THE EFFECTS OF PORCINE INTESTINAL MUCOSA PRODUCTS ON NURSERY PIG GROWTH PERFORMANCE AND FEEDER TROUGH SPACE AND ADJUSTMENT ON FINISHING PIGS

by

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Abstract

A total of 5,480 pigs involving 10 experiments were conducted. Experiment 1 evaluated 3 feeder gap settings: 1.27, 1.91, or 2.54 cm, while Exp. 2 evaluated the effects of feeder trough space (4.45 vs. 8.9 cm/pig) and minimum feeder gap opening of 1.27 vs. 2.54 cm. In Exp. 1, pigs fed with increasing feeder gap had decreased (linear; $P < 0.03$) G:F due to increased (linear; $P < 0.02$) ADFI. In Exp. 2, there was a tendency ($P = 0.08$) for increased ADG as feeder trough space increased from 4.45 to 8.9 cm/pig. Pigs fed with the wide feeder gap setting had increased ($P < 0.01$) ADFI and decreased ($P < 0.01$) G:F compared to pigs with the narrow feeder gap setting.

Experiments 3 and 4 were conducted to determine the effects of diet form (meal vs. pellet) and feeder design (conventional dry vs. wet-dry) on finisher pig performance. In Exp. 3, pigs fed pelleted diets or via a wet-dry feeder had greater ($P < 0.07$ and 0.01, respectively) ADG then those fed meal diets or with a dry feeder. Diet × feeder interactions ($P < 0.02$) were observed for G:F. When pelleted diets were presented in dry feeders, G:F decreased, while no difference in G:F was observed between meal and pelleted diets presented in wet-dry feeders. In Exp. 4, pigs fed with wet-dry feeders had increased ($P < 0.02$) ADG and ADFI compared to those with dry feeders, while pigs presented pelleted diets had improved ($P = 0.05$) G:F compared to those presented meal diets.

Experiments 5 to 9 were conducted to determine the effects of porcine intestinal mucosa products, PEP2+, Peptone 50, and PEP-NS, on the growth performance of nursery pigs. In Exp. 5, pigs fed increasing PEP2 had increased (quadratic; $P < 0.02$) overall ADG, ADFI, and G:F with the greatest response observed at 4% PEP2. In Exp. 6, pigs fed PEP2 had improved ($P < 0.03$) G:F compared to pigs fed select menhaden fish meal (SMFM) and increasing PEP2

improved (quadratic; $P < 0.04$) G:F with the greatest improvement seen when diets contained 4% PEP2. In Exp. 7 pigs fed PEP2+, Peptone 50 and PEP-NS had increased ($P < 0.05$) ADG and ADFI compared to pigs fed a negative control diet. In Exp. 8, pigs fed diets containing 6% SMFM, PEP2+, or PEP-NS had improved ($P < 0.05$) ADG and ADFI compared to pigs fed the negative control or 6% Peptone 50. In Exp. 9, pigs fed increasing PEP-NS had improved (quadratic; $P < 0.01$) ADG and G:F, with the greatest improvement observed in pigs fed 6% PEP-NS.

Experiment 10 evaluated the effects of Liquitein and PCV2/*M. hyo* vaccine regimen on the growth performance of weanling pigs. Overall, there were no effects of Liquitein on growth performance and vaccinated pigs had decreased ($P < 0.01$) ADG and ADFI compared to non-vaccinated pigs.

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CHAPTER 1: Effects of Feeder Adjustment and Trough Space on Growth Performance of Finishing Pigs

ABSTRACT

Two studies were conducted to determine the effects of feeder adjustment and trough space on growth performance of finishing pigs. In Exp. 1, 234 pigs (initial BW 41.5 kg) were used in an 89-d trial. Pigs were randomly alloted to 1 of 3 treatments with 9 replications of 8 pigs/pen and 1 replicate with 6 pigs/pen. Treatments consisted of a minimum feeder gap setting of 1.27, 1.91, or 2.54 cm. Feeders were adjusted to a minimum gap setting, but the agitation plate could be moved upward to a maximum opening of 1.91, 2.54, or 3.18 cm, respectively. Feeder adjustments of 1.27, 1.91, and 2.54 cm averaged 28, 58, and 75% pan coverage, respectively. From d 0 to 58, increasing feeder gap improved (linear; $P \leq 0.04$) ADG and ADFI, but decreased (linear; $P < 0.05$) G:F. Although the response was linear for ADG, there was no increase (quadratic; $P = 0.15$) beyond the 1.91 cm feeder gap setting. From d 58 to 89, increasing feeder gap setting tended (linear; $P = 0.08$) to worsen G:F. Overall (d 0 to 89), pigs fed with increasing feeder gap had decreased (linear; $P < 0.03$) G:F due to increased (linear; $P < 0.02$) ADFI. In Exp. 2, 288 pigs (initial BW 41.3 kg) were used in a 91-d study to evaluate the effects of feeder trough space (4.45 vs. 8.9 cm/pig) and minimum feeder gap opening of 1.27 cm (narrow), vs. 2.54 cm (wide). The treatments were arranged in a 2 × 2 factorial with 6 replications per treatment. Feeder trough space was altered by having pens of either 8 to 16 pigs per pen with all pigs provided 0.74 m^2 floor space per pig. From d 0 to 56 and 56 to 91, no adjustment × space interactions or effects of trough space were observed. From d 0 to 56, pigs with the wide feeder gap setting had decreased ($P < 0.02$) G:F compared to those with the narrow feeder gap setting. From d 56 to 91, pigs with the wider feeder gap setting had increased ($P < 0.001$) ADFI but consequently had decreased ($P < 0.001$) G:F. Overall (d 0 to 91), there were no trough space × feeder adjustment interactions observed. However, there was a tendency ($P = 0.08$) for increased ADG as feeder trough space

increased from 4.45 to 8.9 cm/pig. Pigs fed with the wide feeder gap setting had increased ($P < 0.001$) feed disappearance and decreased ($P < 0.002$) G:F compared to pigs with the narrow feeder gap setting. These data indicate that pigs from 41 to 68 kg need approximately 58% pan coverage while pigs greater than 68 kg, should have approximately 28% pan coverage to optimize growth and reduce feed wastage.

Key words: adjustment, feeder, pig, space,

INTRODUCTION

Continued improvements in swine genetics and nutrition have positively affected pig performance in the finishing stage of growth. However, to capitalize on these advancements, feed must be effectively delivered to the pig. Inefficiencies in feed delivery may result in feed wastage of up to 30% (Baxter, 1986). It has been hypothesized that too little feeder space or too narrow feeder adjustment could limit feed intake and consequently decrease performance. Gonyou and Lou (2000) found that as feed accessibility gets more difficult, pigs tend to spend more time at the feeder and therefore, fewer pigs are able to obtain sufficient amounts of feed. Conversely, too much feeder space or too wide a feeder gap could increase feed wastage and decrease efficiency.

Lindemann et al. (1987) noted that nursery pigs have a minimum feeder space requirement; below that requirement decreased feed intake and consequently decreased daily gain are observed. However, when above the minimum requirement, no advantages in daily gain were observed. Despite these observations, exact feeder space recommendations cannot be easily determined.

Duttlinger et al. (2009) showed that feeder adjustment could be an effective method in improving feed efficiency. Where a feeder gap opening of 2.95 cm (approximately 50% feeder

pan coverage) was optimum for both ADG and G:F. Liptrap et al. (1985) found that a feeder adjustment of 1.9 cm reduced pig growth. However, as feeder adjustment increased from 1.9 to 4.4 cm, ADG increased while G:F remained constant indicating that as feeder adjustment increased, so did ADFI.

Numerous studies have evaluated the effects of feeder adjustment and feeder space separately. However, there has been a large variation in performance across studies that could be attributed to differences in diet form, feeder design, and BW range of pigs evaluated (Gonyou and Lou, 2000). Thus, it becomes difficult to define and standardize the optimal feeder adjustment and feeder space required for 40 to 120 kg pigs. Therefore, the objective of these studies was to evaluate the effects of feeder adjustment and feeder space on the growth performance and carcass traits of finishing pigs.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

General

Both studies were conducted at the Kansas State University Swine Teaching and Research Center finishing facility in Manhattan. The facility is a totally enclosed, environmentally controlled, mechanically ventilated barn. The barn has 2 identical rooms (26.8 × 23.2 m) with 40, 2.4 × 3.1 m pens. The pens are equipped with adjustable gating to allow different space allowances per pig. Each pen was equipped with a dry single sided feeder (Farmweld,Teutopolis, IL) with 2, 35.4 cm × 11.43 cm (length × width) feeder spaces and 1-cup waterer to allow ad libitum access to feed and water. Pens were located over a completely slatted concrete floor with a 1.2 m deep pit underneath for manure storage. The facility utilized a

computerized feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) that both recorded and delivered diets to pens as specified.

Experiment 1

A total of 234 growing pigs (Line TR4 × 1050, PIC, Hendersonville, TN) with an initial BW of 41.5 kg were used in an 89-d study. Pigs were randomly allotted to 1 of 3 experimental treatments. There were 9 pens per treatment with 8 pigs per pen and 1 replicate with 6 pigs per pen.

The treatments consisted of a narrow feeder adjustment (minimum gap opening of 1.27 cm), medium feeder adjustment (minimum gap opening of 1.91 cm), and wide feeder adjustment (minimum gap opening of 2.54 cm). The feeders were adjusted to the minimum feeder gap setting by tightening down the feeder plates onto a wooden block cut to the respective gap setting. However, the agitation plate could be moved upwards by pigs to a maximum gap opening of 1.91, 2.54 or 3.18 cm, respectively. Feeder settings were left at their respective settings for the duration of the trial. To ensure equal floor space among replicates of 6 or 8 pigs per pen, the movable gating was adjusted to provide 0.74 m^2 floor space per pig at the start of the study. No adjustments in floor space were made if a pig was removed for health reasons.

Pigs were fed a common corn-soybean meal based diet containing 20% dried distillers grains with solubles (Table 1) in four phases (42 to 70 kg, 70 to 100 kg, 100 to 122 kg, and 122 to 129 kg, respectively) in meal form. The diet was formulated to meet or exceed NRC (1998) requirement estimates for 20- to 120-kg pigs.

Average daily gain, ADFI, and G:F were determined by weighing pigs and measuring feed disappearance on d 0, 14, 28, 42, 58, 70, 84, and 89. A digital photo of each feeder pan was taken once during each phase. The feeder pan pictures were then individually scored by 4 trained

panelists for percentage of pan coverage. Pan coverage was determined by evaluating each feeding space for percentage of pan covered by feed, values were then averaged for total pan coverage.

On d 81, pigs were weighed and transported (approximately 3 h) to a commercial processing plant (Triumph Foods Inc., St. Joseph, MO). Each pig was individually tattooed in respect to pen number to allow for data retrieval by pen and data collection at the packing plant. Hot carcass weights were taken immediately following evisceration and each carcass was evaluated for backfat and loin depth. Percentage yield was calculated by dividing HCW by live weight obtained at the far before to transport to packing plant. Fat depth and loin depth were measured with an optical probe inserted between the 3rd and 4th last rib (counting from the ham end of the carcass) at a distance approximately 7.1 cm from the dorsal midline. Fat free lean index was calculated using National Pork Producers Council (2000) procedures.

Experiment 2

A total of 288 growing pigs (Line TR4 × 1050, PIC) with an initial BW of 37.2 kg were used in a 91-d growth study. Pigs were randomly allotted to 1 of 4 treatments with either 8 or 16 pigs per pen and 6 pens per treatment.

Treatments were arranged in a 2 × 2 factorial with main effects of feeder space (4.5 vs. 8.9 cm) and feeder gap setting (1.27 cm; narrow or 2.54 cm; wide). The feeders were adjusted to the minimum feeder gap setting by tightening down the feeder plates onto a wooden block cut to the respective gap setting. However, the agitation plate could be moved upwards to a maximum gap opening of 1.91 or 3.18 cm, respectively. Similar to Exp.1, feeder settings were left at their respective settings for the duration of the study. To attain the feeder trough space treatments of 4.5 or 8.9 cm the number of pigs per pen was varied by having either 8 or 16 pigs per pen. For

the 8.9 cm of feeder trough space per pig, pens were stocked with 8 pigs per pen. To achieve the 4.5 cm of feeder space per pig, 2 pens were combined with only 1 feeder for 16 pigs. To ensure equal floor space among pens of 8 and 16, the gating was adjusted at the start of the trial to provide 0.74 m^2/pig.

Pigs were fed corn-soybean meal-based diets containing 20% dried distillers grains with solubles (Table 1) in four phases (37 to 66 kg, 66 to 95 kg, 95 to 124 kg, and 124 to 130 kg, respectively) in meal form. The diet was formulated to meet or exceed NRC (1998) requirement estimates for 20 to 120 kg pigs.

Similar to Exp. 1, feeder and pigs were weighed on d 0, 14, 28, 42, 56, 70, 84, and 91 to determine response criteria of ADG, ADFI, and G:F. In addition, a digital photo of each feeder pan was taken once per dietary phase. As in Exp. 1, the feeder pan pictures were then scored by a trained panel of 4 for percentage of pan coverage.

Statistical Analysis

Data were analyzed as a completely randomized design with repeated measures over time using the PROC MIXED procedure of SAS (SAS Inst., Inc. Cary, NC), and pen as the experimental unit. In Exp. 1, linear and quadratic polynomial contrasts were used to determine the effects of increasing feeder gap adjustment. Repeated measures analysis over time period consisted of 2 time periods from d 0 to 58 and d 58 to 89 representing the grower and finisher periods, respectively. In Exp. 2 treatments were arranged in a 2 × 2 factorial and data were analyzed with repeated measures over time. Repeated measures analysis was conducted across 2 time periods from d 0 to 56 and d 56 to 91, which again represented the grower and finisher phases. Differences among treatments were considered significant with P-values ≤ 0.05 and trends if *P*-values > 0.05 and ≤ 0.10.

RESULTS

Experiment 1

There were no period × treatment interactions observed for growth or carcass traits in this experiment (d 0 to 58 and 58 to 89). From d 0 to 58, increasing feeder gap increased (linear; $P \leq 0.04$) ADG and ADFI, with maximum ADG observed at a feeder gap of 1.91 cm (Table 2). However, G:F was reduced (linear; $P \leq 0.05$) as feeder gap increased. As feeder gap increased there was an increase (linear; $P \leq 0.001$) in feeder pan coverage.

From d 58 to 89, increasing feeder gap did not affect ADG or ADFI: however, there was a tendency for poorer (linear; $P = 0.08$) G:F as feeder gap increased. As feeder gap increased there was an increase (linear; $P \leq 0.001$) in feeder pan coverage.

Overall (d 0 to 89), increasing feeder gap had no effect on ADG but increased (linear; $P < 0.02$) ADFI, which resulted in poorer (linear; $P < 0.03$) G:F. There was an increase ($P < 0.02$) in the feeder pan coverage as feeder gap increased, with the 1.91, 2.54 and 3.18 cm feeder adjustments averaging for the entire trial approximately 28, 58, and 75% pan coverage, respectively (Figures 1, 2, and 3). There were no differences for any of the carcass criteria evaluated among pigs fed any of the different feeder gap settings evaluated.

Experiment 2

There were no feeder adjustment × trough space interactions observed for any of the growth criteria evaluated (d 0 to 56, 56 to 91, and 0 to 91; Table 3). From d 0 to 56, pigs fed with the wide feeder adjustment (2.54 cm) had increased ($P < 0.003$) ADFI, which resulted in a poorer ($P < 0.02$) G:F. There were no differences in growth between pigs fed with either 4.5 or 8.9 cm of feeder trough space. Feeders set to the wide feeder adjustment had greater ($P < 0.001$) feeder pan coverage compared to those set with the narrow feeder adjustment.

From d 56 to 91, pigs fed with the wide feeder-gap setting (2.54 cm) had increased ($P < 0.001$) ADFI and poorer ($P < 0.001$) G:F. There was a tendency ($P = 0.10$) for pigs with 8.9 cm trough space to have increased ADG compared to those with 4.5 cm trough space. Feeders set to the wide feeder adjustment had greater ($P < 0.001$) feeder pan coverage compared to feeders set to the narrow feeder adjustment.

Overall (d 0 to 91), pigs fed with the wide feeder-gap setting had increased ($P < 0.001$) feed disappearance and poorer ($P < 0.002$) G:F compared to pigs with the narrow feeder-gap setting. There was a tendency ($P = 0.08$) for increased ADG as feeder trough space increased from 4.5 to 8.9 cm/pig.

An adjustment × period interaction ($P \leq 0.05$) was observed for ADFI, the interaction is due to a magnitude effect where pigs with the wide feeder gap had an even greater ADFI during the second period (d 56 to 91) when compared to the first period (d 0 to 56).

There was no feeder adjustment × trough space interaction for percentage feeder pan coverage. However, pigs with wide feeder gap setting had increased ($P < 0.001$) feeder pan coverage compared to those with narrow feeder adjustment. Results of the feeder pan coverage evaluations indicated narrow adjusted feeders averaged approximately 48% coverage (Figure 4) and wide adjusted feeders averaged approximately 85% coverage (Figure 5).

DISCUSSION

Maintaining proper feeder adjustments has been shown to be an effective method in decreasing feed wastage and subsequently improving feed efficiency. Both of the current studies assessed feeder adjustments and the findings agree with previous research (Liptrap et al.1985; Smith et al. 2004; and Duttlinger et al. 2009) where ADFI increased as feeder gap increased.

While not significant, Duttlinger et al. (2009), observed a numerical decrease in G:F as feeder adjustment increased from 2.20 to 3.60 cm. These findings agree with those in the present studies where pigs with 1.27 cm feeder gap had improved G:F compared to those with 1.91 or 2.54 cm feeder gap.

Additionally, the present studies showed that as finishing pigs approach market weight, feeder gap should be decreased in order to reduce feed wastage. Gonyou et al. (1998) observed that young pigs (25 kg) ate slowly and thus spent more time at the feeder compared with older pigs. Smith et al. (2004) observed that as feed becomes more difficult to access, pigs compensate by spending more time at the feeder and consequently the number of pigs able to obtain sufficient amount of feed decreases. Combining the observations of Gonyou et al. (1998), Smith et al. (2004) and the present studies, this supports the idea that smaller pigs need a larger feeder gap to help accommodate their slower eating speeds and ensure that all pigs attain an adequate amount of feed for optimum performance. In an effort to reduce feed wastage and improve feed efficiency, feeders should be adjusted accordingly as pigs move from placement (25 kg) to market weight.

