d; 783, 790, 805 ± 11 g/d) also improved (linear, $P < 0.01$) with increasing weaning age. Overall, increasing weaning age increased (linear, $P < 0.001$) wean-to-finish ADG (580, 616, 637, 687 ± 8 g/d; 676, 697, 722 ± 6 g/d), weight sold per pig weaned (94.1, 100.5, 104.4, 113.1 ± 1.3 kg; 107.6, 111.6, 116.2 ± 1.1 kg), and decreased (linear, $P < 0.03$) mortality rate (9.4, 7.9, 6.8, 3.6 ± 0.95%; 3.9, 3.4, 2.5 ± 0.5 %). Altering the nursery feeding program did not affect wean-to-finish growth performance. In this multisite production system, increasing weaning age from 12 to 21.5 d of age increased weight sold per pig weaned by 1.80 ± 0.12 kg for each day increase in weaning age. These studies suggest increasing weaning age up to 21.5 d can be an effective management strategy to improve wean-to-finish growth performance in multisite pig production.

Key Words: Growth Performance, Swine, Weaning Age

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Introduction

Multisite swine production has become a widely applied strategy in commercial pig production. Multisite production has evolved through the implementation of an age segregated production technology called segregated early weaning (**SEW**). Segregated early weaning involves removing weaned pigs from the sow herd and rearing them separately from other age groups of pigs (Harris, 2000). In addition to segregation, it has been suggested that decreasing weaning age decreases the transfer of growth-depressing pathogens to offspring (Harris, 2000). Applying the concepts of SEW and multisite production has improved pig performance in herds with low or high levels of endemic pathogens present (Dritz et al., 1996a; Fangman et al., 1996, and Patience et al., 2000). Although the concepts of segregation and all-in, all-out management (i.e., depopulating and cleaning of facilities between groups of pigs) seem to be essential for improvements in performance, the importance of younger weaning age is less clear. Published research has not been conducted to determine the incremental effects of weaning age on wean-to-finish performance within a commercially applied multisite swine production scheme. Therefore, the objective of our first trial was to quantify the effects of weaning age on pig performance within a multisite production system. A second trial was completed to evaluate the

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Table 1. Feeding programmed diet characteristics (Trial 1, as-fed basis)[a]

	Feed budget, kg/pig					
	Nursery			Finisher		
Item	Phase I	Phase II	Phase III	Phase IV	Phase V	Phase VI
Feed budget, kg/pig	1.36	2.72	Remainder	50	68	Remainder
Diet characteristics						
Spray-dried animal plasma, %	2.85	—	—	—	—	—
Lactose, %	20	12	—	—	—	—
True ileal digestible lysine, %	1.37	1.21	1.14	1.05	0.97	0.86
ME, kcal/kg of diet	3,483	3,483	3,461	3,527	3,547	3,571

[a]All weaning age treatments (12, 15, 18, or 21 d) in Trial 1 were fed the same feeding program.

effects of weaning age and nursery feeding program on pig performance. The second trial served to determine whether growth performance responses due to weaning age were affected by altering the nursery feeding program.

Materials and Methods

Animals and Procedures

Two trials were conducted with pigs in a multisite production system containing a 7,300-sow farm weaning pigs into geographically distinct nursery and finishing sites. The nursery and finishing sites only receive pigs from this single-sow farm and are depopulated, cleaned, and disinfected before another group of pigs are placed in the site. In Trial 1, treatments included weaning litters of pigs at 12, 15, 18, or 21 d of age, with all pigs fed a common nursery feeding program formulated to exceed nutrient requirements provided by NRC (1998; Table 1). Trial 1 was conducted in a randomized complete block design with four wean age treatments (12, 15, 18 or 21 d of age) in four blocks. In Trial 2, litters were weaned at 15, 16, 18, 19, 21, or 22 d of age resulting in three categorized wean age treatments of 15.5, 18.5, and 21.5 d. Pigs within each wean age treatment were fed a nursery feeding program that was classified as either more or less complex. The nursery feeding program classifications were based on the amount of lactose and spray-dried plasma protein in the diet and the quantity fed per pig (Table 2). All diets were formulated to exceed nutrient requirements provided by NRC (1998). The two nursery feeding program classifications and three wean age treatments were arranged in a 2 × 3 factorial with four randomized complete blocks.

