The Pros and Cons of SEW System* - Review -

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ABSTRACT : Early-weaning at an age of less than 21 days and removal of pigs to a second isolated site, which is commonly referred to as segregated early weaning (SEW), has been shown to substantially reduce disease transfer from the dam. This strategy has been successful in reducing the number of pathogens, but has not been successful in eliminating all pathogens. Although SEW has failed in most instances to totally eliminate pathogens, performance as measured by gain and efficiency through the nursery phase has been shown to be enhanced. In addition, SEW pigs have been shown to perform well on less complex nursery diets. Pigs which are continued on a similar isolation regime to market weight have been shown to have a remarkable improvement in feed intake, gain and efficiency. However, pigs which are co-mingled with conventional pigs after the nursery phase have either no improvement in performance or reduced performance. Backfat and carcass lean yield have been shown to be enhanced by SEW in high lean gain pigs, but not in lower lean gain pigs. Exposure of pigs to antigens which activate the immune system and increase the level of immunological stress has been suggested as the mechanism involved in depressing growth and performance of pigs. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 2 : 226-232)*

Key Words : Piglet, SEW, Weaning Pig, Disease

INTRODUCTION

Several studies in the literature suggest that early-weaning (<21 days of age) and removal of pigs to a second isolated site for rearing (SEW) will substantially reduce the potential for disease transfer from the dam (Fangman et al., 1997). The premise is that pigs are removed from the sow while their immunity, as a consequence of maternal antibodies, is still high. This maternally derived passive immunity will prevent vertical transfer of indigenous pathogens. In addition, the assumption is that most pathogenic organisms are unable to cross the placenta. This is consistent with the successful surgically derived specific-pathogen-free and gnotobiotic pigs that are free of specific bacterial pathogens (Whitehair and Thompson, 1956; Trexler, 1961). Pigs reared in isolation have been shown to have reduced immunological stress (Johnson, 1997) resulting in improved growth and efficiency of feed utilization. Numerous studies have shown that pigs managed under all-in, all-out systems have improved feed intake, gain and efficiency when compared to pigs under continuous flow management. SEW is evolving as a management strategy which appears to have the potential to reduce immunological stress even further.

EFFECT OF SEW ON SPECIFIC PATHOGENS

SEW has been shown to be successful in reducing the number of pathogens. Strategies involving weaning as early as 5-10 days of age combined with a vaccination and medication program (Alexander et al., 1980; Connor, 1992) have been shown to be successful, but early-weaning without relying on medication has also been shown to reduce the incidence of disease (Clark et al., 1994). It should be noted that although SEW results in a major reduction in many pathogens, these strategies have not proven to be a successful method to eliminate all pathogens (Clifton-Hadley et al., 1986; Dee et al., 1994; Clark et al., 1994). Pijoan (1995) has suggested that some diseases may be exacerbated by SEW. All pigs may not receive sufficient maternal immunity to prevent infection and a small portion of pigs may be infected prior to weaning. Clinical signs of disease can then be observed as pigs develop in the nursery. Harris (1993) has suggested the following weaning ages for the following diseases. Weaning at an earlier age appears to enhance the success of eliminating pathogens (Wiseman et al., 1994).

Organism	Weaning age
Pseudorabies virus	<21 days
Actinobacillus pleuropneumoniae (APP)	<21 days
Mycoplasma hyopneumoniae	<10 days
Pasteurella multocida	<10 days
Haemophilus parasuis (HPS)	<14 days
Porcine reproductive and respiratory syndrome virus (PRRS)	<10 days
Salmonella cholerasuis	<12 days
Transmissible gastroenteritis virus (TGE)	<21 days

(Harris, 1993)

EFFECT OF SEW ON PIG PERFORMANCE

Although SEW has generally failed to totally eliminate specific pathogens, the level of exposure has

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been reduced substantially. Several recent studies have evaluated the effects of SEW on performance during the subsequent nursery period and growing-finishing period. Williams et al. (1997a) compared performance of pigs reared under two management systems from weaning. Pigs were reared under a medicated early-weaning scheme (SEW) to minimize disease transition by enhancing development of passive immunity in neonatal pigs and by isolating pigs from major vectors of antigen transmission. Pigs were weaned at 12 days of age and fed a milk based diet in an isolation facility until 19 days of age. A conventional rearing scheme (CON) was used to rear the conventional group until weaning at 19 days of age. In addition, during the nursery phase, conventional pigs were exposed to older nursery pigs from the same unit at periodic intervals. Serum alph-1-acylglycoprotein was used as an indicator of immune activation (table 1).