Evaluating a subjective measure of percentage of the feeder pan covered is a common management practice to minimize feed wastage in commercial production. The present studies have attempted to evaluate the subjective measure in a quantitative manner by photographing each feeder at different time points and having multiple evaluators score pan coverage. Our results agree with those of Smith et al. (2004) and Duttlinger et al. (2008) that as feeder gap increases, there is a concomitant increase in the percentage of feeder pan covered by feed. Our studies found that when pigs are 37 to 70 kg the ideal feeder pan coverage is about 60%, and as the pigs grow from 70 to 130 kg, the ideal feeder pan coverage decreases to about 30%. These

findings coincide with those of Smith et al. (2004) who evaluated feeder adjustment in weanling pigs (7 to 30 kg) and found that both growth and feed efficiency was optimized when about 40 to 70% of the feeder pan was covered. Whereas, Duttlinger et al. (2009) reported that about 50% of the feeder pan should be covered without feed accumulating in the corners of the feed pan for pigs 59 to 115 kg.

Studies have evaluated the ideal number of pigs per feeder space but there is limited research on the actual feeder space dimensions required by the pig (Kornegay and Notter, 1984; and Gonyou and Lou, 2000). This led to the second experiment where feeder trough space was evaluated alongside feeder adjustment. In an effort to mimic how feeder space would be adjusted for in commercial operations, the number of pigs per pen was varied (8 or 16 pigs/pen). Even though number of pigs per pen was varied, floor space (0.74 m^2) remained constant across treatments, which was necessary to prevent further confounding of variables. Research conducted by Kornegay and Notter (1984) found that as the number of pigs/pen was altered, the main driver of changes in growth performance was floor space. Gonyou and Lou (2000) found that as many as 12 pigs could be accommodated with a single feeding space. In Exp. 2, there were 16 (4.5 cm) or 8 pigs (8.9 cm) per feeding space, and a tendency ($P = 0.08$) for increased ADG was observed as feeder trough space increased from 4.45 to 8.9 cm/pig. Gonyou et al. (1998) reported that larger pigs could afford to be more crowded when it comes to feeder space due to their increased eating speed. Whereas smaller pigs eat slower and subsequently spend more time at the feeder, which merits fewer pigs per feeding space.

Both Australia (Farran, 1990) and the EU (English et al., 1988) have specific guidelines regarding recommended trough space per pig. Australia recommends about 6.25 cm/pig trough space and the EU recommends 5.9 cm/pig. Australia's and the EU's recommendations indicate

that perhaps feeder trough space was not restricted enough in Exp. 2. Interestingly enough, for the overall study (d 0 to 91), pigs with 8.9 cm of trough space had a tendency for increased ADG. This could be explained by the fact that the pigs averaged 130 kg at the time of marketing and due to their size, feeder space could have became a limiting factor.

Our findings indicate that pigs from 37 to 70 kg need a larger feeder gap, or about 60% feeder pan coverage to maximize ADG, but from 70 to 130 kg, feeder gap needs to be decreased, or about 30% feeder pan coverage, in order to reduce feed wastage while optimizing growth. Utilizing feeder pan coverage as an indicator for proper feeder adjustment may be a practical method that can be standardized across a wide range of commercially available feeder types.

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Table 1. Composition of diets, (Exp. 1 and 2, as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3	Phase 4
Ingredient, %				
Corn	63.23	67.42	70.42	72.40
Soybean meal (46.5% CP)	14.39	10.38	7.57	5.72
Dried distillers grains with solubles	20.00	20.00	20.00	20.00
Limestone	1.25	1.20	1.13	1.07
Salt	0.35	0.35	0.35	0.35
Vitamin premix[2]	0.15	0.13	0.10	0.08
Trace mineral premix[3]	0.15	0.13	0.10	0.08
L-lys HCl	0.34	0.30	0.27	0.26
Phytase 600[4]	0.14	0.09	0.06	0.04
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestible amino acids, %				
Lys	0.88	0.75	0.66	0.60
Ile:lys	66	69	71	73
Met:lys	31	34	37	39
Met & Cys:lys	34	70	75	80
Thr:lys	60	64	67	69
Trp: lys	16.5	16.5	16.5	16.6
Val:lys	80	85	90	94
Total lys, %	1.02	0.88	0.78	0.72
CP, %	17.8	16.3	15.2	14.5
ME, kcal/kg	3,349	3,353	3,360	3,364
Ca, %	0.55	0.52	0.48	0.46
P, %	0.42	0.40	0.39	0.38
Available P, %	0.28	0.25	0.23	0.21

[1] Each dietary phase was fed for approximately 24 d.

[2] Provided per kg of premix: 4,409,200 IU vitamin A; 551,150 IU vitamin D_3; 17,637 IU vitamin E; 1,764 mg vitamin K; 3,307 mg riboflavin; 11,023 mg pantothenic acid; 19,841 mg niacin; and 15.4 mg vitamin B_{12}.

[3] Provided per kg of premix: 26.5 g Mn from manganese oxide, 110 g Fe from iron sulfate, 110 g Zn from zinc sulphate, 11 g Cu from copper sulfate, 198 mg I from calcium iodate, and 198 mg Se from sodium selenite.

[4] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 509 FTU/kg premix.

Table 2. Effects of feeder gap setting (adjustment) on finishing pig performance, Exp. 1[1]

	Feeder gap, cm				*P*-value	
Item	1.27	1.91	2.54	SEM	Linear	Quadratic
d 0 to 58						
ADG, kg	0.97	1.03	1.02	0.018	0.04	0.15
ADFI, kg	2.65	2.92	2.92	0.064	0.005	0.09
G:F	0.365	0.351	0.351	0.005	0.05	0.26
Feeder coverage score, %	29.9	61.3	71.9	6.35	0.001	0.19
d 58 to 89						
ADG, kg	0.68	0.66	0.68	0.018	0.89	0.41
ADFI, kg	2.37	2.42	2.47	0.064	0.26	0.97
G:F	0.289	0.275	0.276	0.005	0.08	0.22
Feeder coverage score, %	26.6	36.7	76.6	6.35	0.001	0.52
d 0 to 89						
ADG, kg	0.83	0.85	0.85	0.013	0.18	0.66
ADFI, kg	2.51	2.67	2.70	0.054	0.02	0.32
G:F	0.327	0.313	0.314	0.004	0.03	0.16
Feeder coverage score, %	27.7	58.2	75.0	7.56	0.001	0.28
Carcass measurements						
Live weight, kg	126.8	128.4	129.4	1.92	0.35	0.92
HCW, kg	93.7	95.7	95.5	1.36	0.37	0.59
Carcass yield, %	73.9	74.5	73.8	0.34	0.81	0.18
FFLI[3]	48.5	48.7	48.9	0.23	0.19	0.96
Back fat depth[4], mm	27.1	26.7	26.0	0.65	0.25	0.89
Loin depth, cm	6.21	6.11	6.26	0.07	0.61	0.17

[1] A total of 234 pigs (PIC TR4 ×1050, initially 41.5 kg) were used in an 89-d study to evaluate the effects of feeder adjustment on finisher pig growth performance. There were 8 pigs per pen and 9 pens per treatment. There was 1 pen per treatment with 6 pigs per pen.

[2] Pictures of feeder pan coverage were taken once during each dietary phase. A panel of 4 scored feeder pan pictures for percentage of pan coverage.

[3] Fat free lean index (FFLI; National Pork Producers Council, 2000).

[4]Backfat depth, and loin depth were adjusted to a common HCW.

Table 3. Effects of trough space and feeder-gap setting (narrow vs. wide) on finishing pig performance, Exp. 2[1]

	Trough space/pig, cm					Probability, P <		
	4.5 cm		8.9 cm					
Item Feeder-gap:[2]	Narrow	Wide	Narrow	Wide	SEM	Adjustment × space	Adjustment	Trough space
d 0 to 56								
ADG, kg	1.01	1.03	1.03	1.05	0.013	0.92	0.18	0.24
ADFI, kg	2.72	2.85	2.76	2.92	0.042	0.80	0.003	0.22
G:F	0.372	0.360	0.371	0.358	0.006	0.89	0.02	0.78
Feeder coverage score[3], %	37.5	77.9	41.5	82.1	5.11	0.98	0.001	0.43
d 56 to 91								
ADG, kg	0.98	0.99	1.02	1.00	0.016	0.33	0.82	0.10
ADFI, kg	3.44	3.66	3.49	3.74	0.050	0.74	0.001	0.20
G:F	0.284	0.270	0.291	0.267	0.004	0.33	0.001	0.66
Feeder coverage score[3], %	48.4	88.6	66.7	90.8	5.11	0.13	0.001	0.05
d 0 to 91								
ADG, kg	0.99	1.01	1.02	1.03	0.011	0.57	0.46	0.08
ADFI[a], kg	2.99	3.16	3.03	3.23	0.041	0.75	0.001	0.17
G:F	0.337	0.319	0.334	0.321	0.004	0.51	0.002	0.93
Average feeder coverage score[3], %	42.9	83.3	54.1	86.5	3.76	0.38	0.001	0.12

[a] Adjustment × period interactions ($P < 0.05$).

[1] A total of 228 pigs (PIC TR4 × 1050, initially 37.2 kg) were used, with either 8 (8.9 cm/pig) or 16 (4.5 cm/pig) pigs per pen with 6 replications per treatment.

[2] Narrow = 1.27 cm minimum gap opening. Wide = 2.54 cm minimum gap opening.

[3] Pictures of feeder pan coverage were taken once during each dietary phase. A panel of 4 then scored feeder pan pictures for percentage of pan coverage.

Figure 1. Narrow feeder adjustment (minimum feeder gap was 1.27 cm with a maximum gap of 1.91 cm) averaged 27% feeder pan coverage, Exp. 1.

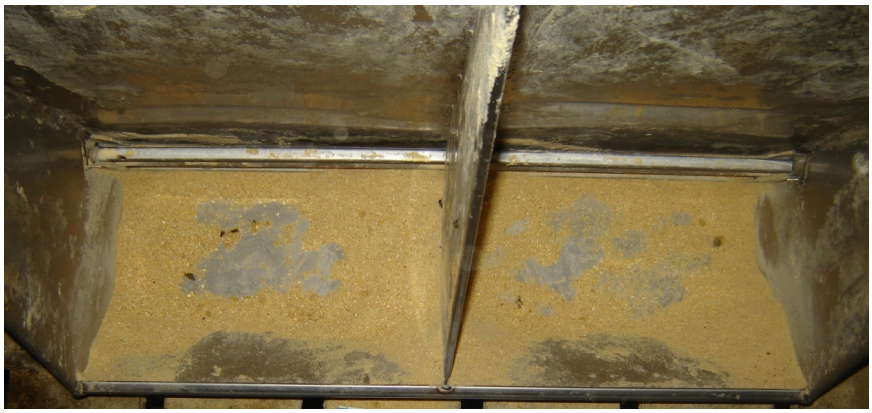

Figure 2. Medium feeder adjustment (minimum feeder gap was 1.91 cm with a maximum gap of 2.54 cm) averaged 58% feeder pan coverage, Exp. 1.

Figure 3. Wide feeder adjustment (minimum feeder gap was 2.54 cm with a maximum gap of 3.81 cm) averaged 75% feeder pan coverage, Exp. 1.

Figure 4. Narrow feeder adjustment (minimum feeder-gap opening was 1.27 cm with a maximum gap of 1.91 cm) averaged 45% feeder pan coverage, Exp. 2.

Figure 5. Wide feeder adjustment (minimum feeder-gap opening was 2.54 cm with a maximum gap of 3.81 cm) averaged 83% feeder pan coverage, Exp. 2.

CHAPTER 2: Effects of Diet Form and Feeder Design on Growth Performance of Finishing Pigs

ABSTRACT

Two studies were conducted to determine the effects of diet form (meal vs. pellet) and feeder design (conventional dry vs. wet-dry) on finisher pig performance. Experiments were arranged as 2 × 2 factorials with 11 replications per treatment and 25 to 27 pigs per pen. In Exp. 1, 1,290 pigs (initial BW 46.8 kg) were used in a 91-d trial. Pelleted diets averaged approximately 35% fines throughout the study. Overall, pigs fed pelleted diets or via wet-dry feeders had greater ($P < 0.07$ and 0.001, respectively) ADG than those fed meal diets or with a dry feeder. Diet form × feeder interactions ($P < 0.02$) were observed for G:F and feeder pan coverage. Pigs fed both meal and pelleted diets via a wet-dry feeder had similar G:F, but pigs fed pelleted diets in dry feeders had poorer G:F than pigs with meal diets in dry feeders. For pan coverage, dry feeders had greater feeder pan coverage with pelleted diets as compared to meal diets or compared to a wet-dry feeder. In Exp. 2, 1,146 pigs (initial BW 38.2 kg) were used in a 104-d study. From d 0 to 28, a diet form × feeder design interaction was observed ($P < 0.01$) for ADG which was due to pigs fed pelleted diets from a conventional dry feeder having decreased ADG compared to pigs fed meal diets from the same feeder type while there was no difference in wet-dry feeders based on diet form. In addition, pigs fed pelleted diets had poorer ($P < 0.01$) G:F compared to those fed meal diets. This appeared to be due to poor pellet quality (39.6% fines). From d 42 to 86, pellet quality improved (4.4% fines), and a diet form × feeder interaction was observed for ADG, where pigs presented meal diets in a dry feeder had lower ($P < 0.05$) ADG compared pigs presented pelleted diets in dry feeders of pigs presented either diet in wet-dry feeders. Pigs presented pelleted diets had improved ($P < 0.001$) G:F. Pigs fed via wet-dry feeders had increased ($P < 0.03$) ADFI and G:F

compared to pigs with dry feeders. Overall, pigs fed with wet-dry feeders had increased ($P < 0.02$) ADG and ADFI, and poorer G:F compared to those with dry feeders, while pigs presented pelleted diets had improved ($P = 0.05$) G:F compared to those presented meal diets. Pelleted diets and wet-dry feeders had increased ($P < 0.01$) feeder pan coverage. These studies found, regardless of diet form, that pigs fed from wet-dry feeders had increased ADG and ADFI compared to pigs fed via dry feeders. Additionally, pellet quality appeared to influence responses as pigs provided higher quality pellets via dry feeders had increased growth performance compared to pigs fed meal diets. Conversely, if pellet quality was poor, feed efficiency benefits associated with pelleting were lost.
Key Words:, feeder, finishing pig, growth, pelleting

INTRODUCTION

Feed represents a significant portion of production cost during the finishing phase of growth. Thus, producers are constantly evaluating ways to improve growth performance and lower feed cost. Pelleting diets has been shown to be an effective feed processing method to improve feed efficiency in nursery and finishing pigs (Stark et al., 1993; Wondra et al., 1995). Wondra et al. (1995) observed that typically there is a 4 to 6% increase in G:F when pigs are presented pelleted diets via conventional dry feeders. However, Stark et al. (1993) observed that pellet quality influences the response, when pigs were presented pelleted diets containing 30% fines, they had decreased G:F compared to pigs fed a high quality pellet (no fines).

Limited research has demonstrated that type of feeder used may influence the response to pelleting as well. Amornthewaphat et al. (2000) found that feeding pelleted

diets via a wet-dry feeder had little impact on growth performance in the finisher phase compared with pigs fed with a dry feeder. However, they found that pigs fed pelleted diets via dry feeders tended to have improved ADG and G:F. Bergstrom et al. (2008) reported that pigs presented meal diets via wet-dry feeders have increased ADG and ADFI than pigs fed with conventional dry feeders. Thus, perhaps there might be an interaction between feeder type and diet form. Where feeding pelleted diets via a conventional dry feeder might result in a proportionately greater improvement in ADG and G:F than if fed in a wet-dry feeder. Therefore, the objective of the study was to evaluate the effects of diet form (meal vs. pellet) and feeder design (conventional dry vs. wet-dry) on finishing pig performance.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

General

Both studies were conducted at a commercial swine research finishing facility in southwestern Minnesota. The facility was a naturally ventilated double curtain sided barn (12.5 × 76.2 m) with pit fans for minimum ventilation. The facility contained 48, 3.05 × 5.5 m pens with approximately 0.69 m^2 provided per pig. Pens were located over a completely slatted concrete floor with a deep pit for manure storage. One half of the pens were equipped with a conventional 5-hole dry feeder (STACO, Shafferstown, PA) with a feed pan dimension of 152.4 × 17.8 × 14.6 cm (length × width × height). The other half of the pens contained a double sided wet-dry feeder that provided both feed and water via a 38.1 cm wide feeder opening on either side of the feeder (Crystal Springs, Gro Master,

Omaha, NE). All pens contained cup waterers. However, pens which contained wet-dry feeders had their cup waterers shut off for the duration of the trials. Thus, the only source of water was the nipple water located under a food shelf located over the center of the feed pan inside each of the wet-dry feeders. Pigs were provided ad libitum access to feed and water for the duration of both studies. The facility utilized a computerized feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) that both recorded and delivered diets to pens as specified. Both Exp. 1 and 2 were conducted in the same barn at the research farm. Experiment 1 was conducted from April to July 2010 and Exp. 2 was conducted from August to November 2010.

Experiment 1

A total of 1,290 growing pigs (1050 × 337, PIC, Hendersonville, TN) with an initial BW of 46.8 kg were used in a 91 d study. Pigs were randomly allotted to 1 of 4 experimental treatments based on average initial BW and number of pigs per pen. There were 25 to 27 pigs per pen and 11 pens per treatment. The number of barrows and gilts within each pen were the same across all treatments.

Treatments were arranged in a 2 × 2 factorial with the main effects of diet form (meal vs. pellet) and feeder design (conventional dry vs. wet-dry). All the wet dry feeders were adjusted to provide a 2.54 cm gap width. Conventional dry feeders that contained meal diets were also adjusted to a minimum gap width of 2.54 cm, but conventional dry feeders with pelleted diets were adjusted to a 1.78 cm minimum gap width. All feeder settings were maintained for the duration of the study.