In both trials, litters were ear notched at birth (approximately 18 litters/d of weaning age in each block), and all pigs were subsequently individually ear-tagged, weighed, and gender recorded 3 d before weaning. Sows' parity of litters used was balanced based on using three parity categories (gilts, first and second parity, and third parity or greater) across weaning age treatments. The PROC REG procedure in SAS (SAS Inst., Inc., Cary, NC) was used to calculate a predicted treatment mean weaning weight using the pig weight and pig age data captured for each nursery pen 3 d before weaning. Each block consisted of all weaning age treatments weaned on the same day into the same nursery. At weaning, pigs (PIC Line 280 × C22; 2,272 and 3,456 total pigs in Trials 1 and 2, respectively) were individually allotted to nursery pens. Each of the four blocks had four randomly assigned pens per age (Trial 1) or age × nursery feeding program combination (Trial 2). Each pen contained an equal number of barrows and gilts. Using the individual pig age, weight, and gender information, each pen was allotted to replicate the normal weight distribution of barrows and gilts weaned within each age group. Pens contained 36 pigs, with the exception that the first block in Trial 1 had 34 pigs in each pen. Nursery pens were 2.44 × 3.66 m, with wire flooring and two nipple waterers. Each pen contained a double-sided feeder with five feeding spaces on each side. Feed delivery was recorded on a pen basis throughout the nursery period. Each pig was weighed on d 42 after weaning. Growth and feed efficiency were calculated using trial allotment weights attained 3 d before weaning. Weighing and tagging pigs before weaning was necessary due to labor availability. Pigs and barn environments were managed according to production system standard operating procedures. Each block remained intact as pigs were transferred from nursery to finishing site. In both the nursery and finishing phases of these trials, pigs were only removed from test pens due to acute death or if identified to be in a nonambulatory condition and not responding to medical treatment. Euthanasia was performed on non-ambulatory pigs and they were recorded as mortality. Pig welfare guidelines were in accordance with published guidelines (FASS, 1999).

Using the individual 42-d postweaning weight and gender information, pigs (1,920 and 3,000 total pigs in Trials 1 and 2, respectively) were individually reallotted within treatment group and block to the finishing phase of the evaluation. Reallotting was required due to different pen sizes in the nursery and finisher sites. As described for the nursery allotment, finishing pens were allotted such that each pen was a replicate of the population of feeder pigs being weighed out of the nursery at d 42 after weaning specific for each treat-

Table 2. Feeding program and diet characteristics (Trial 2, as-fed basis)[a]

		Feed budget, kg/pig[b]						
		Nursery				Finisher		
Wean age, d	Feeding program complexity	SEW[c]	Phase I	Phase II	Phase III	Phase IV	Phase V	Phase VI
15.5	Less	0.00	1.81	2.72	Remainder	50	68	Remainder
15.5	More	0.68	1.81	3.86	Remainder	50	68	Remainder
18.5	Less	0.00	1.81	2.72	Remainder	50	68	Remainder
18.5	More	0.45	1.81	3.18	Remainder	50	68	Remainder
21.5	Less	0.00	0.91	3.63	Remainder	50	68	Remainder
21.5	More	0.00	1.81	2.72	Remainder	50	68	Remainder
Diet characteristics								
Spray-dried animal plasma %		6.70	3.50	—	—	—	—	—
Lactose, %		22.5	20.0	11.0	—	—	—	—
True ileal digestible lysine, %		1.40	1.56	1.37	1.26	1.05	0.90	0.78
ME, kcal/kg of diet		3,516	3,417	3,417	3,483	3.472	3.472	3.472

[a]Each weaning age group (15.5, 18.5, or 21.5 d) was placed on a nursery feeding program that was classified as either being more or less complex. The nursery feeding program classifications were based on diet formulation and the quantity of diets fed. Pigs in each age group fed the more complex feeding program were given an increased allotment of diets containing increased levels of lactose and spray dried animal plasma.

[b]Finishing diets and feed budget were common across treatments.