Table 1. Serum alpha-1-acylglycoprotein concentration in SEW and conventionally reared pigs

Serum alpha-1-acylglycoprotein, AGP, μg/mL	Rearing System	Average body weight, kg		
		9.5	17.5	25
	SEW	1,111	1,112	911
	Conventional	1,499	1,542	1,401

(Williams et al., 1997a)

Pigs from the conventional group had reduced average daily gain and poorer feed efficiency when compared to SEW pigs (table 2).

Table 2. Effect of rearing system and dietary Lysine regimen on feed intake, body weight gain, and gain:feed ratio of pigs fed from 6 to 27 kg BW[a]

Criterion	Rearing System	Dietary Lysine, %			
		0.60	0.90	1.20	1.50
Growth performance of pigs fed from 6.2 to 26.5 kg BW					
Daily gain, g[def]	SEW	400	556	644	663
	Conventional	357	495	510	504
Daily feed, g[bc]	SEW	896	1,025	1,052	1,002
	Conventional	889	954	889	911
Gain/feed, g/kg[de]	SEW	445	544	613	662
	Conventional	395	522	581	565

(Williams et al., 1997a)

[a] Five or six individually penned pigs per rearing system-Lys treatment group. Least squares means reported.
[b] Rearing system effect, p<0.09.
[c] Quadratic lysine effect, p<0.04.
[d] Rearing system effect, p<0.01.
[e] Linear lysine effect, p<0.01.
[f] Rearing system × lysine quadratic effect, p<0.04.

This experiment demonstrated that rearing pigs in a minimal disease environment will enhance performance throughout the nursery phase. The approximately 21.3% improvement in gain in SEW pigs (across all lysine levels) represents a major response to efforts to control pathogens. In addition, the SEW pigs responded to greater dietary lysine concentrations than conventionally reared pigs with a 31.5% improvement in gain at the highest lysine intake. This is consistent with a greater protein accretion rate in SEW pigs when compared to conventional pigs (table 3).

Table 3. Effect of rearing system regimen on protein accretion rates of pigs fed from 6 to 27 kg BW[a]

Criterion	Rearing System	Dietary Lysine, %			
		0.60	0.90	1.20	1.50
Body nutrient accretion rates from 6.2 to 26.5 kg BW					
Protein, g/d[bc]	SEW	47.6	77.8	100.7	110.8
	Conventional	40.3	67.3	80.3	79.4

(Williams et al., 1997a)

[a] Five or six individually penned pigs per rearing system-Lys treatment group. Least squares means reported.
[b] Rearing system effect, p<0.01.
[c] Lysine linear effect, p<0.01.

Pigs in this experiment were managed under the two rearing systems to slaughter (112 kg; Williams et al., 1997b). From 27 to 112 kg gain and efficiency were improved in pigs reared under SEW conditions. In addition, SEW pigs reared to slaughter in isolation had improved longissimus muscle area (LEA) and carcass muscle (table 4). Dietary lysine requirement to optimize LEA and percent muscle were higher in SEW than in conventional pigs.

Table 4. Effect of rearing system and dietary lysine on carcass traits from pigs at 112 kg[a]

Item	Rearing System	Dietary Lysine[b], %				
		0.60	0.90	1.20	1.50	1.80
		0.45	0.60	0.75	0.90	1.05
Longissimus muscle area,[abcd] cm^2						
	SEW	25.23	37.78	35.23	38.38	36.45
	Conventional	24.44	30.52	31.87	31.81	32.65
Estimated carcass muscle,[abc] %						
	SEW	48.06	52.05	54.94	56.79	55.52
	Conventional	47.43	50.96	52.84	52.68	52.90

(Williams et al., 1997b)

[a] Six or seven individually penned barrows per rearing system-dietary Lys concentration treatment group.
[b] Rearing system effect, p<0.01.
[c] Lysine effect, p<0.01.
[d] Rearing system × lysine interaction, p<0.04.