Pigs were fed a common diet containing 45 to 65% byproducts (dried distillers grains with solubles and bakery by-product: Table 1) in 5 dietary phases (47 to 59 kg, 59

to 84 kg, 84 to 97 kg, 97 to 109 kg, and 109 to 126, respectively). The final phase was fed from 109 to 126 kg and contained 5 mg/kg ractopamine HCl (Paylean, Elanco Inc., Greenfield, IN). The only difference between diets was diet form. At different periods throughout the study, a large batch of feed was manufactured at the New Horizon Farm feed mill (Pipestone, MN) then spilt into 2 smaller batches where half of the feed was transported to a commercial feed mill to be pelleted and the other half remained at the farm feed mill and was fed as the meal diet. Corn was ground to 550 microns using a hammer mill. Diets were pelleted at a nearby commercial feed mill with a 125 HP California Pellet Mill (Crawfordsville, IN) equipped with a micro mini 9.53 mm (hole diameter) × 41.28 mm (effective die thickness) pellet die. Feed was steam conditioned at 65.5° C for 15 s prior to pelleting. The diets were formulated to meet or exceed NRC (1998) requirement estimates for 20 to 120 kg pigs.

Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 16, 29, 43, 57, 71, and 91. On d 71, 3 pigs (2 barrows and 1 gilt) from each pen were weighed and then removed for marketing. At the conclusion of the trial (d 91), pigs were individually tattooed by pen and transported approximately 1 h to a commercial packing plant (JBS Swift and Company, Worthington, MN) where carcass data was obtained on 939 pigs to determine HCW, percentage carcass yield, back fat depth, and longissimus muscle depth, which was taken by placing an optical probe between the 3rd and 4th rib from the last rib at 7 cm from the dorsal midline. Fat free lean index was calculated using National Pork Producers Council (2000) procedures.

To determine pan coverage, a digital photo of each feeder pan was taken during

phase 4. The feeder pan pictures were then scored independently by a trained panel of 4 for percentage of pan coverage. In addition, feed samples were taken from the feeders during each phase and then analyzed for percentage fines and pellet durability index (PDI). Percentage fines were determined prior to testing pellets for durability. A number 6 screen (3.35 mm holes) was used to sift off the fines from a 500 g sample of pellets. The amount of fines was then weighed and percentage fines were calculated using the following formula: weight of fines/weight of sample × 100. After fines were sifted off, PDI was determined (ASAE S269.4). The sample of pellets were placed in a box and tumbled for 10 minutes. After 10 minutes, the samples were removed, sieved (No. 6 screen), and the percentage of whole pellets was calculated. Pellet durability index was then calculated using the following formula: wt of pellets after tumbling/wt of pellets prior to tumbling × 100.

Experiment 2

A total of 1,146 growing pigs (1050 × 337, PIC) with an initial BW of 38.2 kg were used in a 104-d growth study. Pigs were randomly allotted to 1 of 4 experimental treatments based on average initial BW and number of pigs per pen. There were 26 to 27 pigs per pen and 11 pens per treatment. The number of barrows and gilts were equalized across all treatments.

Similar to Exp. 1, treatments were arranged in a 2 × 2 factorial with the main effects of diet form (meal vs. pellet) and feeder design (conventional dry vs. wet-dry). All the wet-dry feeders were initially adjusted to 2.54 cm minimum gap width, while conventional dry feeders that contained meal diets were adjusted to a minimum gap width of 2.54 cm. Conventional dry feeders with pelleted diets were adjusted to 1.78 cm

minimum gap width. Unlike Exp. 1, these feeder settings were not maintained for the duration of the trial, feeders were adjusted as needed to ensure consistent feeder pan coverage of 40 to 60%.

Pigs were fed a common corn-soybean meal based diet containing 20% dried distillers' grains with solubles (DDGS) during the first 4 dietary phases (38 to 56 kg, 56 to 70 kg, 70 to 85 kg, and 85 to 115 kg, respectively) and 10% DDGS and 5 mg/kg ractopamine HCl in phase 5 (115 to 129 kg; Table 2). Similar to Exp. 1, throughout the trial, a large batch of feed was manufactured at the New Horizon Farm feed mill (Pipestone, MN) then spilt into 2 smaller batches where half of the feed was transported to a commercial feed mill to be pelleted and the other half remained at the farm feed mill and was fed as the meal diet. Corn was ground to 550 microns using a hammer mill. Diets were pelleted at the same commercial feed mill as used in Exp. 1 with the same pelleting conditions. The diet was formulated to meet or exceed NRC (1998) requirement estimates for 20 to 120 kg pigs.

Average daily gain, ADFI, and G:F were determined by weighing pigs and measuring feed disappearance on d 0, 14, 28, 42, 56, 70, 86 and 104. On d 86, 5 pigs (3 barrows and 2 gilts) from each pen were weighed and then removed for marketing. At the conclusion of the trial (d 104), pigs were individually tattooed by pen and transported 1 h to a commercial packing plant (JBS Swift and Company, Worthington, MN) where carcass data was obtained for 891 pigs. Carcass data measurements were collected using the same procedures as Exp. 1.

In Exp. 2, a digital photo of each feeder pan was taken on d 54, 78, and 104. Feeder pan pictures were then scored independently by a trained panel of 4 for percentage pan

coverage. In addition, feed samples were taken from the feeder once during each phase and then analyzed for percentage fines and PDI as described in Exp. 1.

Statistical Analysis

Treatments were arranged as a 2 × 2 factorial for both experiments and data was analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Pen was the experimental unit in both studies. When significant interactions ($P < 0.05$) were observed, LSD's were used to evaluate the means. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

RESULTS

Experiment 1

From d 0 to 43, no diet form × feeder design interactions were observed for the growth performance criteria evaluated. Pigs fed pelleted diets had improved ($P < 0.01$) ADG and ADFI compared to those presented meal diets. In addition, pigs fed with wet-dry feeders had increased ($P < 0.01$) ADG compared to those with conventional dry feeders. Pigs fed via wet-dry feeders had a tendency for increased ($P < 0.07$) ADFI compared to those fed via conventional dry feeders. There were no significant differences observed among any of the treatments for G:F. During this period, pelleted diets averaged 37.5 % fines and had a PDI of 74.2.

From d 43 to 71, pigs fed with wet-dry feeders had increased ($P < 0.001$) ADG compared to those with conventional dry feeders. A diet form × feeder design interaction was observed ($P < 0.001$) for ADFI which was due to pigs fed meal diets via a dry feeder

having decreased ADFI compared to pigs fed pellets in the same feeder while there was no change in ADFI in the wet-dry feeders based on diet form. A diet form × feeder design interaction was observed ($P < 0.01$) for G:F which was driven by pigs fed pelleted diets via dry feeders having poorer G:F compared to pigs fed meal diets in the same feeder while there was no difference in G:F in the wet-dry feeders based on diet form. During this period, pelleted diets averaged 30.6% fines and a PDI of 80.1.

From d 71 to 91, no diet form × feeder design interactions were observed for ADG or ADFI. Pigs fed with wet-dry feeders had a tendency for increased ADG ($P < 0.06$) and a significant increase in ADFI ($P < 0.001$) compared to those fed with conventional dry feeders. A diet form × feeder design interaction was observed ($P < 0.05$) for G:F which was primarily due to pigs presented meal diets in conventional dry feeders having improved G:F compared to pigs fed pelleted diets in the same feeder while there was no difference in G:F in the wet-dry feeders based on diet form. Pelleted diets averaged 36.6% fines and had a PDI of 74.0.

Overall (d 0 to 91), no diet form × feeder design interactions were observed for ADG. Pigs fed pelleted diets had a tendency for improved ($P < 0.07$) ADG compared to those presented meal diets. In addition, pigs with wet-dry feeders had increased ($P < 0.001$) ADG compared to those with conventional dry feeders. A diet form × feeder design interaction was observed ($P < 0.04$) for ADFI where pigs fed meal diets via dry feeders had lower ADFI to compared pigs fed pelleted diets from the same feeder while there was no difference in ADFI in the wet-dry feeders based on diet form. Additionally, a diet form × feeder design interaction was observed for G:F ($P < 0.01$) which was due to pigs fed both meal and pelleted diets via wet-dry feeders had similar G:F, but pigs fed

pelleted diets in a conventional dry feeder had poorer G:F than pigs presented meal diets in a conventional dry feeder. A diet form × feeder design interaction was observed for feeder coverage score ($P < 0.02$), where pigs fed both pelleted and meal diets in wet-dry feeders had similar feeder pan coverage, but pigs fed pelleted diets via dry feeders had increased feeder pan coverage compared to those fed meal diets from the same feeder type (Figures 1 to 4).

There were no diet form × feeder design interactions or effects of diet detected for any of the carcass criteria evaluated. Pigs fed with wet-dry feeders were heavier at d 104 ($P < 0.01$) and consequently had a tendency for increased ($P < 0.09$) HCW compared to those with conventional dry feeders. However, pigs fed with conventional dry feeders had less ($P < 0.01$) back fat depth compared to pigs with wet-dry feeders. This resulted in pigs fed with dry feeders having greater ($P < 0.01$) FFLI compared to those with wet-dry feeders. There were no significant differences observed between diet forms (meal vs. pellet) for any of the carcass criteria evaluated.

Experiment 2

From d 0 to 28, a diet form × feeder design interaction was observed ($P < 0.01$) for ADG which was due to pigs fed pelleted diets from a conventional dry feeder having decreased ADG compared to pigs fed meal diets from the same feeder type while there was no difference in wet-dry feeders based on diet form. A trend ($P < 0.06$) for a diet form × feeder design interaction was also observed for ADFI. In conventional dry feeders, pigs fed meal or pelleted diets had similar ADFI, which was less than pigs fed meal diets with a wet-dry feeder and less again as those fed pelleted diets in a wet-dry feeder. Despite the interaction, pigs fed with wet-dry feeders had increased ($P < 0.001$)

ADFI compared to those with conventional dry feeders. No diet form × feeder design interactions were observed for G:F. Pigs fed meal diets had improved ($P < 0.001$) G:F compared to those fed pelleted diets. Where pigs with conventional dry feeders had improved G:F compared to those with wet-dry feeders. Pelleted diets averaged 39.6% fines and had a PDI of 87.2.

From d 28 to 42, no diet form × feeder design interactions, or effects of diet form were detected for any of the growth performance criteria evaluated. However, there was a tendency ($P < 0.10$) for pigs with wet-dry feeders to have increased ADFI compared to those with dry feeders. Pelleted diets averaged 3.9 % fines and had a PDI of 89.8. No diet form × feeder design interactions were detected for feeder coverage score. However, pigs fed pelleted diets had increased ($P < 0.02$) feeder pan coverage compared to those with meal diets, where pigs with wet-dry had a tendency for increased ($P < 0.06$) feeder pan coverage compared to those with dry feeders.

From d 42 to 86, a diet form × feeder design interaction was observed ($P < 0.02$) for ADG where pigs fed meal diet from a conventional dry feeder had decreased ($P < 0.05$) ADG compared to pigs fed pelleted diets from the same feeder type while there was no difference in wet-dry feeders based on diet form. There was a tendency for pigs fed meal diets to have increased ($P < 0.08$) ADFI compared to those fed pelleted diets. In addition, pigs with wet-dry feeders had increased ($P < 0.001$) ADFI compared to those fed with conventional dry feeders. Pigs fed pelleted diets had increased ($P < 0.001$) G:F compared to pigs fed meal diets, while pigs with wet-dry feeders had reduced ($P < 0.03$) G:F compared to those with conventional dry feeders. Pelleted diets averaged 4.4% fines

and had a PDI of 93.5. No diet form × feeder design interactions were detected for feeder coverage score.

From d 86 to 104, no diet form × feeder design interactions or effects of feeder design were observed for any of the growth criteria evaluated. There was a tendency ($P < 0.09$) for pigs fed meal diets to have increased feed intake compared to those with pelleted diets. Pigs fed pelleted diets had improved ($P < 0.04$) G:F compared to pigs fed meal diets. Pelleted diets averaged 16.8% fines and had an average PDI of 93.8. There was a tendency for a diet form × feeder design interaction ($P < 0.07$) where pigs fed meal diets in conventional dry feeders had decreased feeder pan coverage compared to pigs fed pelleted diets from the same feeder type and both had less coverage as the meal or pelleted feed offered via the dry or wet-dry feeders. There no differences in feeder pan coverage observed in wet-dry feeders based on diet form.

Overall (d 0 to 104), no diet form × feeder design interactions were observed for any of the growth performance criteria evaluated. Pigs with wet-dry feeders had increased ($P < 0.01$) ADG and ADFI compared to those with dry feeders. Furthermore, pigs with wet-dry feeders had decreased ($P < 0.02$) G:F compared to those fed with dry feeders. In addition, pigs fed pelleted diets were not different for ADG but had improved ($P = 0.05$) G:F when compared to those fed meal diets.

No diet form × feeder design interactions were detected for feeder coverage score. Pigs fed pelleted diets had increased ($P < 0.01$) feeder pan coverage compared to those with meal diets, and pigs with wet-dry had increased ($P < 0.01$) feeder pan coverage compared to those with dry feeders (Figures 5 to 8).

There was no effect of diet form observed for any of the carcass criteria evaluated. Pigs fed with wet-dry feeders had heavier ($P < 0.01$) d 104 weights and subsequently had heavier ($P < 0.01$) HCW compared to those fed with conventional dry feeders. However, pigs fed with dry feeders had increased ($P < 0.03$) carcass yield compared to those fed with wet-dry feeders. There were tendencies ($P = 0.06$) for diet form × feeder type interactions observed for FFLI and backfat depth. For FFLI, pigs fed pelleted diets via a dry feeder had lower FFLI than those fed meal diets, but in wet-dry feeders the opposite effect was observed. For backfat depth, pigs fed pelleted diets in dry feeders had greater backfat than meal fed pigs, but the opposite was true for diets form offered in a wet-dry feeder. Despite the interactions, pigs fed with wet-dry feeders had decreased ($P < 0.01$) FFLI and increased ($P < 0.01$) back fat depth compared to those fed with conventional dry feeders.

DISCUSSION

Several studies have evaluated the effects of offering feed via a conventional dry feeder vs. a wet/dry feeder on the growth performance of finishing pigs. Gonyou and Lou (2000) found that pigs presented meal diets via wet/dry feeders had a 5% improvement in daily feed intake and gain. Bergstrom (2011) conducted several trials evaluating dry vs. wet-dry feeders at the same commercial facility as the present studies, and observed increases in ADG, ADFI, final BW, and HCW when pigs were fed meal diets via wet-dry feeders. Similar to the findings of Gonyou and Lou (2000) and Bergstrom (2011), the present studies observed that pigs fed via wet/dry feeders had about a 4% improvement in daily feed intake and gain. Payne (1991) observed an increase in feed intake and daily gain in 16 of 17 on-farm studies testing single space wet-dry feeders. Payne (1991)

attributed this increase in gain to the fact that pigs presented meal diets via wet-dry feeders consumed more feed and wasted less. Gonyou and Lou (2000) hypothesized that the increase in feed intake was due to an increase in eating speed, where pigs remained at the feeder for the same amount of time but consumed more feed during that meal. Bergstrom (2011) also observed that pigs fed via wet-dry feeders had less visits to the feeder with an increase in eating speed compared to those fed diets via dry feeders. Increased feed intake and gain in pigs presented diets via wet/dry feeders compared to dry feeders has been fairly constant across studies (Payne, 1991; Gonyou and Lou, 2000; Bergstrom, 2011). However, there has been some variation in regards to G:F. Some studies have found that pigs fed with wet/dry feeders have shown improvements in G:F (Amornthewaphat et al., 2000; Brumm et al., 2000; Gonyou and Lou, 2000) while other studies have indicated an actual decrease in G:F when wet/dry feeders were used (Patterson, 1991; Bergstrom, 2011).

Research has indicated that when pigs are presented pelleted diets in conventional dry feeders there is typically a 4 to 6% improvement in G:F (Wondra et al., 1995). Contrary to these findings, improvements in G:F were not consistently observed in pigs fed pelleted diets via dry feeders in these studies and actually worsened in most phases. One reason for this could be a result of the poor pellet quality (a high proportion of fines). Potter et al. (2009) stated that the majority of studies which observed improvements in feed efficiency when feeding pelleted diets have mainly been observed under university research settings where pellet quality might be expected to be better than under large-scale field conditions. Therefore, feeding pelleted diets under field conditions might not yield the same advantages in G:F due to poor pellet quality. The feeder management in

these studies could have also exacerbated the effects of poor pellet quality. In Exp. 1, the feeders were adjusted to their respective settings on d 0 and the settings were maintained for the duration of the study. This could have attributed to the accumulated fines seen in the feeder pans, increased feed disappearance, and consequently poor feed efficiency. In Exp. 2, feeder adjustments were set to an initial setting but then were adjusted throughout the study to maintain feeder pan coverage of 40 to 60%. However, due to variation in pellet quality and flowability among batches of feed, maintaining proper feeder adjustments proved to be rather difficult. Our hypothesis was that perhaps feeding pelleted diets via wet-dry feeders, where the pellets and fines alike could mix with water, could negate the effects of poorer quality pellets. When pigs were presented high quality pellets (< 5% fines), no differences among feeder types were observed. However, as pellet quality decreased (>30% fines), pigs fed pelleted diets in both feeder types (dry or wet-dry) had poorer G:F.

Interestingly, we did not find a consistent increase in ADG in our studies for pigs fed a pellet diet compared to a meal diet. However, previous research by Wondra et al. (1995) found that pigs fed pelleted diets had an increase in ADG of about 4 to 6%. Variation in pellet quality seen throughout both of the present studies could have been an attributing factor. Pigs presented pelleted diets in conventional dry feeders had substantially more feeder pan coverage compared to pigs fed meal diets in conventional dry feeders. The increased pan coverage in dry feeders could be due to increased sorting of the feed due to poorer quality pellets. The pelleted diets averaged 35.1% fines in Exp. 1 with a PDI of 75.8, where pellet quality was consistently poor for the duration of study. In Exp. 2, from d 0 to 28 when pelleted diets averaged 39.6% fines and PDI of 87.2,

ADG and G:F decreased in those pigs fed pelleted diets. However, from d 28 to 42 and 42 to 86 when pelleted diets averaged 3.9% and 4.4% fines and had and average PDI of 89.8 and 93.5, respectively, ADG and G:F improved. Even from d 86 to 104, when pelleted diets averaged 16.8% fines and 93.8 PDI the advantage of feeding pelleted diets was maintained, where pigs fed pelleted diets had improved G:F compared to those fed meal diets. Stark et al. (1993) found that as percentage fines increased from 0 to 40% in the diet, feed efficiency was negatively impacted. However, when feed was presented in the wet-dry feeders, pigs were unable to sort the pelleted diets due to the addition of water. Despite this fact, no advantages in growth performance were observed.