[c]The SEW diet was an additional nursery diet included in Trial 2 containing increased concentrations of spray-dried animal plasma and lactose.

ment and block. In Trial 1 (96 total pens), each finishing block had six randomly assigned pens per weaning age treatment. In Trial 2 (120 total pens), each block had five randomly assigned pens per wean age by nursery feeding program combination. All pigs were fed the same feeding program throughout finishing. Diet specifications and feeding program are outlined in Tables 1 and 2. Finishing feed allocations were designed to exceed nutrient requirements provided by NRC (1998) for all treatments. However, feed delivery data was not collected on a pen basis during the finishing period. In Trial 1, pigs (20 pigs per pen; 10 barrows and 10 gilts) were placed in 2.29 × 6.71-m finishing pens. In Trial 2, pigs (25 pigs per pen; 13 gilts and 12 barrows) were placed in 2.90 × 6.71-m finisher pens. Finishing pens had partially slatted concrete flooring (⅔ solid, ⅓ slatted), and the curtain-sided buildings were naturally ventilated. Each pen had two nipple waterers and a feeder with four feeding spaces. Pens were weighed off-test on d 156 (Trial 1) and d 153 (Trial 2) postweaning with individual weights being recorded.

Growth Performance Calculations and Statistical Analysis

Data from the nursery and finishing phases were used to determine wean-to-finish performance. The nursery allotment weight and nursery mortality data for each treatment and block was applied to each finishing pen placed in that same treatment and block. Transferring the within treatment and block nursery allotment weight and nursery mortality data allowed for the measurement and analysis of wean-to-finish growth performance.

In these analyses, weight and days lost due to mortality were not accounted for in ADG calculations. This allowed for measurement of the effect the imposed treatments (Trial 1 = weaning age, Trial 2 = weaning age and nursery feeding program) had on ADG realized by the production system on a per-pig-placed (or pig space) basis. Similarly, weight sold per pig weaned was calculated to determine the effect of treatment on total weight sold in a fixed number of days postweaning. Expressing weight sold on a per-pig-weaned basis allowed wean-to-finish performance to be quantified in a manner that directly relates to the value of the weaned pig. As a more traditional measure of biological growth not influenced by mortality, weight per day of age was calculated at the end of the nursery and finishing phases, and average pig gain per day after weaning was calculated in the wean-to-finish analysis. Additionally, the effect of treatment on weight variation was evaluated using the individual pig weights to determine the coefficient of variation for each nursery and finishing pen.

Analysis of variance was used to analyze growth performance data as a complete randomized block design using the PROC MIXED procedures of SAS. In both trials, the statistical model included the fixed effect of weaning age, and block as the random component. Linear and quadratic contrasts were used to determine the effects of increasing weaning age. In Trial 2, the model also included the fixed effect of nursery feeding program (less or more complex), and the interactive effect of weaning age × nursery feeding program.

Because of the similarities in the current trials, the lack of significant nursery feeding program effects on wean-to-finish growth performance in Trial 2, and the linear nature of the primary response criteria, data from both trials were pooled for additional modeling. Data from these two trials were fitted using a single mixed model with weaning age as the fixed effect, and

Table 3. Influence of weaning age on nursery performance, Trial 1[a]

	Weaning age					P <	
Item	12	15	18	21	SE	Linear	Quadratic
Allotment weight, kg[b]	3.42	4.26	4.89	5.75	0.05	0.001	0.77
Allotment weight CV, %	20.4	17.1	18.6	17.6	0.04	0.001	0.001
Regressed weaning weight, kg[c]	4.20	4.96	5.73	6.49	—	—	—
ADG, g[de]	299	368	409	474	7	0.001	0.66
ADFI, g (as-fed basis)[de]	426	511	565	654	11	0.001	0.64
G:F[de]	0.703	0.720	0.726	0.723	0.006	0.001	0.03
Mortality, %	5.25	2.82	2.11	0.54	0.76	0.001	0.55
d 42 postweaning, kg	16.9	20.3	22.6	25.8	0.26	0.001	0.60
d 42 postweaning CV, %	20.0	15.6	14.4	12.9	0.68	0.001	0.01
d 42 postweaning weight per day of age, g[f]	313	356	377	410	4	0.001	0.08