Similar improvements in performance were observed by Dritz et al. (1996). Pigs weaned and segregated from the farm of origin were compared with littermate control pigs (14 to 17 days old) that were weaned and raised on-site. By 70 days of age, off-site pigs weighed 52% more than on-site pigs (table 5).

Table 5. Effect of SEW on pig weight

Pig wt, kg	On-site	Off-site
d 0	3.0	3.4
d 14	4.8	5.8
d 28	7.7	14.0
d 42	12.6	23.7
d 56	22.6	34.9
d 70	32.2	49.0

(Dritz et al., 1996)

Pasteurella multocida was isolated from controls. In addition, *Mycoplasma pneumonia* infection was detected in control, but not in SEW pigs.

Edmonds et al. (1997) conducted four 5-week nursery studies to evaluate the effects of allotting littermates to both on- and off-site nursery facilities. Pigs were weaned between 14 and 19 days of age and housed six per pen. Both nurseries were cleaned and disinfected and all-in, all-out management procedures were utilized. Pigs raised off-site had improved averaged daily gain (4.5%) improved feed intake (8.8%) but required more feed per pound of gain when compared to pigs reared on-site (table 6). This study suggests that the magnitude of improvements in performance of SEW pigs may be lower for herds experiencing minimal health problems.

Table 6. Effect of Nursery Location on Performance (35 day study)

	On-Site	Off-Site
Trial 1		
Daily gain, g*	405	444
Daily feed, g*	537	585
Gain:feed, g/kg	756	759
Trial 2		
Daily gain, g*	373	398
Daily feed, g*	467	536
Gain:feed, g/kg*	800	745
Trial 3		
Daily gain, g	384	397
Daily feed, g*	487	530
Gain:feed, g/kg*	789	752
Trial 4		
Daily gain, g	378	383
Daily feed, g*	466	497
Gain:feed, g/kg*	811	772

* $p<0.05$. Edmonds et al. (1997)

All pigs in this study were finished in on-site finishing facilities. Under these conditions, nursery site had no effect on subsequent gain or gain:feed during finishing. This study suggests that the magnitude of improvement may be less under conditions where the herd of origin is not experiencing major infectious disease problems.

Patience et al. (1997) evaluated the impact of age and site of weaning on pig performance under high health conditions. Pigs were derived from a breeding herd free of infectious respiratory disease, internal and external parasites and most infectious gastrointestinal diseases. Sixteen litters were weaned at 12±2 days and housed in an all-in, all-out nursery room at the swine center (Conventional SEW), 16 litters were weaned at 12±2 days of age and moved to an off-site location (Off-site SEW) and 16 litters were weaned at 21 days and retained on-site (Control). At 21 days control pigs were heavier than off-site SEW or conventional SEW pigs. However, at 56 days of age the off-site SEW pigs were heavier than the convention SEW or control group (table 7).

Table 7. Impact of age and site of weaning on pig performance and health conditions

Item	Control 21 d wean	Conventional SEW 12 d wean	Off-site SEW 12 d wean
Wt 21 days, kg	6.48[a]	5.33[b]	5.95[b]
Wt 56 days, kg	21.28[a]	20.72[a]	24.62[b]

Patience et al. (1997)

[a,b] Means with different superscript differ, $p<0.05$.

EFFECT OF SEW ON CARCASS COMPOSITION

Work cited earlier indicated a substantial improvement in performance and carcass composition in SEW pigs when compared to conventional pigs (Williams et al., 1997b). Edmonds et al. (1997) observed little effect of SEW on either performance during the finishing phase or carcass composition. Research by Frank et al. (1997) may explain some of the differences in carcass response to environmental rearing systems. These researchers compared performance and carcass composition of littermate barrows and gilts which were either segregated early-weaned at 13d of age (4.8 kg) to an off-site nursery and finisher or conventionally weaned at 27 d of age (7.25 kg) to an on-site nursery and finisher. Genotypes were Landrace-Yorkshire cross (YL) or European Terminal Sire cross (ETS). The ETS pigs had larger loin eye area, higher percent lean and lower 10th rib backfat (table 8).