The diet formulation and feeder pan coverage may explain why pigs in Exp. 1 fed pelleted diets had poorer feed efficiency compared to those fed meal diets in the dry feeders. The high inclusion of by-products (40 to 65%) may have played a role in decreased pellet quality during this experiment. Wang et al. (2007) noted that as inclusion rate of DDGS increased from 0, 15, to 30%, the visual quality of pellets decreased. Stender and Honeyman (2008) found that as DDGS increased from 0, 20, to 40% in the diet, PDIs decreased from 78.9 to 66.8, and 47.4%, respectively. Potter et al. (2009) found that as the inclusion rate of by-products increased in finishing diets, percent fines increased from 25% in corn-soybean meal diet to 35% in the diet containing increased by-products. In the present studies, it was observed that when the percent fines exceeded 30% all G:F benefits of pelleted diets were negated.

Pellet mill throughput could have also been a contributing factor to the variation seen among different batches of pellets. Even though, in both studies, all pelleted diets passed through the same pellet mill, a wide variation among batches were observed. The

differences in pellet quality seen among batches could be attributed to mill throughput. Greenwood and Beyer (2003) stated that increasing pellet mill throughput could reduce the extent of heat transfer to the meal, as well as friction and shear occurring in the die. Thus, the extent of protein denaturation and starch gelatinization will be lessened and a decrease in particle binding will occur. Consequently, PDI will decrease and incidence of fines will increase. Pellet quality is influenced by multiple factors. However, in these studies diet formulation and potentially increased throughput played a large role in reducing pellet quality. Although pellet throughput was not recorded, anecdotal observations from the pellet mill operator suggest that throughput was negatively correlated with pellet quality.

In conclusion, these experiments support previous findings (Bergstrom, 2011) that feeding pigs via wet-dry feeders increased ADG and ADFI. These studies also indicated the impact of pellet quality on growth performance, where pigs provided higher quality pellets via dry feeders had increased growth performance compared to pigs fed meal diets. Conversely, if pellet quality was poor, feed efficiency benefits associated with pelleting were lost. More research needs to be done to evaluate the effects of by-product inclusion on pellet quality and its effect on the growth performance of finishing pigs.

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Table 1. Composition of diets, (as-fed basis), Exp. 1[1]

Item	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Ingredient, %					
Corn	33.32	22.15	21.11	27.72	28.18
Soybean meal, (46.5% CP)	16.70	12.10	9.05	9.20	13.60
Dried distillers grains with solubles	45.00	45.00	35.00	30.00	25.00
Bakery meal	---	15.00	30.00	30.00	30.00
Choice white grease	2.55	3.60	2.94	1.20	1.20
Limestone	1.30	1.25	1.07	1.04	0.99
Salt	0.38	0.14	0.20	0.20	0.20
VTM premix[2]	0.09	0.09	0.08	0.08	0.08
Liquid lys, 60%	---	---	0.54	0.54	0.59
Lys sulfate	0.64	0.65	---	---	---
L-thr	---	---	---	0.01	0.12
Phytase[3]	0.01	0.01	0.01	0.01	0.01
Medication[4]	0.01	0.01	---	---	---
Ractopamine HCl[5]	---	---	---	---	0.03
Total	100	100	100	100	100
Calculated analysis					
Standardized ileal digestible amino acids, %					
Lys	1.06	0.95	0.84	0.84	0.97
Ile:lys	76	78	76	73	68
Met:lys	34	35	35	34	30
Met & Cys:lys	68	72	72	69	61
Thr:lys	66	67	65	64	70
Trp:lys	19.7	19.9	19.3	18.6	17.8
Total lys, %	1.19	1.07	0.94	0.94	1.08
CP, %	23.5	22.0	19.3	18.6	19.5
ME kcal/kg	3,203	3,305	3,377	3,329	3,358
Ca, %	0.65	0.63	0.55	0.53	0.52
P, %	0.56	0.53	0.47	0.45	0.44
Available P,%	0.42	0.42	0.36	0.33	0.31

[1] Phase 1, 2, 3, 4, and 5 diets were fed from 47 to 59, 59 to 84, 84 to 97, 97 to 109, and 109 to 126 kg BW, respectively. All dietary phases were fed in both diet forms to each feeder type.

[2] VTM = vitamin and trace mineral premix which provided per kg premix: 927,818 IU vitamin A; 144,327 IU vitamin D3; 4,984 IU vitamin E; 288 mg vitamin K; 619 mg riboflavin; 2,474 mg pantothenic acid; 3,711 mg niacin; 3,093 mg vitamin B12; 8,247 mg Mn from manganese oxide, 18,556 mg Fe from iron sulfate, 20,618 mg Zn from zinc oxide, 2,062 mg Cu from copper sulfate, and 62 mg Se from sodium selenite.

[3] OptiPhos 2000; Enzyvia LLC, Sheridan, IN, provided 500 FTU/kg, with an expected release of 0.07% available P.

[4] Tylan 40; Elanco Animal Health, Greenfield, IN.

[5] Paylean; Elanco Animal Health, Greenfield, IN.

Table 2: Composition of diets, (as-fed basis), Exp. 2[1]

Item	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Ingredient, %					
Corn	59.55	62.77	65.43	68.54	66.16
Soybean meal, (46.5% CP)	18.54	15.36	12.78	9.70	22.21
Dried distillers grains with solubles	20.00	20.00	20.00	20.00	10.00
Limestone	1.00	0.98	0.95	0.95	0.95
Salt	0..35	0.35	0.35	0.35	0.35
VTM premix[2]	0.10	0.09	0.08	0.08	0.08
Liquid lys, 60%	0.45	0.45	0.40	0.38	0.23
Phytase[3]	0.01	0.01	0.01	0.01	0.01
Ractopamine HCl[4]	---	---	---	---	0.03
Total	100	100	100	100	100
Calculated analysis					
Standardized ileal digestible amino acids,%					
Lys	0.95	0.87	0.78	0.69	0.90
Ile:lys	69	69	72	73	74
Met:lys	31	32	34	37	31
Met & Cys:lys	64	66	71	76	64
Thr:lys	62	63	66	68	66
Trp:lys	17.7	17.4	17.6	17.6	19.8
Total lys, %	1.10	1.01	0.91	0.82	1.03
CP, %	19.5	18.3	17.2	16.1	18.8
ME kcal/kg	3,366	3,369	3,371	3,372	3,365
Ca, %	0.47	0.45	0.43	0.42	0.46
P, %	0.44	0.42	0.41	0.40	0.41
Available P,%	0.28	0.28	0.26	0.24	0.21

[1] Phase 1, 2, 3, 4, and 5 diets were fed from 38 to 56, 56 to 70, 70 to 85, 85 to 115, and 115 to 129 kg BW, respectively. All dietary phases were fed in both diet forms to each feeder type.

[2] VTM = vitamin and trace mineral premix which provided per kg premix: 927,818 IU vitamin A; 144,327 IU vitamin D3; 4,984 IU vitamin E; 288 mg vitamin K; 619 mg riboflavin; 2,474 mg pantothenic acid; 3,711 mg niacin; 3,093 mg vitamin B12; 8,247 mg Mn from manganese oxide, 18,556 mg Fe from iron sulfate, 20,618 mg Zn from zinc oxide, 2,062 mg Cu from copper sulfate, and 62 mg Se from sodium selenite.

[3] OptiPhos 2000; Enzyvia LLC, Sheridan, IN, provided 500 FTU/kg, with an expected release of 0.07% available P.

[4] Paylean; Elanco Animal Health, Greenfield, IN.

Table 3. Effects of diet form and feeder design on finishing pig performance, Exp. 1[1]

	Conventional-dry[7]		Wet dry[8]			*P* <		
Item	Meal	Pellet	Meal	Pellet	SEM	Diet form × Feeder	Diet form	Feeder
d 0 to 43								
ADG, kg	0.81	0.85	0.85	0.87	0.01	0.25	0.0001	0.0001
ADFI, kg	2.07	2.22	2.18	2.23	0.03	0.14	0.01	0.07
G:F	0.395	0.384	0.391	0.391	0.006	0.38	0.34	0.79
Fines, %[2]	---	37.5	---	37.5	---	---	---	---
PDI[3]	---	74.2	---	74.2	---	---	---	---
d 43 to 71								
ADG, kg	0.85	0.86	0.93	0.94	0.01	0.60	0.24	0.0001
ADFI, kg	2.48[a]	2.67[b]	2.72[b]	2.70[b]	0.02	0.0001	0.01	0.0001
G:F	0.344[b]	0.322[a]	0.340[b]	0.350[b]	0.005	0.01	0.21	0.01
Fines, %	---	30.6	---	30.6	---	---	---	---
PDI	---	80.1	---	80.1	---	---	---	---
d 71 to 91								
ADG, kg	0.91	0.86	0.94	0.93	0.03	0.43	0.27	0.06
ADFI, kg	2.55	2.67	2.94	2.90	0.06	0.17	0.44	0.0001
G:F	0.356[b]	0.322[a]	0.319[a]	0.320[a]	0.008	0.05	0.06	0.03
Fines, %	---	36.6	---	36.6	---	---	---	---
PDI	---	74.0	---	74.0	---	---	---	---
d 0 to 91								
ADG, kg	0.84	0.85	0.89	0.91	0.01	0.70	0.07	0.001
ADFI, kg	2.29[a]	2.45[b]	2.50[b]	2.51[b]	0.02	0.04	0.01	0.0001
G:F	0.369[a]	0.349[c]	0.357[b,c]	0.361[a,b]	0.004	0.01	0.07	0.96
Fines, %	---	35.1	---	35.1	---	---	---	---
PDI	---	75.8	---	75.8	---	---	---	---
Feeder coverage score, %[4]	59[a]	90[c]	74[ab]	78[b]	5.70	0.02	0.01	0.79
Carcass measurements[5]								
Live weight, kg	123.1	124.0	127.2	128.5	2.52	0.85	0.35	0.01
HCW, kg	91.7	92.7	94.1	93.8	1.16	0.54	0.77	0.09
Carcass yield, %	75.6	75.3	75.6	76.0	0.01	0.24	0.95	0.19
FFLI, %[6]	50.4	50.4	49.7	49.9	0.20	0.64	0.52	0.01
Back fat depth, mm[4]	17.3	17.2	18.8	18.3	0.41	0.57	0.40	0.01
Loin depth, cm[4]	6.19	6.05	5.97	5.93	0.12	0.64	0.39	0.11

[a,b,c] Means without a common superscript within a row differ ($P < 0.05$).

[1] A total of 1.290 growing pigs (PIC 1050 × 337, initially 47 kg) were used with 25 to 27 pigs per pen and 11 pens per treatment.
[2] Percentage fines were determined using a number 6 screen.
[3] Pellet Durability Index (PDI) was determined by tumbling 500 g samples of feed for 10 minutes, then using a number 6 screen to sift off the fines.
[4] Pictures of feeder pan coverage were taken once during phase 4. A panel of 5 then scored feeder pan pictures for percentage of feeder pan coverage.
[5] Carcass data were obtained for 939 pigs from 44 pens to determine the effects of diet form and feeder design on carcass characteristics.
[6]Fat free lean index (FFLI; National Pork Producers Council, 2000), back fat depth, and loin depth were adjusted to a common HCW.
[7] STACO, Shafferstown, PA.
[8] Crystal Springs, Gro Master, Omaha, NE.

Table 4. Effects of diet form and feeder design on finishing pig performance, Exp. 2[1]

	Conventional-dry		Wet-dry			*P* <		
Item	Meal	Pellet	Meal	Pellet	SEM	Diet form × Feeder	Diet form	Feeder
d 0 to 28								
ADG, kg	0.66[b]	0.58[a]	0.67[b]	0.63[b]	0.02	0.01	0.06	0.06
ADFI, kg	1.45[a]	1.44[a]	1.56[b]	1.68[c]	0.03	0.06	0.14	0.0001
G:F	0.454	0.404	0.431	0.379	0.010	0.93	0.001	0.02
Fines, %[2]	---	39.6	---	39.6	---	---	---	---
PDI[3]	---	87.2	---	87.2	---	---	---	---
d 28 to 42								
ADG, kg	0.96	1.01	1.01	1.01	0.02	0.27	0.33	0.17
ADFI, kg	2.21	2.30	2.35	2.32	0.05	0.24	0.53	0.10
G:F	0.437	0.438	0.433	0.436	0.008	0.90	0.78	0.67
Fines, %	---	3.9	---	3.9	---	---	---	---
PDI	---	89.8	---	89.8	---	---	---	---
Feeder coverage score[4], %	52.40	67.15	63.78	78.84	6.38	0.98	0.02	0.06
d 42 to 86								
ADG, kg	0.96[a]	1.03[b]	1.05[b]	1.06[b]	0.01	0.02	0.01	0.001
ADFI, kg	2.80	2.79	3.09	2.96	0.04	0.14	0.08	0.001
G:F	0.344	0.371	0.340	0.358	0.003	0.20	0.001	0.03
Fines, %	---	4.4	---	4.4	---	---	---	---
PDI	---	93.5	---	93.5	---	---	---	---
Feeder coverage score, %	54.80	60.75	58.46	70.60	6.38	0.62	0.15	0.28
d 86 to 104								
ADG, kg	0.86	0.87	0.90	0.87	0.02	0.62	0.83	0.59
ADFI, kg	2.72	2.54	2.81	2.62	0.10	0.96	0.09	0.41
G:F	0.317	0.345	0.320	0.333	0.010	0.46	0.04	0.66
Fines, %	---	16.8	---	16.8	---	---	---	---
PDI	---	93.8	---	93.8	---	---	---	---
Feeder coverage score, %	31.34[a]	56.18[b]	70.09[b]	72.00[b]	6.38	0.07	0.03	0.001
d 0 to 104								
ADG, kg	0.86	0.88	0.91	0.90	0.01	0.18	0.73	0.01
ADFI, kg	2.33	2.30	2.51	2.46	0.04	0.68	0.25	0.001
G:F	0.370	0.382	0.364	0.368	0.004	0.32	0.05	0.02

Feeder coverage score, %	46.18	61.36	64.11	73.81	4.79	0.56	0.01	0.01
Carcass measurements[7]								
Live weight, kg	126.0	128.4	132.1	130.1	1.65	0.27	0.90	0.01
HCW, kg	94.0	94.6	98.3	97.4	1.14	0.49	0.88	0.01
Carcass yield, %	75.6	76.3	74.7	74.6	0.01	0.52	0.63	0.03
FFLI, %[8]	51.3[b]	51.1[b]	50.4[a]	50.7[a]	0.14	0.06	0.55	0.001
Back fat depth, mm	15.9[a]	16.3[a]	17.8[b]	17.1[b]	0.28	0.06	0.52	0.001
Loin depth, cm	6.17	6.20	6.17	6.18	0.07	0.90	0.72	0.88

[a,b,c] Means lacking a superscript within row differ ($P < 0.05$).

[1] A total of 1,146 growing pigs (PIC 1050 × 337, initially 38.2 kg) were used with 26 to 27 pigs per pen and 11 pens per treatment.

[2] Percentage fines were determined using a number 6 screen.

[3] Pellet Durability Index (PDI) was determined by tumbling 500 g samples of feed for 10 minutes, then using a number 6 screen to sift off the fines.

[4] Pictures of feeder pan coverage were taken on d 54, 78, and 104. A panel of 4 then scored feeder pan pictures for percentage of feeder pan coverage.

[5] STACO, Shafferstown, PA

[6] Crystal Springs, Gro Master, Omaha, NE

[7] Carcass data were obtained for 891 pigs from 44 pens. Back fat depth, and loin depth were adjusted to a common HCW.

[8] Fat Free Lean Index (FFLI; National Pork Producers Council, 2000.

Figure 1. Conventional dry feeder with meal diets averaging 59% feeder pan coverage. Exp. 1

Figure 2. Conventional dry feeder with pelleted diets averaging 90% feeder pan coverage. Exp. 1

Figure 3. Wet-dry feeders with meal diets averaging 74% feeder pan coverage. Exp. 1

Figure 4. Wet-dry feeder with pelleted diets averaging 78% feeder pan coverage. Exp. 1

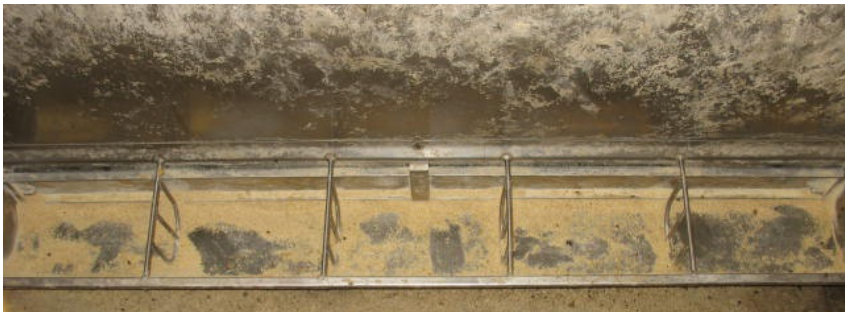

Figure 5. Conventional dry feeder with meal diets averaging 46% feeder pan coverage. Exp. 2

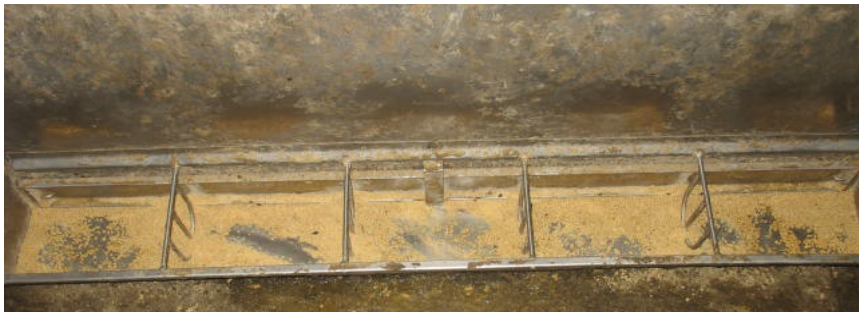

Figure 6. Conventional dry feeder with pelleted diets averaging 61% feeder pan coverage. Exp. 2

Figure 7. Wet-dry feeder with meal diets averaging 64% feeder pan coverage. Exp. 2

Figure 8. Wet-dry feeder with pelleted diets averaging 74% feeder pan coverage. Exp. 2

CHAPTER 3: Effects of Porcine Intestinal Mucosa Protein Sources on Nursery Pig Growth Performance

ABSTRACT

Two studies were conducted to evaluate the effects of 2 porcine intestinal mucosa by-products, PEP2 and Peptone 50 (Tech Mix Inc., Stewart, MN), on the growth performance of nursery pigs. PEP2 and Peptone 50 are by-products of heparin production, but differ based on their carriers. PEP2 is co-dried with enzymatically processed vegetable proteins and Peptone 50 is co-dried with a vegetable protein. In Exp. 1, 300 nursery pigs (PIC 327 × 1050, initially 5.4 ± 0.84 kg and 19 ± 2 d of age) were used in a 25-d study. Pigs were randomly allotted to 1 of 5 dietary treatments with 12 replications of 5 pigs per pen. Treatments were initiated at weaning and consisted of a negative control containing no specialty protein sources, the negative control diet with 4, 8, or 12% PEP2 in phase 1 (d 0 to 11) and 2 (d 11 to 25), and a positive control containing 4% spray dried animal plasma (SDAP) in phase 1 and 4% select menhaden fish meal (SMFM) in phase 2. From d 0 to 11, pigs fed SDAP had greater ($P < 0.05$) ADG and G:F than pigs fed PEP2 diets. From d 11 to 25, increasing PEP2 increased (quadratic; $P < 0.02$) ADG and G:F with the greatest response observed at 4%. Pigs fed PEP2 also had greater ($P < 0.04$) ADG and ADFI than pigs fed the positive control diet. In Exp. 2, 350 nursery pigs (PIC 1050 × C327, initially 6.5 ± 0.97 kg and 28 ± 1.5 d of age) were used in a 24 d study. Pigs were randomly allotted to 1 of 10 dietary treatments with 7 pens per treatment and 5 pigs per pen 6 d after weaning. The dietary treatments were fed from d 0 to 14 and are as follows: a negative control containing no specialty protein sources, negative control diet with 2, 4, and 6% SMFM, 2, 4, and 6% PEP2 or 2, 4, and 6% Peptone 50. A common diet was fed from d-14 to 24. From d 0 to 14, pigs fed diets containing PEP2 had increased ($P < 0.05$) ADFI compared to pigs fed SMFM or

Peptone 50. Pigs fed increasing PEP2 had improved (quadratic; $P < 0.01$) ADFI with the greatest improvement seen in pigs fed 4%. Overall (d 0 to 24), pigs fed PEP2 had improved ($P < 0.02$) ADFI compared to pigs fed Peptone 50. In addition, pigs fed PEP2 had improved ($P < 0.03$) G:F compared to pigs fed SMFM. These results suggest that 4% PEP2 may be a suitable replacement for SMFM in nursery pig diets.