[a]Based on 2,272 pigs, with 34 or 36 pigs per pen (50% barrows, 50% gilts), and 16 replications (pens) per treatment, or a total of 64 pens on test.
[b]Allotment weights were taken on all pigs 3 d before weaning.
[c]The PROC REG procedure in SAS (SAS Inst., Inc., Cary, NC) was used to calculate a predicted treatment mean weaning weight using the pig weight and pig age data captured for each nursery pen 3 d before weaning (weaning weight, kg = 0.25455 wean age + 1.1455; R^2 = 0.97).
[d]Allotment weights were used for all growth and efficiency calculations.
[e]ADG, ADFI, and G:F are all calculated with allotted pen weight, 42 d pen weight, and total pen space days (pigs placed × d postweaning).
[f]Day 42 postweaning weight per day of age = off-test weight/pig age.

trial and block as random components. This enabled a collective estimate of the rate of change (slope) in wean-to-finish performance observed for each day change in weaning age. Pen was the experimental unit in all data analyses.

Results

Nursery Performance

In Trial 1, allotment weight increased (linear, $P < 0.001$, Table 3) with increasing weaning age. Furthermore, the variation in allotment weight (i.e., as measured by determining the coefficient of variation for each pen) was decreased as weaning age increased (quadratic, $P < 0.001$). Allotment weight variation was most noticeably increased in the pigs to be weaned at 12 d of age, with variation being similar in pigs weaned at 15, 18, or 21 d of age. Nursery ADG, ADFI, mortality rate, d 42 after weaning weight, and d 42 postweaning weight per day of age improved (linear, $P < 0.001$) as weaning age increased from 12 to 21 d. Feed efficiency (quadratic, $P < 0.03$) and variation in d 42 postweaning weight (quadratic, $P < 0.01$) also improved as weaning age increased. Feed efficiency and d 42 after weaning weight variation were poorer in the 12-d wean pigs, with feed efficiency and weight variation among older weaning ages being similar. However, step-wise improvements in d 42 postweaning weight variation were observed as weaning age increased.

In Trial 2, there was no weaning age × feeding program interaction ($P \geq 0.26$) during the nursery phase (Table 4). Allotment weight increased (quadratic, $P < 0.001$; Table 4) with increasing weaning age. Nursery ADG, ADFI, d 42 postweaning weight, and d 42 postweaning weight per day of age improved (linear, $P < 0.001$) as weaning age increased from 15.5 to 21.5 d. Weight variation at the end of the nursery phase improved (linear, $P < 0.003$) and mortality rate tended to decrease ($P < 0.09$) as weaning age increased. Contrary to Trial 1, feed efficiency was poorer (linear, $P < 0.001$) as weaning age increased. The decrease in mortality observed with increasing weaning age in Trial 2 did not overcome the expected decreasing feed efficiency with increasing body weight. Altering the nursery feeding program did not affect ($P \geq 0.29$) growth rate, feed efficiency, or mortality. However, pigs fed the more complex nursery feeding program tended ($P < 0.06$) to have decreased variation in weight at d 42 after weaning.

Finishing Performance

In Trial 1, finishing ADG, off-test weight, off-test weight variation, and off-test weight per day of age improved (linear, $P < 0.002$; Table 5) as weaning age was increased from 12 to 21 d. However, there were no differences ($P \geq 0.19$) in finishing mortality.

In Trial 2, similar to the nursery phase, there were no weaning age × nursery feeding program interactions ($P \geq 0.14$) on finishing growth performance. Finishing ADG, off-test weight, and off-test weight per day of age improved (linear, $P < 0.003$, Table 6) as weaning age increased from 15.5 to 21.5 d. Contrary to Trial 1, the decreased variation in d 42 postweaning weight observed with increasing weaning age did not translate into decreased variation at slaughter. There were no treatment differences ($P \geq 0.20$) in finishing mortality.