Table 8. Environmental effects of genetic potential for lean gain

	Conventional		SEW	
	ETS	YL	ETS	YL
LEA, Cm[ab]	47.1	38.8	49.2	38.8
% Lean[b]	56.6	51.4	57.6	49.9
BF, Cm[c]	1.69	2.24	1.64	2.62
Death Loss, %[c]	18.5	5.6	3.6	2.8

[a] Genotype, $p<0.01$. Adapted from Frank et al. (1997)
[b] Environment × Genotype, $p<0.05$.
[c] Environment × Genotype, $p<0.01$.

In addition, the lower lean gain pigs (YL) had increased backfat and a lower percent lean in the SEW environment while the ETS pigs had no difference in backfat thickness and an improvement in percent lean in the SEW environment (Environment × genotype interaction, $p<0.05$ and $p<0.01$, respectively). This study suggests that low lean gain pigs might get fatter and have lower lean yield under the faster growth SEW conditions whereas pigs with higher lean gain potential may have improved carcass composition.

It is also interesting to note that death loss was higher in pigs reared in the conventional environment than those reared in the SEW environment. This difference was primarily due to increased death losses in ETS pigs in the conventional environment suggesting that genetic differences exist for pig survival.

Why do pigs exposed to pathogens have reduced intake and gain?

The variability in response to SEW depending upon the health of the herd of origin and exposure to pathogens is not surprising. Exposure of animals to antigens has been shown to result in the release of cytokines that activate the immune system (Dinarello, 1984). This results in a major alteration of metabolic processes (Klasing, 1988) which can induce anorexia (Mrosovsky et al., 1989), depress protein synthesis (Jepson et al., 1986) and stimulate protein degradation in skeletal muscle (Zamir et al., 1994). Therefore, pigs which are undergoing exposure to antigens which activate the immune system would be expected to exhibit reduced feed intake and weight gain during the period of antigen exposure.

This is consistent with the concept described by Johnson (1997) who indicated that a dirty, less hygienic environment increases the level of immunological stress and depresses growth and performance of pigs. These effects are mediated by cytokines which impact feed intake and alter the utilization of protein. A second important feature of the inflammatory response is an increase by the liver of acute phase proteins. Synthesis of some acute phase proteins may increase several 100-fold. These acute phase proteins are synthesized at the expense of degradation of skeletal muscle protein. Reeds et al. (1994) estimated that to provide sufficient amounts of the limiting amino acid for acute phase protein synthesis (phenylalanine) would require more than a 2-fold increase in degradation of muscle protein. Thus, immunological stress is linked by cytokines to enhanced hepatic acute phase protein synthesis, and decreased muscle protein synthesis and (or) increased muscle protein degradation.

This concept explains the impact that specific rearing regimes may have on pig performance. Numerous studies have shown that pigs kept under all-in, all-out management eat more, grow faster and are more efficient when compared to pigs under continuous flow management. SEW is a management system which appears to have the potential to reduce immunological stress even further than that observed with all-in, all-out management.

Induction of immunological stress with lipopolysaccharide has demonstrated the relationship of this stressor with increased cytokine production (Johnson, 1997; Mandali et al., 1997). Schinckel et al. (1995) evaluated the impact of antigen challenge on pig performance from 12 days of age to market weight. Pigs received either no antigen challenge or a moderate or high level of antigenic challenge. Antigen including an *Escherichia coli* lipopolysaccharide and vaccines were given between 12 and 84 days of age at times corresponding to expected commercial exposure. In the nursery, (d 12 to 53), antigen-challenged pigs had lower growth rates than control pigs (table 9).

Table 9. Effect of antigenic challenge on growth rate

Item	Control	Moderate Treatment	Intense Treatment
Average Daily Gain, kg			
D 12-23	0.22[a]	0.17[b]	0.20[b]
D 24-44	0.50[a]	0.44[b]	0.39[b]
D 44-54	0.63[a]	0.52[b]	0.56[b]
D 54-93[a]	0.85	0.84	0.83
D 93-120[b] kg	1.06	1.07	1.10

[a] adjusted for initial weight at d 54. (Schinckel et al., 1995)
[b] adjusted for initial weight at d 93.