Key words: animal plasma, fish meal, growth, peptide, pig

INTRODUCTION

Spray dried animal plasma (SDAP) and fish meal are widely used protein sources in weaned pig diets due to their desirable amino acid profiles and positive effects on feed intake. Studies have found that when SDAP was included in diets (d 0 to14) after weaning, ADG was improved as a result of increased feed intake (Gatnau and Zimmerman, 1990; Hansen et al., 1993; deRodas et al., 2005). Stoner et al. (1990) found that when select menhaden fish meal (SMFM) was added to diets at the expense of soybean meal, ADG, ADFI, and G:F was improved.

Research has shown that nursery pigs fed porcine intestinal mucosa, a co-product of heparin production, had improved growth performance compared with pigs fed SDAP (DeRouchey et al., 2003) or SMFM (Lindemann et al., 1998; Jones, 2010). Because newly weaned pigs are able to more efficiently utilize short chain peptides compared to intact proteins, feeding peptide products could be a viable alternative to SDAP or fish meal in nursery pig diets (McCalla et al., 2010). Recently, 2 new porcine intestinal mucosa by-products, PEP2 and Peptone 50 (Protein Resources, West Bend, IA), have become available. Similar to previously tested mucosa products, PEP2 and Peptone 50 are also co-products of heparin production. Mucosa linings from the intestines collected

at pork packing plants are removed and hydrolyzed and the remaining material consists of small chain peptides. In addition, unique co-products are co-dried with the mucosa to create a final product. Proteins enzymatically processed (PEP2) is co-dried with enzymatically processed vegetable protein and Peptone 50 is co-dried with an unprocessed vegetable protein. Several studies have been conducted across different species, including swine, on feeding co-products of heparin production. However, the differing carrier proteins, collection methods, and dietary concentrations make it difficult to compare the sources and draw conclusions about the efficacy of the products (Gilbert et al., 2008). Therefore, the objective of this study was to evaluate 2 new sources of porcine intestinal mucosa on nursery pig growth performance.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

General

Both studies were conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan, KS. The facility consists of 2 totally enclosed, environmentally controlled, mechanically ventilated barns. Each barn has 40, 1.2 m^2 pens located over metal tri-bar flooring. Each pen housed 5 pigs and provided 0.30 m^2 floor space per pig. Pigs were provided unlimited access to feed and water via a 4-hole dry self-feeder (44 cm) and 1 cup waterer. Initial temperaure was maintained at 32° C for the first week then lowered 1.5° C each week thereafter.

Experiment 1

A total of 300 weanling pigs (337 ×1050, PIC, Hendersonville TN; initially 5.4 ± 0.84 kg and 19 ± 2 d of age) were used in a 25-d trial to evaluate the effect of porcine intestinal mucosa on growth performance of weaned pigs. Pigs were allotted to 1 of 5 dietary treatments. There were 5 pigs per pen and 12 replicate pens per treatment.

The 5 dietary treatments were: a negative control containing no specialty protein sources, the negative control diet with 4, 8, or 12% proteins enzymatically processed (PEP2; Protein Resources, West Bend, IA) in phase 1 (d 0 to 11) and 2 (d 11 to 25), and a positive control containing 4% spray dried animal plasma (SDAP) in phase 1 and 4% select menhaden fish meal (SMFM) in phase 2. All diets were fed in 2 phases, and treatments containing PEP2 had the same inclusion rate in both phases. A sample of PEP2 was collected and submitted to University of Missouri Chemical Laboratories for analysis of CP and amino acid content (AOAC, 2000; Table 1). The values obtained from analysis were then used in diet formulation. The standardized ileal digestible (SID) AA digestibility coefficients for SDAP were obtained from the manufacturer (APC Inc., Ames, IA) and used as the AA digestibility coefficients for PEP2. The phosphorus in PEP2 was assumed to be 61% available for diet formulation. Nutrients other than total amino acids and values for SDAP and SMFM (including SID AA digestibility) used in diet formulation were obtained from the manufacturer and NRC (1998), respectively.

Phase 1 diets were fed in pellet form from d 0 to 11 after weaning (Table 2) and were manufactured at the Kansas State University Grain Science Feed Mill. Phase 2 diets were fed in meal form from d 11 to 25 (Table 3). Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 5, 11, 18, and 25.

Experiment 2

A total of 350 nursery pigs (PIC 1050 × C327, initially 6.8 ± 0.97 kg and 28 ± 2 d of age) were used in a 24-d study to evaluate the effects of SMFM, PEP2, and Peptone 50 (Protein Resources, West Bend, IA), on nursery pig performance. After arrival to the nursery facility, pigs were fed a common pretest diet for the first 6 days after weaning. Pigs were then allotted to 1 of 10 dietary treatments. There were 5 pigs per pen and 7 replicate pens per treatment.

The 10 dietary treatments included: negative control containing no specialty protein products, the negative control diet with 2, 4, or 6% SMFM, the negative control with 2, 4, or 6% PEP2, or the negative control with 2, 4, or 6% Peptone 50. The common pre-test diet was manufactured and pelleted at the K-State Grain Science Feed Mill. Treatment diets were fed in meal form from d 0 to 14. From d 14 to 24, all pigs were fed a common diet (Table 4). Nutrient analysis for PEP2 used in Exp. 1, was also used in diet formulation for Exp. 2 (Table 5). A nutrient profile and SID AA profile for Peptone 50 was provided by the manufacturer and used in diet formulation. The standardized ileal digestible (SID) AA digestibility coefficients for SDAP were obtained from the manufacturer (APC Inc., Ames, IA). Nutrients and SID AA digestibility values for SDAP and SMFM used in diet formulation were the same as used in Exp. 1.

Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 7, 14, and 24.

Statistical Analysis

Pigs were housed in 2 different barns within each experiment. Pen was the experimental unit with treatments randomly assigned to pen in a completely randomized

design within each barn. Analysis of variance for both experiments was performed using the MIXED procedure in SAS (SAS Institute, Inc., Cary, NC) with barn as random effect and treatments as fixed effects. There were an equal number of replicates within each barn in each experiment. In Exp. 1, the following preplanned contrast statements used were: (1) linear and quadratic effects of increasing PEP2, and (2) mean of PEP2-fed pigs vs. mean of pigs fed the positive control diet. In Exp. 2, contrast statements used were: (1) linear and quadratic effects of increasing fish meal, PEP2, and Peptone 50; (2) Fish meal vs. PEP2; (3) Fish meal vs. Peptone 50; and (4) PEP2 vs. Peptone 50. In both experiments, linear and quadratic contrasts included the negative control in the analysis. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

RESULTS

Experiment 1

In Phase 1 (d 0 to 11), pigs fed the positive control diet had a tendency ($P < 0.09$) for improved ADG and had improved ($P < 0.03$) G:F compared with pigs fed the negative control diet (Table 6). Pigs fed the positive control diet also had improved ($P < 0.04$) ADG and G:F compared to pigs fed diets containing PEP2. No effects of increasing PEP2 were observed for any of the growth criteria.

During Phase 2 (d 11 to 25), pigs fed the positive control diet had improved ($P < 0.05$) ADG and G:F compared with pigs fed the negative control diet. Pigs fed increasing PEP2 had improved (quadratic; $P < 0.01$) ADG and G:F with the greatest improvement observed as PEP2 increased from 0 to 4%, with no improvement thereafter. Furthermore,

the mean ADG and ADFI of pigs fed PEP2 were greater ($P < 0.04$) than that of positive control pigs fed SMFM during this phase.

Overall (d 0 to 25), pigs fed the positive control diet had improved ($P < 0.04$) ADG and G:F compared with pigs fed the negative control diet. There were no differences in ADG or ADFI, but G:F improved ($P < 0.02$) for pigs fed SDAP followed by SMFM compared with pigs fed the PEP2 diets. Increasing PEP2 tended ($P = 0.07$) to increase ADG, with the greatest improvement observed as PEP2 increased from 0 to 4%. Increasing PEP2 in the diet improved G:F (quadratic; $P < 0.02$), with the greatest improvement observed as PEP2 increased from 0 to 4%.

Experiment 2

From d 0 to 14, no significant effects of increasing PEP2, SMFM, or Peptone 50 were observed for ADG or G:F. Pigs fed PEP2 had increased ($P < 0.03$) ADFI compared to those fed SMFM and Peptone 50. Pigs fed increasing PEP2 had increased (quadratic; $P < 0.02$) ADFI, with the greatest improvement observed as PEP2 increased from 0 to 4%.

From d 14 to 24, there were no significant differences of pigs previously fed increasing PEP2, SMFM, or Peptone 50 observed for ADG, ADFI, or G:F.

Overall, there were no differences among treatments for ADG. However, pigs fed PEP2 had greater ($P < 0.02$) ADFI compared to those fed diets containing Peptone 50. Pigs fed PEP2 had poorer ($P <0.03$) G:F compared to those fed SMFM. As PEP2 increased, there was a tendency (quadratic; $P < 0.06$) for improved G:F with the best G:F observed in pigs fed 6% PEP2.

DISCUSSION

Specialty protein sources are used in nursery pig diets to help maintain gut integrity while stimulating feed intake (Bergstrom et al., 1997). Spray dried animal plasma is a widely used animal protein source for nursery pig diets as it has consistently shown improvement in feed intake and growth performance in weaned pigs (Gatnau and Zimmerman, 1990; Hansen et al. 1993). Similar to previous findings, pigs fed diets containing SDAP in Exp. 1 had increased ADG, ADFI, and G:F compared to pigs fed the negative control (which did not contain any specialty protein sources) or diets containing PEP2. However, in phase 2, pigs fed PEP2 had improved ADG and feed intake compared with pigs fed SMFM. This partially coincides with the findings of Jones (2010) where pigs fed a porcine intestinal mucosa by-product of heparin production from d 7 to 21 post-weaning had improved ADG compared to pigs fed select menhaden fish meal during this period.

The increase in ADG seen in pigs fed PEP products during phase 2 could be attributed to increase in feed intake. It has also been hypothesized that the improved feed intake and growth performance seen in pigs fed diets containing porcine intestinal mucosa products compared to those provided fish meal could be due to improvements in gut health and nutrient uptake (Ji, 1999; Stein, 2002). Peptides have been widely used in human infants to help treat gastrointestinal disorders (McCalla et al., 2010). Perhaps providing peptides in young animal diets can aid in GI tract development while maintain feed intake and gut integrity.

Unlike fish meal, which provides the pigs with intact proteins (long chains of AA), peptide products, such as porcine intestinal mucosa by-products, are hydrolyzed

protein sources (short chains of AA). Silk et al (1985) found that peptides with five or fewer AA were absorbed with greater efficiency compared to larger peptides, while Furst and Stehle (1993) stated that certain AA may be more difficult to absorb in their free form and may have a greater availability when provided as a dipeptide. Furthermore, a larger amount of AA were absorbed in the small intestine when provided in peptide form vs. intact protein, suggesting that amino acids provided as peptides maybe more readily available for absorption (Gilbert et al, 2008). Thus, providing newly weaned pigs with protein sources in the peptide form versus intact proteins may help to explain the increase seen in growth performance and feed intake in pigs fed diets containing PEP2 compared to those fed fish meal. Cho et al. (2010), found that weanling pigs fed diets containing dried porcine solubles (porcine intestinal mucosa by-product) had similar and in some instances even improved growth performance compared to pigs fed diets containing spray dried animal plasma. They hypothesized that this improvement in growth performance could be due to this product containing more short chain peptides and consequently having AA that are more readily absorbed (Gilbert et al. 2008; Cho et al. 2010).

Even though improved feed intake and growth performance was observed with PEP2, there was no improvements in growth performance when pigs were provided diets containing Peptone 50. This could be due to the different carriers in which the Peptone products were dried. PEP2 is co-dried with an enzymatically processed vegetable protein while Peptone 50 is spray dried onto a vegetable protein in its native form. It has been well documented that feeding newly weaned pigs plant proteins has resulted in transient hypersensitivity and depressed growth post-weaning (Li et al., 1990), while plant protein sources that have been enzymatically processed may have had many of the anti-

nutritional factors that elicit unfavorable gut immune responses removed (Goebel, 2010). Thus it seems logical that perhaps the difference seen between pigs fed PEP2 and Peptone 50 could potentially be attributed to the difference in carriers.

In conclusion, increased growth performance and feed intake were observed in pigs fed by-products of heparin production compared to pigs fed SMFM. Thus, porcine intestinal mucosa products are a potential replacement for fish meal in nursery pig diets from d 7 to 21 post-weaning.

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Table 1. Analyzed nutrient composition (as-fed basis) Exp. 1[1]

Item	SDAP[2]	SMFM[3]	PEP2[4]
CP, %	75.17	56.10	55.2
Fat, %	6.50	0.10	16.60
Ash, %	9.01	19.44	8.76
Amino acids, %			
Arg	4.32	3.62	3.46
His	2.32	1.36	1.28
Ile	2.31	2.53	2.43
Leu	7.36	4.34	4.22
Lys	7.00	4.71	3.70
Met	0.88	1.68	0.88
Phe	3.98	2.33	2.47
Thr	4.61	2.45	2.18
Trp	1.48	0.55	0.65
Val	5.28	2.99	2.76

[1] Amino acids were analyzed by the University of Missouri Agriculture Experiment Station Chemical Laboratories, Columbia.
[2] Spray dried animal plasma; APC Inc., Ames, IA.
[3] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[4] Proteins Enzymatically Processed; Protein Resources; West Bend, IA.

Table 2. Composition of diets, Phase 1 (Exp. 1, as-fed basis)[1]

			Proteins enzymatically processed (PEP2)[2]		
Ingredient, %	Negative control	Positive control	4%	8%	12%
Corn	37.80	43.80	43.30	44.55	45.75
Soybean meal, (46.5% CP)	40.40	30.50	30.50	25.30	20.10
Spray-dried animal plasma	---	4.00	---	---	---
PEP2	---	---	4.00	8.00	12.00
Spray-dried whey	15.00	15.00	15.00	15.00	15.00
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium P, (21% P)	1.40	1.18	1.40	1.30	1.25
Limestone	0.88	1.05	0.93	1.00	1.03
Salt	0.30	0.30	0.30	0.30	0.30
Zinc oxide	0.38	0.38	0.38	0.38	0.38
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[3]	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.20	0.20	0.35	0.35	0.35
DL-Met	0.16	0.14	0.21	0.21	0.21
L-Thr	0.08	0.05	0.14	0.13	0.14
L-Val	---	---	0.08	0.08	0.08
Calculated analysis[4]					
Standardized ileal digestible amino acids, %[5]					
Lysine	1.45	1.45	1.45	1.45	1.45
Ile:lys	65	60	59	58	57
Met:lys	33	30	36	36	36
Met & Cys:lys	58	58	58	58	58
Thr:lys	62	62	62	62	62
Trp:lys	19.1	18.8	17.0	17.0	16.9
Val:lys	69	69	69	69	69
Total lys, %	1.61	1.60	1.59	1.59	1.58
CP, %	24.2	23.2	22.5	22.3	22.2
ME kcal/kg	3,408	3,433	3,399	3,391	3,384
Ca, %	0.85	0.85	0.85	0.85	0.85
P, %	0.79	0.76	0.77	0.75	0.74
Available P, %	0.48	0.48	0.48	0.48	0.48

[1]Phase 1 diets were fed from d 0 to 11.

[2]Protein Resources, West Bend, IA.

[3] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.

[4] Values for animal plasma were from NRC (1998) and values for PEP2 were from University of Missouri analysis.

[5]Amino acid digestibility values for plasma were used as the estimate of standardized amino acid digestibility of amino acids in PEP2.