Wean-to-Finish Performance

Wean-to-finish ADG, average pig gain per day after weaning, weight sold per pig weaned (linear, $P < 0.001$; Tables 7 and 8), and wean-to-finish mortality (linear, $P < 0.03$) improved as weaning age increased from 12

Table 4. Influence of weaning age and nursery feeding program on nursery performance, Trial 2[a]

	Less complex nursery feeding program			More complex nursery feeding program				P <			
	Weaning age, d										
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear age	Quadratic age	Feed program	Age × feed program
Allotment weight, kg[b]	4.09	4.78	5.63	4.06	4.78	5.65	0.09	0.001	0.001	0.99	0.63
Allotment weight CV, %	19.5	20.0	19.2	19.8	20.4	19.5	0.52	0.49	0.04	0.30	0.99
Regressed weaning weight, kg[c]	4.83	5.62	6.40	4.83	5.62	6.40	—	—	—	—	—
ADG, g[de]	437	479	529	433	484	521	14	0.001	0.70	0.51	0.30
ADFI, g (as-fed basis)[de]	570	629	706	560	634	696	15	0.001	0.79	0.29	0.26
G:F[de]	0.769	0.761	0.750	0.773	0.763	0.749	0.005	0.001	0.69	0.71	0.87
Mortality, %	1.91	1.91	1.22	2.43	1.22	1.39	0.50	0.09	0.69	0.99	0.46
d 42 postweaning, kg	22.9	25.4	28.2	22.8	25.4	28.0	0.64	0.001	0.57	0.37	0.60
d 42 postweaning CV, %	15.4	14.2	13.1	14.0	13.1	13.0	0.75	0.003	0.58	0.06	0.47
42 postweaning weight per day of age, g[f]	399	419	444	396	420	439	10	0.001	0.91	0.25	0.48

[a]Based on 3,456 pigs, with 36 pigs per pen (18 barrows, 18 gilts), and 16 replications (pens) per treatment, or a total of 96 pens on test. Pigs within each wean age group were fed alternative nursery feeding programs (classified as less or more complex), which are described in Table 2.

[b]Allotment weights were taken on all pigs 3 d before weaning.

[c]The PROC REG precedure in SAS (SAS Inst., Inc., Cary, NC) was used to calculate a predicted treatment mean weaning weight using the pig weight and pig age data captured for each nursery pen 3 d before weaning (weaning weight, kg = 0.26094 wean age + 0.78776; $R^2 = 0.92$).

[d]Allotment weights were used for all growth and efficiency calculations.

[e]ADG, ADFI, and G:F are all calculated with allotted pen weight, d 42 pen weight, and total pen space days (pigs placed × d postweaning).

[f]Day 42 postweaning weight per day of age = off-test weight/pig age.

Table 5. Influence of weaning age on finishing performance, Trial 1[a]

	Weaning age					*P* <	
Item	12	15	18	21	SE	Linear	Quadratic
Finishing placement weight, kg	16.9	20.4	22.6	25.8	0.23	0.001	0.14
Finishing placement weight CV, %	19.5	14.8	13.7	12.4	0.55	0.001	0.001
ADG, g[b]	722	728	736	768	11	0.002	0.19
Mortality, %	4.38	5.21	4.79	3.13	0.94	0.32	0.19
Off-test weight, kg	103.9	109.1	112.1	117.3	0.81	0.001	0.94
Off-test weight, CV, %	12.4	10.4	10.4	9.0	0.64	0.001	0.51
Off-test weight, per day of age, g[c]	618	637	643	662	5	0.001	0.93

[a]Based on 1,920 pigs allotted from the nursery to the finishing phase of this study on d 42 after weaning with 20 pigs (10 barrows, 10 gilts) per pen and 24 replications (pens) per treatment, or 96 pens on test.
[b]ADG = (off-test pen weight − allotment pen weight)/(pigs placed × d on-test).
[c]Off-test weight per day of age = off-test weight/pig age.

Table 6. Influence of weaning age and nursery feeding program on finishing performance, Trial 2[a]

	Less complex nursery feeding program			More complex nursery feeding program							
	Weaning age, d							*P* <			
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear age	Quadratic age	Feed program	Age × feed program
Finishing placement weight, kg	22.9	25.4	28.2	22.9	25.5	28.0	0.64	0.001	0.33	0.10	0.22
Finishing placement weight CV, %	14.2	12.7	12.0	13.0	12.2	12.1	0.61	0.001	0.23	0.08	0.23
ADG, g[b]	786	792	808	779	786	803	12	0.003	0.58	0.39	0.98
Mortality, %	1.00	2.00	1.00	2.60	1.80	1.40	0.62	0.30	0.42	0.20	0.29
Off-test weight, kg	111.6	115.9	119.4	112.5	115.3	119.0	1.33	0.001	0.91	0.99	0.30
Off-test weight CV, %	10.2	9.8	9.2	9.7	8.7	9.8	0.43	0.34	0.17	0.33	0.14
Off-test weight per day of age, g[c]	661	674	683	667	672	681	6	0.001	0.97	0.98	0.34