From day 53 to 93, the antigen-challenged pigs grew more slowly and had higher feed intakes. However, when the data were adjusted for differences in initial weight, ADG was similar among the treatments suggesting that differences in growth from day 53 to 93 were due to lower initial weight. From 93 days of age to market weight, weight gain was similar among the treatments when corrected for initial weight. This study demonstrates that lipopolysaccharides and (or) vaccines can reduce performance when the treatments are being imposed, however, performance returns to control levels once treatment ceases. Unfortunately, the immunological stress imposed by a high level of exposure to pathogens is not transitory and continues to impact performance throughout the finishing period.

A second study which demonstrates the impact of immunological stress on subsequent performance was reported by Ragland et al. (1997). In this study, SEW pigs were co-mingled with farm reared pigs at approximately 60 days of age in a control test station. Average daily gain, feed efficiency, average daily lean gain and efficiency of lean gain were lower in SEW pigs when compared to conventional farm reared pigs (table 10).

This suggests that the SEW reared pigs were undergoing increased immunological stress and reduced performance during the finishing period as a consequence of exposure to higher levels of pathogens during finishing. The best strategy for inhibiting the costly effects of increased immunological stress appears to avoid contact with potential bacterial and viral stressors from nursery to finishing. In fact, performance during finishing may be compromised by a strategy of co-mingling pigs from nurseries with varying levels of disease.

Table 10. Performance traits of SEW and farm reared pigs

	Farm Reared	SEW
Average daily gain	0.818±0.009[a]	0.751±0.010[b]
Feed efficiency	3.31 ±0.07[a]	3.53 ±0.08[b]
Average daily lean gain	0.320±0.005[a]	0.288±0.006[b]
Efficiency of lean gain	8.47 ±0.22[a]	9.28 ±0.25[b]

[a,b] $p<0.05$ Ragland et al. (1997)

EFFECT OF SEW ON LYSINE REQUIREMENTS

Advances in nutrition, facility design, and management practices have allowed the adoption of SEW as a common management technique. Owen et al. (1995) indicated that the lysine requirement of segregated early-weaned pigs was higher than previously thought. This is consistent with research in our lab (Chung et al., 1996) and Seoul National University (Cho et al., 1998). In this study, 80 pigs (14±2 days of age and 4.5 kg body weight) penned in groups of four (4 pens/treatment) were used to evaluate five dietary lysine levels (1.30, 1.45, 1.60, 1.75 & 1.90%). The control diet contained 5.0% AP 920, 5.0% dried skim milk, 4.0% egg protein, 8.0% menhaden select fish meal and 21.96% whey (edible grade) as the protein sources. Corn starch and sucrose were replaced by increasing levels of whey protein concentrate (77% protein) to increase lysine levels. Amino acid levels were maintained to meet the ideal protein ratio according to Chung and Baker (1992). Lactose content of all diets was 24%. Experimental diets were fed from day 0 to 14 postweaning and then all pigs were fed a common transition diet (1.40% lysine) from day 14 to 28 and a phase 2 diet (1.35% lysine) from day 28 to 42. ADG and gain:feed increased with increasing dietary lysine during day 0 to 6, 0 to 14 and 0 to 42 postweaning, (table 11). Both response criteria were maximized at 1.90% lysine. These results suggest that segregated early-weaned pigs require at least 1.75% of total dietary lysine to optimize growth performance during day 0 to 14 postweaning.

Similar conventional nursery studies were conducted. Davis et al. (1996) reported that pigs weaned at 16 to 24 days (average age and weight of 20±3 days and 6 kg, respectively) were fed four dietary levels of lysine from whey protein concentrate to determine the lysine requirement of nursery pigs during Phase 1 (d 0 to 14 postweaning). Two trials involving 12 pens of 6 pigs each were performed using a total of 144 pigs. Protein source in the control diet included 20% whey (edible grade), 1.50% AP 301, 6.57% fish meal, 2.67% soybean protein concentrate and 3.50% AP 920. The four experimental diets were formulated by substituting whey protein concentrate (77% protein) for corn starch and sucrose to attain the desired levels of 1.15%, 1.30%, 1.45%, and 1.60% lysine.