Table 3. Composition of diets, Phase 2 (Exp. 1, as-fed basis)[1]

			Proteins enzymatically processed (PEP2)[2]		
Ingredient, %	Negative control	Positive control	4%	8%	12%
Corn	55.10	62.90	62.05	63.25	64.50
Soybean meal, (46.5% CP)	40.10	28.75	28.75	23.50	18.30
Select menhaden fish meal	---	4.00	---	---	---
PEP2	---	---	4.00	8.00	12.00
Spray-dried whey	---	---	---	---	---
Soybean oil	1.00	1.00	1.00	1.00	1.00
Monocalcium P, (21% P)	1.60	1.10	1.55	1.53	1.45
Limestone	0.92	0.72	1.02	1.05	1.10
Salt	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[3]	0.15	0.15	0.15	0.15	0.15
Lys HCl	0.15	0.30	0.35	0.35	0.35
DL-Met	0.09	0.12	0.15	0.15	0.15
L-Thr	0.04	0.11	0.13	0.13	0.13
L-Val	---	---	---	0.01	0.01
Total	100	100	100	100	100
Calculated analysis[4]					
Standardized ileal digestible amino acids, %[5]					
Lys	1.32	1.32	1.32	1.32	1.32
Ile:lys	69	61	60	59	58
Met:lys	32	35	34	35	35
Met & Cys:lys	58	58	58	58	58
Thr:lys	62	62	62	62	62
Trp:lys	19.9	16.9	16.9	16.9	16.9
Val:lys	75	68	68	68	68
Total lys, %	1.47	1.45	1.45	1.45	1.44
CP, %	23.6	21.7	21.4	21.3	21.1
ME kcal/kg	3,336	3,364	3,331	3,322	3,314
Ca, %	0.80	0.80	0.80	0.80	0.80
P, %	0.77	0.73	0.73	0.73	0.71
Available P, %	0.42	0.42	0.42	0.42	0.42

[1]Phase 2 diets were fed from d 11 to 25.

[2]Protein Resources, West Bend, IA

[3]Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.

[4] Values for Select menhaden fish meal were from NRC (1998) and values for PEP2 were from University of Missouri analysis.

[5]Amino acid digestibility values for spray-dried animal plasma were used for the AA digestibility of PEP2.

Table 4. Composition of diets, (Exp. 2, as-fed basis)[1]

			PEP2[2]			Fish meal			Peptone 50[3]			
Ingredient, %	Pre-test diet	SBM control	2%	4%	6%	2%	4%	6%	2%	4%	6%	Common diet
Corn	39.70	55.10	61.50	62.10	62.70	61.90	62.95	63.95	61.50	62.10	62.65	62.79
Soybean meal, (46.5% CP)	22.90	40.10	31.30	28.70	26.10	31.30	28.7	26.10	31.30	28.70	26.10	32.27
Spray dried animal plasma	6.00	---	---	---	---	---	---	---	---	---	---	---
PEP2	---	---	2.00	4.00	6.00	---	---	---	---	---	---	---
Select menhaden fish meal	---	---	---	---	---	2.00	4.00	6.00	---	---	---	---
Peptone 50	---	---	---	---	---	---	---	---	2.00	4.00	6.00	---
Spray-dried whey	25.00	---	---	---	---	---	---	---	---	---	---	---
Soybean oil	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P, (21% P)	0.90	1.60	1.60	1.55	1.55	1.38	1.10	0.85	1.60	1.55	1.55	1.25
Limestone	0.93	0.93	0.98	1.03	1.03	0.83	0.72	0.60	0.98	1.03	1.03	1.05
Salt	0.30	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.38	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[4]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine HCl	0.28	0.15	0.35	0.35	0.35	0.32	0.30	0.28	0.36	0.36	0.37	0.33
DL-Methionine	0.19	0.09	0.15	0.15	0.15	0.14	0.12	0.12	0.15	0.16	0.16	0.14
L-Threonine	0.08	0.04	0.13	0.13	0.13	0.12	0.11	0.11	0.13	0.13	0.14	0.13
Total	100	100	100	100	100	100	100	100	100	100	100	100
Calculated analysis[5]												
Standardized ileal digestible amino acids, %[6]												
Lys	1.50	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.26
Ile:lys	54	69	60	60	59	61	61	61	60	60	59	61
Met:lys	31	32	34	34	34	34	35	36	34	34	34	34
Met & Cys:lys	58	58	58	58	58	58	58	59	58	58	57	59
Thr:lys	63	62	62	62	62	62	62	62	62	62	62	63
Trp:lys	17.7	19.9	17.1	16.9	16.7	17.1	16.9	16.7	16.9	16.7	16.7	17.5
Val:lys	65	75	67	67	67	68	68	69	67	67	68	68
Total lys, %	1.65	1.47	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.44	1.39
CP, %	22.1	23.6	21.4	21.3	21.3	21.5	21.6	21.8	21.4	21.4	21.3	20.8
ME kcal/kg	3,503	3,398	3,398	3,393	3,389	3,416	3,427	3,441	3,398	3,394	3,389	3,412
Ca, %	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.76
P, %	0.74	0.77	0.74	0.73	0.73	0.74	0.73	0.72	0.74	0.73	0.73	0.66
Available P, %	0.51	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42

[1] The pre-test diet was a common diet fed the first 6 days post-weaning.

vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.

[5] Values for select menhaden fish meal were from NRC (1998), values for PEP2 from University of Missouri Analysis, and Peptone 50 were provided by the manufacturer (Protein Resources; West Bend, IA.).

[6]Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility. of amino acids in PEP2 and Peptone 50.

Table 5. Analyzed nutrient composition (as-fed basis) Exp. 2

	SMFM[1]		PEP2[2]		Peptone 50[3]	
Item	Formulated[4]	Analyzed[7]	Formulated[5]	Analyzed[7]	Formulated[6]	Analyzed[7]
CP, %	62.90	62.60	55.23	52.80	55.23	52.5
Fat, %	---	0.10	---	16.6	---	23.2
Ash,	---	19.44	---	8.76	---	10.43
AA, %						
Arg	---	3.53	---	3.28	---	4.42
His	---	1.46	---	1.29	---	1.29
Ile	2.57	2.54	2.43	2.36	1.72	2.27
Leu	4.54	4.25	4.22	4.01	3.30	4.04
Lys	4.81	4.68	3.70	3.42	3.18	3.43
Met	1.77	1.62	0.88	0.81	0.64	0.76
Phe	---	2.33	---	2.40	---	2.27
Thr	2.64	2.31	2.18	1.98	1.87	2.25
Trp	0.66	0.70	0.65	0.65	0.57	0.50
Val	3.03	2.95	2.76	2.69	2.02	2.87

[1] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[2] Proteins enzymatically processed; Protein Resources; West Bend, IA.
[3] Peptone 50; Protein Resources; West Bend, IA.
[4] Nutrient values from the NRC (1998).
[5] Amino acids were analyzed by the University of Missouri Agriculture Experiment Station Chemical Laboratories, Columbia, MO.
[6] Nutrient values provided by the manufacturer; Protein Resources, West Bend, IA.
[7] Values represent the mean of 2 samples.

Table 6. Effects of PEP2 and spray-dried animal plasma on nursery pig performance (Exp. 1)[1]

Item	Negative control[2]	Positive control[3]	PEP2[4] 4%	PEP2[4] 8%	PEP2[4] 12%	SEM	Negative vs. Positive	Positive vs. PEP2	*P*-value Linear	*P*-value Quadratic
d 0 to 11										
ADG, g	193	221	188	190	195	10	0.09	0.04	0.86	0.59
ADFI, g	198	209	188	193	194	13	0.53	0.26	0.93	0.67
G:F	0.972	1.067	0.999	0.981	1.002	0.047	0.03	0.04	0.51	0.89
d 11 to 25										
ADG, g	372	400	434	426	416	14	0.05	0.04	0.02	<0.01
ADFI, g	558	543	582	587	568	12	0.39	0.04	0.53	0.12
G:F	0.667	0.737	0.746	0.726	0.734	0.015	<0.01	0.85	<0.01	<0.01
d 0 to 25										
ADG, g	293	321	324	322	319	9	0.04	0.95	0.07	0.07
ADFI, g	400	395	406	414	403	11	0.78	0.34	0.69	0.44
G:F	0.734	0.813	0.798	0.779	0.791	0.008	<0.01	0.04	<0.01	0.02

[1]A total of 300 nursery pigs (initial BW 5.4 kg) were used in a 25-d trial to determine the effects of PEP2 on nursery pig growth performance. There were 7 pens per treatment with 5 pigs per pen.
[2]Contained no specialty protein products.
[3]Contained 4% spray-dried animal plasma in Phase 1 (d 0 to 11) and 4% select menhaden fish meal in Phase 2 (d 11 to 25). [4]Protein Resources, West Bend, IA.

Table 7. Effects of protein source on nursery pig performance (Exp. 2)[1]

												P -value[4]					
	Negative	PEP2[3]			SMFM[2]			Peptone 50[3]				PEP2		Fish meal		Peptone 50	
Item	Control	2%	4%	6%	2%	4%	6%	2%	4%	6%	SE	Lin	Quad	Lin	Quad	Lin	Quad
d 0 to 14																	
ADG, g	328	350	366	348	325	353	335	331	317	352	15	0.28	0.23	0.48	0.61	0.39	0.33
ADFI[5,6],g	439	478	506	461	435	447	448	448	418	467	20	0.22	0.02	0.59	0.87	0.45	0.24
G:F	0.750	0.735	0.725	0.758	0.743	0.792	0.747	0.741	0.754	0.754	0.028	0.82	0.15	0.56	0.24	0.70	0.76
d 14 to 24																	
ADG, g	554	529	531	534	547	541	565	500	542	524	21	0.47	0.44	0.75	0.40	0.56	0.32
ADFI, g	822	804	833	806	812	824	832	767	787	809	24	0.84	0.84	0.68	0.69	0.86	0.11
G:F	0.676	0.658	0.637	0.665	0.676	0.654	0.681	0.651	0.690	0.649	0.016	0.46	0.18	0.95	0.41	0.55	0.60
d 0 to 24																	
ADG, g	422	425	435	426	418	432	431	400	411	424	14	0.74	0.68	0.53	0.90	0.78	0.22
ADFI[6], g	598	613	642	604	592	604	608	577	572	610	21	0.56	0.17	0.61	0.77	0.72	0.12
G:F[5]	0.706	0.693	0.677	0.706	0.705	0.713	0.709	0.692	0.717	0.695	0.012	0.69	0.06	0.71	0.90	0.86	0.70

[1] A total of 350 pigs (initial BW 6.5 kg) were used in a 24-d growth study. Pigs were randomly allotted to 1 of 10 treatments with 5 pigs/pen and 6 pens/treatment.
[2] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[3] Protein Sources; West Bend, IA.
[4] Linear (Lin) and Quadratic (Quad) contrasts.
[5] Contrast: mean of PEP2 vs. mean of fish meal, $P = 0.03$.
[6] Contrast: mean of PEP2 vs. mean of Peptone 50, $P = 0.02$.

CHAPTER 4: Evaluation of By-Products of Heparin Production in Nursery Pig Diets

ABSTRACT

Three studies were conducted to evaluate porcine intestinal mucosa products (PEP 2+, PEP-NS, and Peptone 50; Tech Mix Inc., Stewart, MN) on nursery pig performance. PEP2+, Peptone 50 and PEP-NS are by-products of heparin production, but differ based on the carriers with which they are dried. PEP2+ is co-dried with enzymatically processed vegetable proteins, Peptone 50 is co-dried with a vegetable protein while PEP-NS is co-dried with by-products of corn wet-milling. In Exp. 1, 360 weanling pigs (PIC 327 × 1050, initially 5.4 ± 0.81 kg, and 19 ± 2 d of age) were used in a 35-d study. Pigs were randomly allotted to 1 of 5 dietary treatments with 5 pigs per pen and12 replications per treatment. Treatment diets were fed in two phases (d 0 to 8 and d 8 to 21) with a common diet fed to all pigs in the third phase (d 21 to 35). Treatments consisted of: negative control (NC) diet containing 2.5% spray-dried animal plasma (SDAP) in phase 1 followed by no specialty protein sources in phase 2, 5% SDAP in phase 1 and 3% select menhaden fish meal (SMFM) in phase 2, 5% SDAP and either 3% SMFM, PEP2+, Peptone 50, or PEP-NS during phase 1 and either 6% SMFM, PEP2+, Peptone 50, or PEP-NS during phase 2. From d 0 to 21, pigs fed PEP2+, Peptone 50 and PEP-NS had increased ($P < 0.05$) ADG and ADFI compared to pigs fed the NC. Pigs fed PEP2+ had improved ($P < 0.05$) G:F compared to all other treatments. In Exp. 2, 1,152 weanling pigs (Newsham GPK35 × PIC380, initially 5.6 ± 0.59 kg, 20 ± 2 d of age) were used in a 39-d study. Pigs were randomly allotted to 1 of 6 dietary treatments with 32 pigs per pen and 6 replications per treatment. Treatment diets were fed in two phases (d 0 to 7 and d 7 to 21) with a common diet fed to all pigs in the third phase (d 21 to 39). Treatments consisted of: NC diet containing 3% SDAP in phase 1 and no specialty protein sources in phase 2 or NC diet with 6% poultry meal (PM), PEP2+, Peptone 50, or PEP-NS. From d 0 to 21, pigs fed diets containing 6% SMFM, PEP2+, or PEP-NS had improved ($P < 0.05$)

ADG and ADFI compared to pigs fed the NC or 6% Peptone 50. Pigs fed 6% PM had lower ($P < 0.05$) ADG than pigs fed PEP-NS but greater ADG than pigs fed NC. In Exp. 3, 180 nursery pigs (PIC 1050 × 327, initially 6.4 ± 1.03 kg and 28 ± 2 d of age) were used in a 24-d study. Pigs were randomly allotted to 1 of 5 dietary treatments with 5 pigs per pen and 6 replications per treatment. Treatment diets were fed starting 7 d post-weaning for 14 d followed by 10 d of common diet. Treatments consisted of: NC containing no specialty proteins, NC with 3, 6, 9, or 12% PEP-NS, or NC with 6% SMFM. Overall, pigs fed increasing PEP-NS had improved (quadratic; $P < 0.01$) ADG and G:F, with the greatest improvement observed in pigs fed 6% PEP-NS. These results suggest PEP2+ and PEP-NS can effectively replace SMFM and PM in nursery pig diets.

Key words: fish meal, growth, peptide, pig, poultry meal

INTRODUCTION

Numerous protein sources have been investigated for their efficacy to stimulate both feed intake and growth performance in the weanling pig. Research has indicated that porcine intestinal mucosa, by-products of heparin production, may be suitable replacements for fish meal in nursery pig diets (Jones et al., 2010; Myers et al., 2010). Porcine digest is derived when mucosa linings from the intestines collected at pork packing plants are removed and hydrolyzed, and the remaining material consists of small chain peptides. It has been observed that pigs may have an increased absorptive capacity for AA in peptide form rather than intact proteins (Gilbert et al., 2008). PEP2+, Peptone 50, and PEP-NS (Protein Resources, West Bend, IA), like their predecessors, are by-products of heparin production. While all originate from intestinal mucosa lining, they are all different in that they are co-dried with different carriers to create a final

product. PEP2+ is co-dried with enzymatically processed vegetable protein and by-products of AA production while Peptone 50 is co-dried with an unprocessed vegetable protein. PEP-NS is co-dried with by-products of corn-wet milling.

Other specialty sources are routinely used in nursery pig diets. Fish meal is a commonly used protein source in nursery pig diets due to its digestibility and desirable AA profile (Stoner et al., 1990; Kim and Easter, 2001). Poultry meal has also been evaluated for use in nursery pig diets. Studies have indicated that poultry meal could replace fish meal in nursery pig diets without adversely affecting performance (Keegan et al. 2004; Zier et al. 2004), which led us to our objectives: 1) to evaluate the effects of Peptone products (PEP2+, Peptone 50, and PEP-NS), select menhaden fish meal and poultry meal on the growth performance of nursery pigs and 2) to evaluate the effects of increasing PEP-NS on nursery pig growth performance.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

Experiment 1

A total of 360 nursery pigs (C327 ×1050, PIC, Hendersonville, TN; initially 5.4 ± 0.81 and 19 ± 2 d of age) were used in a 35-d trial to evaluate the effects of peptone products on the growth performance of weaned pigs. The study was conducted at the Kansas State University segregated early weaning facility in Manhattan. The facility consists of 2 totally enclosed, environmentally controlled, mechanically ventilated barns. Each barn has 40, 1.2 m^2 pens located over metal tri-bar flooring. Each pen housed 5 pigs and provided 0.30 m^2 floor space per pig. Pigs were provided unlimited access to feed and water via a 4-hole dry self-feeder (44 cm) and 1

cup waterer. Initial temperaure was maintained at 32° C for the first week then lowered 1.5° C each week thereafter.

After arrival to the segregated early weaning facility, pigs were allotted to 1 of 6 dietary treatments. There were 5 pigs per pen and 12 replicate pens per treatment.

The 6 dietary treatments were: a negative control containing 2.5% spray-dried animal plasma (SDAP) from Phase 1 (d 0 to 8) followed by no specialty protein sources in Phase 2 (d 8 to 21), a positive control containing 5% SDAP in Phase 1 and 3% select menhaden fish meal (SMFM) in Phase 2, and the diets including specialty protein sources containing 5% SDAP and either 3% SMFM, PEP2+, Peptone 50, or PEP-NS in Phase 1, and 6% SMFM, PEP2+, Peptone 50, or PEP-NS in Phase 2, respectively (Table 1 and 2). Crystalline AA levels were altered to provide similar levels of soybean meal in diets with specialty protein sources. Nutrient profiles for PEP2+, Peptone 50, and PEP-NS were provided by the manufacturer (Tech Mix Inc., Stewart, MN) and used in diet formulation. The standardized ileal digestible (SID) AA values for PEP2+, Peptone 50, and PEP-NS, were provided by the manufacturer (Tech Mix Inc., Stewart, MN) and for SDAP (APC, Ames, IA; Table 3). Nutrients and SID AA digestibility values for SMFM used in diet formulation were obtained from NRC (1998).

Phase 1 diets were fed in pellet form from d 0 to 8 after weaning and were manufactured at the Kansas State University Grain Science Feed Mill. Phase 2 diets were fed in meal form from d 8 to 21 and were manufactured at the Kansas State University Animal Science Feed Mill. A common Phase 3 diet was fed from d 21 to 35. Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 8, 16, 21 and 35. Samples of SMFM, PEP2+, Peptone 50, and PEP-NS were collected and analyzed for CP and amino acid content (AOAC, 2000; Table 3).