[a]Based on 3,000 pigs allotted from the nursery to the finishing phase of this study on d 42 after weaning, with 25 pigs (12 barrows, 13 gilts) per pen and 20 replications (pens) per treatment, or a total of 120 pens on test. Pigs within each wean age group were fed alternative nursery feeding programs (classified as less or more complex), which are described in Table 2.
[b]ADG = (off-test pen weight − allotment pen weight)/(pigs placed × d on-test).
[c]Off-test weight per day of age = off-test weight/pig age.

Table 7. Influence of weaning age on wean-to-finish performance, Trial 1[a]

	Weaning age					*P* <	
Item	12	15	18	21	SE	Linear	Quadratic
Allotment weight, kg	3.42	4.26	4.89	5.75	0.05	0.001	0.68
Off-test weight, kg	103.9	109.1	112.1	117.3	0.81	0.001	0.94
ADG, g[b]	580	616	637	687	8	0.001	0.36
Mortality, %[c]	9.39	7.88	6.80	3.68	0.95	0.001	0.39
Average pig gain per day postweaning, g[d]	643	671	686	714	5	0.001	0.96
Weight sold per pig weaned, kg[e]	94.1	100.5	104.4	113.1	1.30	0.001	0.35

[a]Linking nursery allotment weights and nursery mortality data within treatment and block to respective finisher pen to quantify wean to finish performance.
[b]ADG = {[finisher pen weight sold − (nursey allotment weight × wean pigs required to place finishing pen)]/(wean pigs required to place finishing pen × day postweaning)}.
[c]Mortality = [1 − (finishing pen inventory weighed off-test/weaned pigs required to place finishing pen)] × 100.
[d]Average pig gain per day postweaning = (off-test weight − allotment weight)/d postweaning.
[e]Weight sold per pig weaned = off-test pen weight/weaned pigs required to place finishing pen.

to 21 d or 15.5 to 21.5 d in Trials 1 and 2, respectively. Nursery feeding program did not affect ($P \geq 0.27$) wean-to-finish growth performance in Trial 2.

Estimating Rate of Change per Day Increase in Weaning Age

Data from Trials 1 and 2 were pooled to enable a collective estimate of the rate of linear improvement observed in postweaning performance as weaning age increased from 12 to 21.5 d. These linear rates of improvement (slope) describe the effect of increasing weaning age on a daily increase in weaning age basis. For example, these studies indicate that the total weight sold per pig weaned will increase by 5.40 kg (1.80 kg × 3 d) as weaning age is increased from 18 to 21 d in this multisite production system (Table 9). The estimated slopes for several primary response criteria are illustrated in Table 9. These modeled slopes are intended to provide a reference that succinctly illustrates the rate of linear improvement in growth performance observed in these studies as weaning age increased. Understanding these slopes (rate of improvement on a per day increase in weaning age basis) enables the implications of altering weaning age within a production system to be readily modeled.

Discussion

Previous studies have illustrated positive effects of SEW production systems in which weanling pigs are removed from the sow farm of origin and reared in environments isolated from other age groups of pigs (Dritz et al., 1996a; Fangman et al., 1996; Patience et al., 2000). This management practice is also referred to as isowean production, age-segregated rearing, and segregated disease control (Harris, 2000). Multisite pig production systems have become commonplace due to the positive effects on postweaning growth performance. The improvements in growth performance in SEW are due to reduced pathogen or antigenic exposure to the growing pig (Harris and Alexander, 1999; Harris, 2000). Additionally, the site segregation and all-in, all-out management (i.e., facilities depopulated, cleaned, and disinfected between groups of pigs) accompanying this technology decreases the opportunities for pathogens to be continuously passed between groups of growing pigs. Reducing weaning age and segregated production have been shown to be a means of rearing pigs free of specific pathogens that are present in the sow farm of origin (Alexander, 1980; Harris, 1988; Alexander and Harris, 1999). However, limited research has been conducted to independently determine the effects weaning age without being confounded by site segregation (Dritz et al., 1996b; Fangman et al., 1996). On commercial farms, weaning age is generally an outcome determined secondarily from the number of sows farrowing each week, lactation space available, and how efficiently the lactation space available is being used. Furthermore,