Table 11. The effect of increasing dietary lysine on growth performance and blood urea N of segregated early-weaned pigs[a]

Item	Lysine level, %					
	1.30	1.45	1.60	1.75	1.90	SEM
d 0 to 7						
ADG, g[b]	183.87	193.19	238.95	265.68	265.68	16.70
ADFI, g	200.41	206.12	208.91	226.73	213.82	12.36
Gain:feed[b]	0.92	0.94	1.16	1.17	1.26	0.05
d 0 to 14						
ADG, g[b]	259.00	298.28	349.72	356.00	365.31	18.33
ADFI, g	315.34	338.65	359.96	345.18	329.94	17.09
Gain:feed[b]	0.85	0.90	1.03	1.07	1.16	0.03
d 0 to 42						
ADG, g[b]	454.75	474.66	504.43	517.05	525.89	17.70
ADFI, g	618.32	642.20	651.99	672.81	664.50	24.69
Gain:feed[b]	0.76	0.77	0.83	0.84	0.88	0.01

(Chung et al., 1996)

[a] Data are means of 4 pens of 4 pigs each. Pigs averaged 4.5 kg and 25.3 kg at initiation and termination, respectively.

[b] Linear effect of increasing dietary lysine ($p<0.006$).

Each trial was conducted for six weeks. The four experimental diets were fed for the first two weeks postweaning. All pigs were fed a common Phase 2 diet (1.35% lysine) from day 14 to 28 and Phase 3 diet (1.15% lysine) from day 28 to 42 to monitor any carryover effect from Phase 1 diets. Average daily gain, average daily feed intake, and gain:feed were determined weekly. Average daily gain and gain:feed ratio increased linearly with increasing lysine level during Phase 1 and over the entire six weeks of the study (table 12). Average daily feed intake did not differ in any phase of the trial. The results of this study demonstrate that pig performance improves as dietary lysine level increases when whey protein concentrate is used as the lysine source. Average daily gain and gain:feed responses indicate that the lysine requirement for maximum performance of conventionally-weaned pigs during the first two weeks postweaning may be lower than the level required for SEW pigs and is at least 1.60% of the diet.

Similar design was used by Jin et al. (1998) for estimating lysine requirement of conventionally weaned pig (21 days of age). They suggested that 1.55% of total lysine should be contained in the phase I diet. Not only have SEW pigs been shown to have a higher lysine requirement, but response to plasma protein has been demonstrated to be lower in SEW than in conventionally reared pigs (Coffey and Cromwell, 1995). Pigs reared under SEW conditions exhibited little response to spray dried plasma protein whereas pigs reared in a conventional on-farm nursery exhibited a 32% improvement in gain when the diet was supplemented with spray dried plasma protein (table 13). And the digestibility of threonine, which has been known to one of the major amino acids in immunoprotein, was highest comparing DSM, ISP, SDBM, FM and SBM (Cho et al., 1997). This may be an indication that the improvement in immuno- competence of young pigs mediated by immunoglobulins present in spray dried plasma protein may not be an essential in an SEW environment and suggests that excellent performance can be obtained with SEW pigs fed less complex diets.

Table 12. Performance of pigs (20±3 d of age) fed increasing levels of dietary lysine during Phase I[a]

Item	Lysine level, %				SEM
	1.15	1.30	1.45	1.60	
d 0 to 7					
ADG, g[b]	207.72	221.76	244.62	293.94	15.70
ADFI, g	239.40	230.22	233.10	248.22	9.62
Gain:feed[b]	0.87	0.96	1.04	1.18	0.04
d 7 to 14					
ADG, g[b]	343.44	394.56	429.12	457.56	14.20
ADFI, g	498.06	514.08	518.76	504.36	19.45
Gain:feed[b]	0.69	0.77	0.83	0.92	0.03
d 0 to 14					
ADG, g[b]	275.58	308.16	336.87	375.75	14.23
ADFI, g	368.73	372.15	375.93	376.29	17.75
Gain:feed[b]	0.78	0.87	0.93	1.05	0.02
d 14 to 28					
ADG, g	484.20	478.17	490.23	483.21	13.45
ADFI, g	703.62	701.73	730.71	694.44	24.75
Gain:feed	0.69	0.68	0.67	0.69	0.03
d 28 to 42					
ADG, g	569.25	593.46	602.01	612.99	19.82
ADFI, g	1049.85	1098.83	1151.10	1130.58	36.66
Gain:feed	0.55	0.54	0.52	0.54	0.02

[a] Six pens of 6 pigs/mean. (Davis et al., 1996)
[b] Linear effect of increasing dietary lysine. p<0.01.