Experiment 2

A total of 1,152 nursery pigs (Newsham GPK35 X PIC380; initial BW of 5.6 ± 0.59 kg and 20 ± 2 d of age) were used in a 39-d study to evaluate the effects of Peptone products on the growth performance of nursery pigs. The study was conducted at a commercial research wean-to-finish facility in Anchor, IL. The facility was an environmentally controlled, fully slatted, wean-to-finish barn. Pigs were provided ad libitum access to feed and water via a 4-hole dry self-feeder (152.4 cm long) and 2 cup waterers. Each pen was 20.51 m^2 and provided each pig with 0.64 m^2 floor space. At weaning, pigs were weighed by pen and were randomly allotted to 1 of 6 dietary treatments based upon average pen weight. Number of barrows and gilts were equalized across pens. There were 32 pigs per pen and 6 replicate pens per treatment.

The 6 dietary treatments were: a negative control containing 4.5% SDAP in Phase 1 (d 0 to 7) followed by no specialty protein sources in Phase 2 (d 7 to 21), or the negative control containing 6% SMFM, poultry meal, PEP2+, Peptone 50, or PEP-NS (Tables 4 and 5). The specialty protein source and crystalline AA replaced soybean meal in the negative control diet. Nutrient profiles, including standardized ileal digestible values of AA for PEP2+, Peptone 50, and PEP-NS were provided by the manufacturer (Tech Mix Inc., Stewart, MN) and used in diet formulation. Spray dried animal plasma digestibility coefficients obtained from the manufacturer (APC, Ames, IA) Nutrients and SID AA digestibility values for SMFM and poultry meal used in diet formulation were obtained from NRC (1998).

Phase 1 diets were fed in pellet form from d 0 to 7 post-weaning. Phase 2 diets were fed in meal form from d 7 to 21 (Table 5). A common Phase 3 diet was fed in meal form from d 21 to 39. Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 7, 21, and 39.

Experiment 3

A total of 180 nursery pigs (C327 × 1050, PIC, Hendersonville, TN; initial BW of 6.4 ± 1.03 kg and 28 ± 2 d of age) were used in a 24-d study to evaluate the effects of increasing PEP-NS on nursery pig growth performance. Similar to Exp. 1 this study was also conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan. However, this study was conducted in only 1 of the 2 barns at this facility. Pigs used in this study were subjected to the same management protocol as outlined in Exp. 1. After arrival at the nursery facility, pigs were fed a common pretest diet (Table 7) for the first 7 d after weaning. On d 7 after weaning, pigs were allotted to 1 of 6 dietary treatments. Thus, d 7 after weaning was d 0 of the experiment. There were 5 pigs per pen and 6 replicate pens per treatment.

The 6 dietary treatments included: a negative control containing no specialty protein products, the negative control diet with 3, 6, 9, or 12% PEP-NS, or the negative control with 6% SMFM (Table 7). Similar to Exp. 2, SID AA values for PEP-NS were provided by the manufacturer (Table 8). Nutrients and SID AA digestibility values for SMFM used in diet formulation were obtained from NRC (1998). Samples of SMFM and PEP-NS were collected and analyzed for CP and amino acid content (AOAC, 2000; Table 8).

Treatment diets were fed in meal form from d 0 to 14 and were manufactured at the Kansas State University Animal Science Feed Mill. From d 14 to 24, all pigs were fed a common diet. Average daily gain, ADFI, and G:F was determined by weighing pigs and measuring feed disappearance on d 0, 7, 14, and 24.

Statistical Analysis

In Exp. 1 pigs were housed in two different barns during the study. Pen was the experimental unit with treatments randomly assigned to pen in a completely randomized design

within each barn. Analysis of variance for Exp. 1 was performed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC) with barn as random effect and treatments as fixed effects. There were multiple but equal number of replicates within barn. Experiments 2 and 3 were analyzed as a completely randomized design with pen as the experimental unit. Analysis of variance was performed using the MIXED procedure in SAS. In Exp. 1 and Exp. 2, means were separated using LSD. In Exp 3, preplanned contrast statements used were: (1) linear and quadratic effects of increasing PEP-NS, and (2) 6% PEP-NS vs. 6% SMFM. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

RESULTS

Crude protein and AA analysis of the porcine intestinal mucosa products were generally consistent with values supplied by the manufacturer that were used in diet formulation (Tables 3, 6, and 8).

Experiment 1

From d 0 to 21, pigs fed 3% PEP2+, Peptone 50, or PEP-NS in Phase 1 and 6% PEP2+, Peptone 50, or PEP-NS in Phase 2 had improved ($P < 0.05$) ADG compared to those fed the negative control diet. Pigs fed 3% PEP2+ in Phase 1 and 6% PEP2+ in Phase 2 had improved ($P < 0.02$) ADG compared to pigs fed 5% SDAP in Phase 1 and 3% SMFM in Phase 2 or 3% SMFM in Phase 1 and 6% SMFM in Phase 2. In addition, pigs fed 3% PEP2+ or Peptone 50 in Phase 1 and 6% PEP2+ or Peptone 50 during Phase 2 had improved ($P < 0.03$) feed intake compared to those fed the negative control. Pigs fed 3% PEP2+ during Phase 1 and 6% PEP2+ had improved ($P < 0.05$) G:F compared to those fed all other dietary treatments.

During Phase 3 (d 21 to 35), when all pigs were fed a common diet, there were no significant differences found among treatments for ADG and ADFI. However, pigs previously

fed 5% SDAP in Phase 1 and 3% SMFM in Phase 2 had improved ($P < 0.04$) G:F compared to pigs previously fed 3% PEP2+ during Phase 1 and 6% PEP2+ during Phase 2.

Overall (d 0 to 35), pigs fed diets containing PEP2+ had improved ($P < 0.03$) ADG compared to pigs fed the negative control diet. Additionally, pigs fed diets containing PEP2+, Peptone 50, and PEP-NS had improved ($P < 0.03$) feed intake compared to pigs fed the negative control, while pigs fed 3% PEP2+ during Phase 1 and 6% PEP2+ during Phase 2 had increased ($P < 0.05$) feed intake compared to pigs fed 3% SMFM during Phase 1 and 6% SMFM during Phase 2.

Experiment 2

From d 0 to 21, pigs fed diets containing 6% SMFM, poultry meal (PM), PEP2+, or PEP-NS had improved ($P < 0.05$) ADG compared to those fed the negative control diet or diets containing 6% Peptone 50. Pigs fed 6% PEP-NS had increased ($P < 0.05$) ADG compared to those fed 6% PM. Furthermore, pigs fed 6% SMFM, PM, PEP2+, or PEP-NS had increased ($P < 0.05$) ADFI compared to those fed the negative control diet. Pigs fed 6% SMFM, PEP2+, and PEP-NS had increased ($P < 0.01$) ADFI compared to pigs fed diets containing 6% Peptone 50. Pigs fed diets containing 6% SMFM, PM, PEP2+, or PEP-NS had improved ($P < 0.05$) G:F compared to pigs fed 6% Peptone 50, while pigs fed diets containing 6% PEP-NS had improved ($P < 0.05$) compared to those fed the negative control diet.

During phase 3 (d 21 to 39), pigs previously fed diets containing 6% PEP2+ or PEP-NS had improved ($P < 0.05$) ADG compared to those previously fed the negative control diet. Pigs previously fed 6% SMFM, PM, PEP2+, or PEP-NS had increased ($P < 0.05$) feed intake compared to pigs previously fed the negative control diet or diets containing 6% Peptone 50.

Pigs previously fed the negative control diet and diets containing 6% Peptone 50 had increased ($P < 0.05$) G:F compared to all other treatments.

Overall (d 0 to 39), pigs fed diets containing 6% SMFM, PM, PEP2+, or PEP-NS had improved ($P < 0.05$) ADG and ADFI compared to pigs fed the negative control diet. Pigs fed diets containing 6% SMFM, PEP2+, or PEP-NS had improved ($P < 0.05$) ADG and ADFI compared to pigs fed diets containing 6% Peptone 50. There were no significant differences observed among treatments for G:F.

Experiment 3

From d 0 to 14, pigs fed increasing PEP-NS had improved (quadratic; $P< 0.01$) ADG, ADFI, and G:F, with an increase observed in pigs fed up to 9% PEP-NS and little improvement thereafter. There were no differences observed between pigs fed the diet with 6% SMFM and 6% PEP-NS. From d 14 to 24, when all pigs were fed a common diet, there were no differences in ADG, ADFI, or G:F observed in pigs previously fed increasing PEP-NS.

Overall (d 0 to 24), pigs fed increasing PEP-NS had improved (quadratic; $P < 0.01$) ADG and G:F, with the greatest improvement observed in pigs fed 6% PEP-NS. Additionally, pigs fed increasing PEP-NS tended to have increased ($P < 0.10$) ADFI. There were no differences observed between pigs fed 6% PEP-NS and those fed 6% SMFM.

DISCUSSION

There is a continual search to find alternative protein sources that are not only economical but compliment the digestive capability of the weaned pig. Fish meal has historically been a widely used protein source in nursery pig diets due to its desirable amino acid profile (Stoner et al. 1990). Recent price volatility has made fish meal a less attractive option in

weanling pig diets. Poultry meal, which has an AA profile similar to that of fish meal, has also been evaluated in its effectiveness to stimulate feed intake and promote growth performance in the newly weaned pig (Keegan et al., 2004; Zier et al., 2004). The response to poultry meal is dependent on source and quality, as poultry meal must be low-ash (< 10.9%) in order to positively affect growth performance (Keegan et al., 2004). Previous research has indicated that growth performance was improved in weaned pigs that consumed diets containing a porcine intestinal mucosa product (Lindemann et al., 2000; DeRouchey et al., 2003, Jones et al., 2010).This led us to our first objective, that porcine intestinal mucosa products could potentially replace fish meal or poultry meal in nursery pig diets.

Our findings coincide with previous studies (Lindemann et al., 2000; DeRouchey et al., 2003, Jones et al., 2010) evaluating porcine intestinal mucosa products, where pigs fed diets containing PEP2+ or PEP-NS had similar and in some cases improved growth performance compared to pigs fed diets containing fish meal. However, there were some noted differences in the response to the porcine intestinal mucosa products in the present studies. In Exp. 1, all three porcine intestinal mucosa products (PEP2+, Peptone 50, and PEP-NS) evaluated improved ADG compared to the negative control. In Exp. 2, pigs fed diets containing Peptone 50 had decreased ADG and ADFI compared to pigs fed PEP2+ and PEP-NS. It is unclear as to why there were differences in growth performance seen in pigs fed Peptone 50 between Exp. 1 and Exp. 2. A possible contributing factor to the difference could have been the SID AA digestibility coefficients that were utilized in diet formulation. We used estimated standardized AA values provided by the manufacturer because actual values were not available at the time of diet formulation. Mathai et al. (2011) recently conducted a study evaluating SID of AA in PEP2+ and Peptone 50. The calculated digestibility coefficients for lys used for PEP2+ and Peptone 50 were

higher (88 and 91%, respectively) in the present studies than the SID values (84.1 and 87.5%, respectively) observed by Mathai et al. (2011). It was also observed that Peptone 50 and fish meal had similar SID values for all indispensible AA, which coincides with the Peptone 50 SID values used in our present studies. In addition, Mathai et al. (2011) observed that PEP2+ had lower SID values for indispensible AA when compared to Peptone 50 and fish meal, which also corroborates with the SID AA values used in the present studies.

Another possibility for the difference in growth response to Peptone 50 could be due to inclusion level. In Exp. 1, phase 1 diets included only 3% Peptone 50 in the diet whereas in Exp. 2, 6% Peptone 50 was included in the diet. Perhaps feeding 6% Peptone 50 during phase 1 was detrimental to pig performance, thus more research is warranted to determine the optimal inclusion level of Peptone 50 in diets immediately post-weaning.

All of the Peptone products evaluated in these studies contain porcine intestinal mucosa that was collected from the same pork processing plants and processed in a similar fashion. The differences between PEP2+, Peptone 50 and PEP-NS can be found in their carriers. The different carriers could be the reasoning behind the differences seen in growth performance among pigs fed the differing products. Previous research found that pigs fed PEP2, which utilizes enzymatically processed vegetable protein as its carrier, had improved growth performance compared to Peptone 50, which uses a vegetable protein in its native form as its carrier (Myers, 2011). Thus, the anti-nutritional factors associated with the unprocessed vegetable protein could have been a contributing factor in the decreased growth performance seen in pigs fed diets containing Peptone 50. Perhaps further processing the vegetable protein sources used as the carriers for porcine intestinal mucosa positively impacts weaned pig growth performance, as evidenced by these studies.

In Exp. 2, we also evaluated poultry meal, which is another commonly used protein source in nursery pig diets. Poultry meal is a by-product from the poultry slaughtering process and depending upon processing method can have a very similar amino acid profile to that of fish meal (Keegan et al., 2004). Keegan et al (2004) and Zier et al. (2004) found that fish meal could be replaced by a high quality source of poultry meal. Little research has been done comparing porcine intestinal mucosa products to that of poultry meal. Pigs fed diets containing fish meal and poultry meal had similar overall growth performance and feed intake, and both had improved growth performance compared to the negative control diet. Pigs fed diets containing PEP2+ or PEP-NS had similar growth performance to poultry meal, which indicates that PEP2+ or PEP-NS could effectively replace poultry meal in nursery pig diets.

In Exp. 1 and Exp. 2, pigs fed diets containing PEP2+ and PEP-NS consistently had improved ADG and ADFI compared to pigs fed negative control diets or diets containing fish meal or poultry meal. The improvements in ADG and ADFI seen with PEP2+ and PEP-NS could be due to more short chain peptides as a result of the hydrolysis process. McCalla et al. (2010) and Cho et al. (2010) observed that newly weaned pigs are able to more efficiently utilize short chain peptides compared to intact proteins and that feeding peptide products could be a viable alternative to SDAP or fish meal in nursery pig diets. Gilbert et al. (2008) observed that there appears to be a considerable capacity for the small intestines to absorb amino acids in the peptide form. Thus it is reasonable to predict that by incorporating small peptides or hydrolyzed proteins into the diet would exploit this ability and potentially enhance animal growth and development (Gilbert et al., 2008).

Previous studies have found that feeding PEP2 at a level of 4 to 6 % was effective in promoting weaned pig growth performance (Myers, 2011). In Exp. 3, feeding pigs 9% PEP-NS

seemed to have the greatest impact on growth performance during the first 14 d. However, overall (d 0 to 35) it appeared that 6% level was sufficient for increasing ADG and ADFI. These findings coincide with previous research indicating that peptone products fed at 6% inclusion in the diet are effective in promoting weaned pig growth performance.

In conclusion, PEP2+ and PEP-NS are suitable replacements for fish meal and poultry meal in nursery diets from d 7 to 21 post-weaning. PEP-NS can be included at 6 to 9% of the diet for optimal growth performance.

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Table 1. Composition of diets, Phase 1 (as-fed basis)[1], Exp. 1

Ingredient, %	Negative control	5% SDAP[2]	3% SMFM[3]	3% PEP2+[4]	3% Peptone 50[5]	3% PEP-NS[6]
Corn	36.19	38.50	38.99	38.36	38.35	38.31
Soybean meal (46.5% CP)	29.62	24.98	22.21	22.20	22.19	22.21
Spray-dried animal plasma	2.50	5.00	5.00	5.00	5.00	5.00
Select menhaden fish meal	---	---	3.00	---	---	---
PEP2+	---	---	---	3.00	---	---
Peptone 50	---	---	---	---	3.00	---
PEP-NS	---	---	---	---	---	3.00
Spray-dried whey	25.00	25.00	25.00	25.00	25.00	25.00
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium P (21% P)	1.30	1.18	0.78	1.13	1.05	1.10
Limestone	0.95	1.03	0.83	1.05	1.10	1.08
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.21	0.16	0.08	0.11	0.15	0.15
DL-Met	0.17	0.13	0.11	0.14	0.15	0.14
L-Thr	0.07	0.03	0.01	0.02	0.03	0.03
Calculated analysis[8]						
Standardized ileal digestible amino acids, %[9]						
Lys	1.40	1.40	1.40	1.40	1.40	1.40
Ile:lys	60	59	60	60	59	59
Met:lys	32	29	30	30	30	30
Met & Cys:lys	58	58	58	58	58	58
Thr:lys	63	63	63	63	63	63
Trp:lys	18.5	18.9	19.1	19.3	19.2	18.8
Val:lys	67	69	71	71	70	70
Total lys, %	1.55	1.55	1.55	1.56	1.55	1.56
CP, %	22.2	22.1	22.6	22.4	22.2	22.2
ME kcal/kg	3,128	3,140	3,158	3,134	3,136	3,140
Ca, %	0.90	0.90	0.90	0.90	0.90	0.90
P, %	0.80	0.79	0.78	0.79	0.78	0.78
Available P, %	0.55	0.55	0.55	0.55	0.55	0.55

[1] Phase 1 diets were fed from d 0 to 8 and were in pellet form.
[2] Spray dried animal plasma; APC, Ames, IA.
[3] Special select menhaden fish meal; Omega Protein Corp., Houston TX.
[4] PEP2; Protein Resources, West Bend, IA.
[5] Peptone 50; Protein Resources, West Bend, IA.
[6] PEP-NS; Protein Resources, West Bend, IA.

of Cu as $CuSO_4$ $5H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4$ H_2O; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_2$ 2HI.

[8] Values for select menhaden fish meal were from the NRC (1998), spray dried animal plasma were from manufacturer (APC, Ames, IA) and nutrient profiles for PEP2+, Peptone 50, PEP-NS were provided by the manufacturer and used in diet formulation (Protein Resources, West Bend, IA).

[9] Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility of amino acids in PEP2+, Peptone 50, and PEP-NS.