Table 8. Influence of weaning age and nursery feeding program on wean-to-finish performance, Trial 2[a]

	Less complex nursery feeding program			More complex nursery feeding program				*P* <			
	Weaning age, d										
Item	15.5	18.5	21.5	15.5	18.5	21.5	SE	Linear age	Quadratic age	Feed program	Age × feed program
Allotment weight, kg	4.09	4.78	5.63	4.06	4.78	5.65	0.09	0.001	0.001	1.00	0.52
Off-test weight, kg	111.6	115.9	119.4	112.5	115.26	119.0	1.33	0.001	0.91	0.99	0.30
ADG, g[b]	680	696	725	671	699	718	7	0.001	0.78	0.37	0.53
Mortality, %[c]	2.89	3.86	2.20	4.95	2.99	2.77	0.69	0.03	0.69	0.27	0.08
Average pig gain per day postweaning, g[d]	700	725	742	707	722	740	7	0.001	0.76	0.85	0.27
Weight sold per pig weaned, kg[e]	108.3	111.4	116.7	106.9	111.8	115.7	1.2	0.001	0.70	0.35	0.53

[a]Nursery allotment weights and nursery mortality data for each treatment and block were applied to each finishing pen placed of that same treatment and block to determine the effects of weaning age and nursery feeding program on wean-to-finish performance. Pigs within each wean age group were fed alternative nursery feeding programs (classified as less or more complex), which are described in Table 2.
[b]ADG = [finisher pen weight sold − (nursery allotment weight × weaned pigs required to place finishing pen)] ÷ (weaned pigs required to place finishing pen × d postweaning).
[c]Mortality = [1 − (finishing pen inventory weighed off-test/weaned pigs required to place finishing pen)] × 100.
[d]Average pig gain per d postweaning = (off-test weight − allotment weight)/d postweaning.
[e]Weight sold per pig weaned = off-test pen weight/weaned pigs required to place finishing pen.

Table 9. Modeling the linear rate of change observed as wean age increased from 12 to 21.5 d in Trials 1 and 2[a]

	Rate of linear change per day increase in wean age	
Item	Change per day	SE
Allotment weight, kg[b]	0.257	0.003
d 42 postweaning, kg	0.93	0.017
Off-test weight, kg[c]	1.35	0.08
Wean-to-finish ADG, g[d]	9.9	0.74
Wean-to-finish mortality, %[e]	–0.47	0.09
Weight sold per pig weaned, kg[f]	1.80	0.12

[a]Modeling the linear rate of change (magnitude of change per day increase in weaning age) in wean-to-finish performance observed as weaning age increased from 12 to 21.5 d (Trial 1 = 96 finishing pens with 20 pigs per pen, and Trial 2 = 120 finishing pens with 25 pigs per pen).
[b]Allotment weights were taken on all pigs 3 d before weaning.
[c]Off-test weight = average finishing sale-weight at a fixed number of days postweaning.
[d]Wean-to-finish ADG = [finisher pen weight sold – (nursery allotment weight × weaned pigs required to place finishing pen)]/(weaned pigs required to place finishing pen × d postweaning).
[e]Wean-to-finish mortality = [1 – (finishing pen inventory weighed off-test/weaned pigs required to place finishing pen)] × 100.
[f]Weight sold per pig weaned = off-test pen weight/weaned pigs required to place finishing pen.

weaned pigs within commercial production systems are commonly considered to be of equal value and are assumed to have similar postweaning performance potential, as long as minimum quality standards are met. The performance differences observed in our studies strongly suggest that weaning age has a significant impact on the economic value of a weaned pig.

The effects of incrementally increasing or decreasing weaning age on postweaning performance in a commercially applied SEW production scheme, given a uniform health status and environment, have not been previously reported. The extensive individual pig allotment procedures described were implemented to make certain that each nursery and finishing pen replicated the actual weight distribution within each treatment. Replicating the weight distribution within each pen ensured that each pen was a similar and representative sample of the treatment populations being evaluated. We feel the extensive allotment procedures used, and numbers of population replications achieved, were the critical components in our effort to estimate the effects of weaning age on wean-to-finish performance in this multisite production system.