Table 13. Effect of nursery environment and protein source on performance of early weaned pigs

Protein source	SEW off-site		Conventional on-site	
	DSM	SDPP	DSM	SDPP
ADG, 0~14d, g[a]	284	300	203	269
ADFI[b]	402	470	251	399
Feed/gain[c]	1.53	1.70	1.18	1.34

(Coffey and Cromwell, 1995)

[a] Protein source × nursery environment interaction, p<0.001 (Exp. 2 and 3).
[b] Protein source × nursery environment interaction, p<0.05 (Exp. 2).
[c] DSM vs SDPP across nursery environment, p<0.04 (Exp. 2).

REFERENCES

Alexander, T. J. L., K. Thornton, G. Boon, R. J. Lysons, A. F. Gush. 1980. Medicated early weaning to obtain pigs free from pathogens endemic in the herd of origin. Vet. Rec. 106:114.

Cho, S. B., J. H. Kim, In K. Han, H. K. Moon, B. J. Chae and W. T. Cho. 1997. Apparent digestibility of amino acids, energy and proximate nutrients in dietary protein sources for young pigs. Asian-Aus. J. Anim. Sci. 10(6):643-651.

Cho, W. T., J. H. Kim, S. H. Bae, In. K. Han and I. S. Shin. 1998. Studies on amino acids requirements of early weaned pigs. Korean J. Anim. Nutr. Feed. 22(3):165-180.

Chung, T. K., and D. H. Baker. 1992. Ideal amino acid pattern for 10-kilogram pigs. J. Anim. Sci. 70:3102.

Chung, J. S., B. Z. de Rodas, C. V. Maxwell and M. E. Davis. 1996. Determination of lysine requirement in segregated early-weaned pigs. Okla. Exp. Sta. P 953:267.

Clark, L. K., M. A. Hill T. S. Kniffen, W. VanAlstein, G. Stevenson, K.B. Meyer, C.C. Wu, A. B. Scheidt, K. Know, and S. Albregts. 1994. An evaluation of the components of medicated early weaning. Swine Health and Prod. 2(3):5.

Clifton-Hadley, F. A., T. Alexander, M. R. Enright. 1986. The epidemiology, diagnosis, treatment and control of *Streptococcus suis* type 2 infection. Proc AASP Annual Meeting. P. 473.

Coffey, R. D., and G. L. Cromwell. 1995. The impact of environment and antimicrobial agents on the growth response of early-weaned pigs to spray-dried porcine plasma. J. Anim. Sci. 73:2532.

Connor, J. 1992. Elimination of specific agents from herds: Elimination by medication. Proc. MN Swine Conf. Vet. p. 151.

Davis, M. E., B. Z. de Rodas, C. V. Maxwell and J Chung. 1996. Effect of increasing dietary lysine level with addition of whey protein concentrate on pig performance during phase 1 of the nursery period. Okla. Exp. Sta. P. 953:272.

Dee, S. A. 1994. Apparent prevention of *Mycoplasma hyopneumoniae* infection in growing pigs with a low-cost modified-medicated-early-weaning program. Swine Health and Prod. 2(6):7.

Dinarello, C. A. 1984. Interleukin-1. Rev. Infect. 44:105.

Dritz, S., M. M. Chengappa, J. L. Nelssen, M. D. Tokach, R. D. Goodband, J. C. Nietfeld, and J. J. Staats. 1996. Growth and microbial flora of nomedicated, segregated, early weaned pigs from a commercial swine operation. JAVMA 208(5): 711.

Fangman, T. J., M. S. Roderick and C. Tubbs. 1997. Segregated early weaning. Swine Health and Production. 5 (5):195.

Edmonds, M. S., B. E. Arentson, W. A. Nipper, and D. L. Froe II. 1997. Segregated early weaning: Effects of raising pigs on-site and off-site with and without vaccination on performance and economics. J. Anim. Sci. 75(Suppl. 1):195.

Frank, J. W., B. T. Richert, A. P. Schinckel, B. A. Belstra, and A. L. Grant. 1997. Environmental effects on genetic potential for lean gain. J. Anim. Sci. 75 (Suppl.1): 38.

Harris, D. L. 1993. Medicated early weaning. Proc. SE Swine Pract. Raleigh, North Carolina.

Jepson, M. M., J. M. Pell, P. C. Bates, and D. J. Millward. 1986. The effects of endotoxemia on protein metabolism in skeletal muscle and liver of fed and fasted rats. Biochem. J. 235:329.

Jin, C. F., J. H. Kim, W. T. Cho, K. Kwon and In K. Han. 1998. Lysine requirement of piglets. Asian-Aus. J. Anim. Sci. 11(1):89-96.

Johnson, R. W. 1997. Explanation for why sick pigs neither eat well nor grow well. Proc. Carolina Swine Nutr. Conf. P. 49.

Klasing, K. C. 1988. Nutritional aspects of leukocytic

cytokines. J. Nutr. 124:906.
Mandali, S, B. Z. de Rodas, C. V. Maxwell, A. B. Arquitt, and B. J. Stoker. 1997. Effect of endotoxin on trace minerals and immunological parameters in weanling pigs. J. Anim. Sci. 75(Suppl. 1):192.
Mrosovsky, N., L. A. Molony, C. A. Conn, and M. J. Kluger. 1989. Anorexic effects of interleukin-1 in the rat. Am. J. Physiol. 257:R1315.
Owen, K. Q., J. L. Nelssen, R. D. Goodband. 1995. Dietary lysine requirements of segregated early-weaned pigs. J. Anim. Sci. 73(Suppl. 2)68.
Patience, J. F., H. W. Gonyou, E. Beltranena, D. L. Whitington and C. S. Rhodes. 1997. The impact of age and site of weaning on pig performance under high health conditions. J. Anim. Sci. 75(Suppl. 1):246.
Pijoan, C. 1995. Disease of high health pigs: Some ideas on pathogenesis. Proc. AD Leman Swine Conf. St. Paul Minnesota. P. 16.
Reeds, P. J., C. R. Fjeld and F. Jahoon. 1994. Do the differences between the amino acid composition of acute-phase and muscle proteins have a bearing on nitrogen loss in traumatic stress? J. Nutr. 124:906.
Ragland, K. D., L. L. Christian, J. D. McKean and T. J. Baas. 1997. Performance carcass and muscle quality traits of centrally tested segregated early weaned and farm reared pigs. J. Anim. Sci. 75 (Suppl. 1):246.
Schinckel, A. P. , L. K. Clark, G. Stevenson, K. E. Knox, J. Nielsen, A. L. Grant, D. L. Hancock, and J. Turek. 1995. Effects of antigenic challenge on growth and composition of segregated early-weaned pigs. Swine Health and Prod. 3(6): 228.
Trexler, P. C. 1961. The gnotobiotic-review and future. Bio-med Purview. 1:7.
Whitehair, C. K., C. M. Thompson. 1956. Observations on raising disease-free swine. J. Amer. Vet. Med. Assoc. 128: 94.
Williams, N. H., T. S. Stahly, and D. R. Zimmerman. 1997a. Effect of chronic Immune system activation on the rate, efficiency and composition of growth and lysine needs of pigs fed from 6 to 27 kg. J. Anim. Sci. 75:2463.
Williams, N. H., T. S. Stahly, and D. R. Zimmerman. 1997b. Effect of chronic immune system activation on the growth and dietary lysine needs of pigs fed from 6 to 112 kg. J. Anim. Sci. 75:2481.
Wiseman, B., T. Molitor, M. White, R. Morrison and G. Dial. 1994. Health and immunological aspects of early weaning. Proc. AASP Annual Meeting. P. 191.
Zamir, O., W. OBrien, R. Thompson, D. C. Bloedow, J. E. Fischer, and P. Hasselgren. 1994. Reduced muscle protein breakdown in septic rats following treatment with interleukin-1 receptor antagonist. Int. J. Biochem. 26:943.