In these studies, wean-to-finish growth performance and productivity (as measured by ADG, mortality, off-test weight per day of age, and weight sold per pig weaned) improved as weaning age increased from 12 to 21 and 15.5 to 21.5 d of age. These improvements in growth and mortality largely occurred in the initial 42 d after weaning, with some further improvements in growth in finishing. The improvements in postweaning ADG and ADFI with increased weaning age are similar to those reported by Dritz et al. (1996b) and Fangman et al. (1996). However, the improvement in weight per day of age at slaughter was not observed when 9- and 19-d weaned pigs were segregated at weaning and raised in a common off-site location (Dritz et al., 1996b). Hohenshell et al. (2000) weaned pigs at 10 or 30 d of age into a common environment in a behaviorally focused study and did not find weight per day of age differences between treatments at slaughter. The differences between the Dritz et al. (1996b) and the Hohenshell et al. (2000) studies and the current trials may be due to differences in age range evaluated (Hohenshell et al., 2000), health status, group or pen size, or growing environment. The Dritz et al. (1996b) and Hohenshell et al. (2000) studies were completed in facilities with not greater than five pigs per pen, whereas the Fangman et al. (1996) study was completed in commercial facilities with 28 pigs per pen, more similar to the current studies.

The linear improvements in wean-to-finish growth and productivity observed with increasing wean age in the current trials is likely a function of both weight and physiological maturity at weaning. Weaning weight has been shown to improve wean-to-finish growth rate (Mahan and Lepine, 1991; Mahan et al., 1996; Wolter and Ellis, 2001); however, weaning weight is directly confounded within weaning age in this study. Therefore, it is not appropriate to translate the weaning age effects directly back to weaning weight in the current studies. Wolter et al. (2002) found that increasing weaning weight by means of a supplemental milk replacer during lactation had no effect on ADG from weaning at 21 d to 14 kg, or from weaning to 110 kg. However, Wolter et al. (2002) did observe a reduction in days from birth to 110 kg in pigs supplemented with milk throughout the 21-d suckling period. Translating weaning age performance improvements back to an incremental increase in weaning weight basis is only appropriate when the improved weaning weights are due to an increased weaning age. The effect of weaning age on weaning weight (0.257 ± 0.003 kg increase in weaning weight per day increase in weaning age) was similar in Trials 1 and 2.

It should be recognized that the improvements in wean-to-finish growth performance observed in these studies might vary between different multisite production systems due to differences in health status, environment, or genotype. These studies suggest the magnitude of growth rate improvement observed with increasing wean age is rather predictable within a given multisite production system. However, the magnitude of the mortality improvement likely depends on baseline mortality rates, as well as pig-flow, site, or other system-specific challenges.

There were no weaning age × nursery feeding program interactions on growth performance in Trial 2. Additionally, altering the nursery feeding program did not affect wean-to-finish growth performance. A trend toward reducing variation in d 42 postweaning weight was the only performance measure affected by altering the nursery feeding program. Increasing diet complexity has been shown to increase wean-to-finish performance in pigs (Mahan, 1998) when increasing diet complexity was defined as increasing the inclusion rates of whey and specialty proteins. The differences in nursery feeding programs fed in Trial 2 may not have been large enough to create detectable differences in mean growth performance. Other research has found that increasing diet complexity increased growth performance in the initial postweaning period (weaning to 7.0 kg), with no detectable improvements through slaughter (Dritz et al., 1996b). Therefore, these data and the numerical reductions in variation indicate that diet complexity is most important for the transition to eating feed after weaning. However, once pigs start consuming feed, the importance rapidly declines. Finally, the observations in Trial 2 are consistent with other research indicating that weight at weaning has more influence on postweaning growth than altering postweaning feeding regimens (Mahan et al., 1991, 1998; Wolter and Ellis, 2001).

Implications

Increasing weaning age from 12 to 21.5 d improved wean-to-finish growth performance in a multisite swine production system. Linear improvements in growth and mortality rate largely occurred in the initial 42 d postweaning period, with some ongoing growth improvements in finishing. These studies suggest increasing weaning age up to 21.5 d can be an effective production strategy to improve wean-to-finish growth performance in a multisite pig production.

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