Table 2. Composition of diets, Phase 2 and 3 (as-fed basis)[1], Exp. 1

	Phase 2						Phase 3[2]
Ingredient, %	Negative control	3% SMFM[3]	6% SMFM[3]	6% PEP2+[4]	6% Peptone 50[5]	6% PEP-NS[6]	Common
Corn	54.46	55.81	56.02	54.78	54.70	54.63	62.80
Soybean meal (46.5% CP)	30.76	27.07	24.61	24.58	24.59	24.60	32.25
Select menhaden fish meal	---	3.00	6.00	---	---	---	---
PEP2+	---	---	---	6.00	---	---	---
PEP50	---	---	---	---	6.00	---	---
PEP-NS	---	---	---	---	---	6.00	---
Spray-dried whey	10.00	10.00	10.00	10.00	10.00	10.00	---
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	1.2	0.83	0.43	1.10	1.00	1.13	1.25
Limestone	0.88	0.68	0.48	0.93	1.00	0.95	1.05
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.35	0.30	0.21	0.27	0.34	0.34	0.33
DL-Met	0.16	0.15	0.11	0.17	0.18	0.17	0.14
L-Thr	0.14	0.13	0.10	0.12	0.14	0.14	0.13
Phytase[8]							.05
Calculated analysis[9]							
Standardized ileal digestible amino acids, %[10]							
Lys	1.30	1.30	1.30	1.30	1.30	1.30	1.26
Ile:lys	60	60	62	61	60	58	61
Met:lys	34	35	35	35	35	36	34
Met & Cys:lys	58	58	58	58	58	58	59
Thr:lys	63	63	63	63	63	63	63
Trp:lys	17	17	17	18	17	17	17.5
Val:lys	65	66	69	67	65	65	68
Total lys, %	1.44	1.43	1.43	1.45	1.43	1.45	1.39
CP, %	20.7	20.9	21.5	21.2	20.8	20.7	20.8
ME kcal/kg	3,061	3,079	3,095	3,049	3,053	3,061	3,075
Ca, %	0.75	0.75	0.75	0.75	0.75	0.75	0.76
P, %	0.69	0.68	0.67	0.68	0.67	0.67	0.66
Available P, %	0.39	0.39	0.39	0.39	0.39	0.39	0.34

[1] Phase 2 diets were fed from d 8 to 21 and were in meal form.
[2] A common phase 3 diet was fed from d 21 to 35 in meal form.
[3] Special select menhaden fish meal; Omega Protein Corp., Houston TX.
[4] PEP2; Protein Resources, West Bend, IA.
[5] Peptone 50; Protein Resources, West Bend, IA.
[6] PEP-NS; Protein Resources, West Bend, IA.

[7] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_4$ $5H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4$ H_2O; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_2$ 2HI.

[8] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 231 FTU/kg, with a release of 0.10 available P.

[9] Values for select menhaden fish meal were from the NRC (1998), spray dried animal plasma were from manufacturer (APC, Ames, IA) and nutrient profiles for PEP2+, Peptone 50, PEP-NS were provided by the manufacturer and used in diet formulation (Protein Resources, West Bend, IA).

[11] Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility of amino acids in PEP2+, Peptone 50, and PEP-NS.

Table 3. Analyzed nutrient composition of ingredients (as-fed basis), Exp. 1

	SMFM[1]		PEP2+[2]		Peptone 50[2]		PEP-NS[2]	
Item	Formulated[3,4,6]	Analyzed	Formulated[5]	Analyzed	Formulated[5]	Analyzed	Formulated[5]	Analyzed
CP, %	62.9	62.9	58.0	58.7	50.0	52.2	47.5	46.4
Amino Acids, %								
Ile	2.42 (94)	2.42	2.63 (88)	2.67	2.23 (91)	2.38	2.06 (83)	1.99
Leu	4.27 (94)	4.28	4.23 (89)	4.55	3.78 (91)	4.03	3.44 (72)	3.55
Lys	4.57 (95)	4.67	4.29 (88)	4.51	3.12 (91)	3.57	3.50 (83)	3.44
Met	1.66 (94)	1.55	1.09 (88)	0.97	0.81 (93)	0.75	0.97 (86)	0.80
Thr	2.32 (88)	2.56	2.47 (83)	2.47	2.00 (88)	2.15	2.06 (77)	1.94
Trp	0.59 (88)	0.56	0.77 (87)	0.68	0.67 (90)	0.68	0.59 (83)	0.55
Val	2.82 (93)	2.78	3.03 (86)	3.03	2.44 (89)	2.59	2.56 (81)	2.43
Cys	0.50 (88)	0.49	0.79 (77)	0.68	0.80 (88)	0.62	0.62 (68)	0.47

[1] Special select menhaden fish meal ; Omega Protein Corp., Houston TX.

[2] Protein Resources, West Bend, IA.

[3] Diets were prepared using the formulated values.

[4] Nutrient values from NRC (1998).

[5] Nutrient values provided by the manufacturer.

[6] ( ) indicate standardized ileal digestible amino acid coefficients (%) used in diet formulation.

Table 4. Composition of diets, Phase 1 (as-fed basis)[1], Exp. 2

		6%				
Ingredient, %	Negative control	Poultry meal[2]	SMFM[3]	PEP2+[4]	Peptone 50[5]	PEP-NS[6]
Corn	43.60	44.31	44.78	43.54	43.36	43.48
Soybean meal, (46.5% CP)	22.45	16.68	16.69	16.70	16.69	16.70
Spray-dried animal plasma	4.50	4.50	4.50	4.50	4.50	4.50
Select menhaden fish meal	---	---	6.00	---	---	---
Poultry meal	---	6.00	---	---	---	---
PEP2+	---	---	---	6.00	---	---
Peptone 50	---	---	---	---	6.00	---
PEP-NS	---	---	---	---	---	6.00
Spray-dried whey	25.00	25.00	25.00	25.00	25.00	25.00
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P, (21% P)	0.85	0.30	0.10	0.75	0.80	0.65
Limestone	1.00	0.63	0.60	1.05	1.07	1.13
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.28	0.27	0.12	0.17	0.24	0.23
DL-Met	0.17	0.16	0.11	0.16	0.18	0.17
L-Thr	0.10	0.10	0.05	0.08	0.11	0.09
Phytase[8]	0.05	0.05	0.05	0.05	0.05	0.05
Calculated analysis[9]						
Standardized ileal digestible (SID) amino acids, %[10]						
Lys	1.40	1.40	1.40	1.40	1.40	1.40
Ile:lys	55	58	54	57	55	56
Met:lys	31	31	32	32	33	32
Met & Cys:lys	58	58	58	58	58	58
Thr:lys	65	65	65	65	65	65
Trp:lys	18	18	17	18	18	18
Val:lys	65	69	65	68	66	67
Total lys, %	1.54	1.54	1.56	1.56	1.56	1.54
CP, %	21.1	22.1	22.3	21.8	21.2	21.5
ME kcal/kg	3,331	3,366	3,331	3,318	3,329	3,322
Ca, %	0.82	0.82	0.82	0.82	0.82	0.82
P, %	0.71	0.70	0.70	0.70	0.70	0.69
Available P, %	0.56	0.56	0.56	0.55	0.56	0.56

[1]Phase 1 diets were fed from d 0 to 11 and were in meal form.

[2] Poultry meal; Hubbard Feeds, Mankato, MN.

[3] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.

[4] PEP2; Protein Resources, West Bend, IA.
[5] Peptone 50; Protein Resources, West Bend, IA.
[6] PEP-NS; Protein Resources, West Bend, IA.
[7] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_4$ $5H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4$ H_2O; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_2$ 2HI.
[8] Natuphos (BASF Animal Nutrition; Mount Olive, NJ) provided 509 FTU/kg, with a release of 0.10 available P.
[9] Values for select menhaden fish meal and poultry meal were from the NRC (1998) and nutrient profiles for Spray dried animal plasma, PEP2+, Peptone 50, PEP-NS were provided by the manufacturer and used in diet formulation.
[10] Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility of amino acids in PEP2+, Peptone 50, and PEP-NS.

Table 5. Composition of diets, Phase 2 (as-fed basis)[1], Exp. 2

		6%				
Ingredient, %	Negative control	Poultry meal[2]	SMFM[3]	PEP2+[4]	Peptone 50[5]	PEP-NS[6]
Corn	54.46	54.35	54.81	53.55	53.41	53.53
Soybean meal, (46.5% CP)	30.76	25.92	25.89	25.91	25.89	25.88
Select menhaden fish meal	---	---	6.00	---	---	---
Poultry meal	---	6.00	---	---	---	---
PEP2+	---	---	---	6.00	---	---
Peptone 50	---	---	---	---	6.00	---
PEP-NS	---	---	---	---	---	6.00
Spray-dried whey	10.00	10.00	10.00	10.00	10.00	10.00
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P, (21% P)	1.20	0.60	0.43	1.10	1.15	1.00
Limestone	0.88	0.50	0.48	0.93	0.93	1.07
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.35	0.32	0.17	0.22	0.28	0.28
DL-Met	0.16	0.15	0.10	0.15	0.16	0.15
L-Thr	0.14	0.12	0.08	0.10	0.13	0.11
Phytase[8]	0.05	0.05	0.05	0.05	0.05	0.05
Calculated analysis[9]						
Standardized ileal digestible (SID) amino acids, %[10]						
Lys	1.30	1.30	1.30	1.30	1.30	1.30
Ile:lys	60	64	60	63	60	62
Met:lys	34	35	35	35	35	34
Met & Cys:lys	58	58	58	58	58	58
Thr:lys	63	63	63	63	63	63
Trp:lys	17	18	17	18	17	18
Val:lys	65	71	66	69	67	68
Total lys, %	1.44	1.44	1.46	1.45	1.46	1.44
CP, %	20.7	22.0	22.2	21.7	21.1	21.4
ME kcal/kg	3,333	3,371	3,336	3,049	3,331	3,051
Ca, %	0.75	0.75	0.75	0.75	0.75	0.75
P, %	0.69	0.68	0.67	0.68	0.68	0.67
Available P, %	0.47	0.47	0.47	0.47	0.47	0.47

[1]Phase 2 diets were fed from d 11 to 25 and were in meal form.
[2] Poultry meal; Hubbard Feeds, Mankato, MN
[3] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[4] PEP2; Protein Resources, West Bend, IA.
[5] Peptone 50; Protein Resources, West Bend, IA.
[6] PEP-NS; Protein Resources, West Bend, IA.

[7] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.
[8] Natuphos (BASF Animal Nutrition; Mount Olive, NJ) provided 509 FTU/kg, with a release of 0.10 available P.
[9] Values for select menhaden fish meal and poultry meal were from the NRC (1998) and nutrient profiles for Spray dried animal plasma, PEP2+, Peptone 50, PEP-NS were provided by the manufacturer and used in diet formulation.
[10] Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility of amino acids in PEP2+, Peptone 50, and PEP-NS.

Table 6. Nutrient composition of ingredients (as-fed basis), Exp. 2

Item	SMFM [1, 4, 5, 7]	Poultry meal [2, 4, 5, 7]	PEP2+[3, 4, 6, 7]	Peptone 50 [3, 4, 6, 7]	PEP-NS [3, 4, 6, 7]
CP, %	62.90	64.10	58.00	52.20	47.50
Amino Acids, %					
Ile	2.57 (94)	2.01 (81)	2.67 (88)	2.35 (91)	2.06 (83)
Leu	4.54 (94)	3.89 (80)	4.55 (89)	3.98 (91)	3.78 (72)
Lys	4.81 (95)	3.32 (80)	4.51 (88)	3.53 (91)	3.75 (83)
Met	1.77 (94)	1.11 (77)	0.97 (88)	0.75 (93)	0.95 (86)
Thr	2.64 (88)	2.18 (77)	2.47 (83)	2.13 (88)	2.06 (77)
Trp	0.66 (88)	0.48 (75)	0.68 (87)	0.67 (90)	0.67 (83)
Val	3.03 (93)	2.51 (74)	3.03 (86)	2.55 (89)	2.60 (81)
Cys	0.57 (88)	0.65 (72)	0.68 (77)	0.61 (88)	0.49 (68)

[1] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[2] Poultry meal; Hubbard Feeds, Mankato, MN
[3] Protein Resources, West Bend, IA.
[4] Diets were prepared using the formulated values.
[5] Nutrient values from NRC (1998).
[6] Nutrient values provided by the manufacturer.
[7] ( ) indicate standardized ileal digestible amino acid coefficients (%) used in diet formulation.

Table 7. Composition of diets (as-fed basis)[1], Exp. 3

		PEP-NS[3,5]						
Ingredient, %	Pre-test[2]	0%	3%	6%	9%	12%	6% SMFM[6]	Phase 3[4]
Corn	38.50	53.70	53.90	53.45	38.36	38.35	38.31	62.80
Soybean meal, (46.5% CP)	25.00	31.55	28.30	25.85	22.20	22.19	22.21	32.25
Spray-dried animal plasma	5.00	---	---	---	---	---	---	---
Select menhaden fish meal	---	---	---	---	---	---	6.00	---
PEP-NS	---	---	3.00	6.00	9.00	12.00	---	---
Spray-dried whey	25.00	10.00	10.00	10.00	10.00	10.00	10.00	---
Soybean oil	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P, (21% P)	1.18	1.20	1.18	1.15	1.10	1.08	0.43	1.25
Limestone	1.03	0.88	0.93	0.93	0.98	1.00	0.48	1.05
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lys HCl	0.16	0.33	0.33	0.30	0.28	0.25	0.17	0.33
DL-met	0.13	1.6	0.16	0.15	0.15	0.14	0.09	0.14
L-thr	0.03	0.13	0.14	0.13	0.12	0.11	0.08	0.13
Phytase[8]	---	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calculated analysis[9]								
Standardized ileal digestible amino acids, %[10]								
Lys	1.40	1.30	1.30	1.30	1.30	1.30	1.30	1.26
Ile:lys	59	61	60	60	60	61	64	61
Met:lys	29	34	35	35	35	35	35	34
Met & Cys:lys	58	58	58	58	58	58	58	59
Thr:lys	63	63	63	63	63	63	63	63
Trp:lys	18.9	17.4	17.1	17.1	17.1	17.1	17.6	17.5
Val:lys	69	66	66	67	68	69	71	68
Total lys, %	1.55	1.44	1.45	1.46	1.46	1.47	1.44	1.39
CP, %	22.1	20.9	20.9	21.1	21.3	21.5	21.9	20.8
ME kcal/kg	3,140	3,333	3,333	3,331	3,331	3,329	3,371	3,349
Ca, %	0.90	0.75	0.76	0.75	0.75	0.75	0.75	0.76
P, %	0.79	0.69	0.69	0.68	0.68	0.67	0.68	0.66
Available P, %	0.55	0.47	0.47	0.47	0.47	0.47	0.47	0.34

[1]A total of 180 nursery pigs (initial BW 6.4 kg) were used in a 24-d trial to determine the effects of increasing PEP-NS on nursery pig growth performance.

[2] The pretest diet was a common diet fed the first 7 days post-weaning and was in pellet form.

[3] Phase 2 diets were fed from d 0 to 14 and were in meal form.

[4] Phase 3 diet was a common diet fed from d 14 to 24 and was in meal form.

[5] PEP-NS; Protein Resources, West Bend, IA.

[6] Special select menhaden fish meal; Omega Protein Corp., Houston.

[7] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.

[8] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 231 FTU/kg, with a release of 0.10 available P.

[9] Values for select menhaden fish meal were from the NRC (1998) and nutrient profiles for PEP-NS were provided by the manufacturer and used in diet formulation.

[10] Amino acid digestibility values for spray-dried plasma and respective vegetable protein carriers were averaged and used as the estimate of standardized amino acid digestibility of amino acids in PEP-NS.

Table 8. Analyzed nutrient composition of ingredients, Exp. 3

	SMFM[1]		PEP-NS[2]	
Item	Formulated[3,4,6]	Analyzed	Formulated[5]	Analyzed
CP, %	62.90	62.99	47.50	49.20
Amino Acids, %				
Ile	0.50 (88)	0.49	0.62 (68)	0.49
Leu	2.42 (94)	2.42	2.06 (83)	2.16
Lys	4.27 (94)	4.28	3.44 (72)	3.78
Met	4.57 (95)	4.67	3.50 (83)	3.44
Thr	1.66 (94)	1.55	0.97 (86)	0.95
Trp	2.32 (88)	2.56	2.06 (77)	2.05
Val	0.59 (88)	0.56	0.59 (83)	0.67
Cys	2.82 (93)	2.78	2.56 (81)	2.60

[1] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.
[2] Protein Resources, West Bend, IA
[3] Diets were prepared using the formulated values.
[4] Nutrient values from NRC (1998).
[5] Nutrient values provided by the manufacturer.
[6] ( ) indicate standardized ileal digestible amino acid coefficients (%) used in diet formulation.

Table 9. Effects of protein source on nursery pig performance[1], Exp. 1

Phase 1:[2] Phase 2:[3]	2.5% SDAP[7] Corn-SBM[9]	5% SDAP 3% SMFM[8]	3% SMFM 6% SMFM	3% PEP2+[4] 6% PEP2+	3% Peptone 50[5] 6% Peptone 50	3% PEP-NS[6] 3%PEP-NS	SEM
d 0 to 21							
ADG, g	251[c]	259[bc]	266[bc]	298[a]	279[ab]	277[ab]	14
ADFI, g	322[b]	334[ab]	334[ab]	358[a]	360[a]	353[a]	18
G:F	0.780[b]	0.778[b]	0.797[b]	0.834[a]	0.775[b]	0.784[b]	0.011
d 21 to 35[10]							
ADG, g	441	468	444	438	448	457	16
ADFI, g	790	821	799	826	811	818	16
G:F	0.557[ab]	0.569[a]	0.554[ab]	0.531[b]	0.552[ab]	0.558[ab]	0.014
d 0 to 35							
ADG, g	327[b]	343[ab]	337[ab]	354[a]	346[ab]	348[ab]	13
ADFI, g	510[c]	529[ac]	520[bc]	545[a]	537[ab]	539[ab]	13
G:F	0.641	0.647	0.646	0.649	0.643	0.647	0.011

[a,b,c] Within a row, means without a common superscript differ $P < 0.05$.

[1] A total of 360 nursery pigs (initial BW 5.4 kg) were used in a 35-d trial to determine the effects of fish meal , PEP2+, PEP50, PEP-NS on nursery pig growth performance. Pigs were randomly allotted to 1 of 6 dietary treatments with 5 pigs/pen and 12 pens per treatment,

[2] Fed from d 0 to 8 in pellet form.

[3] Fed from d 8 to 21 in meal form.

[4] PEP2; Protein Resources, West Bend, IA.

[5] Peptone 50; Protein Resources, West Bend, IA.

[6] PEP-NS; Protein Resources, West Bend, IA.

[7] Spray dried animal plasma; APC, Ames, IA.

[8] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.

[9] SBM = Soybean meal

[10] Common diet was fed from d 21 to 35.

Table 10. Effects of protein source on nursery pig performance[1,2], Exp. 2

Item	3% SDAP[3]	6% SMFM[4]	6% poultry[5]	6% PEP2+[6]	6% PEP-NS[7]	6% Peptone 50[8]	SEM
Initial wt, kg	5.66	5.61	5.71	5.65	5.64	5.66	---
d 0 to 21							
ADG, g	199^{c}	242^{ab}	230^{b}	247^{ab}	256^{a}	197^{c}	9
ADFI, g	288^{c}	343^{a}	322^{ab}	346^{a}	349^{a}	297^{bc}	11
G:F	0.693^{bc}	0.706^{ab}	0.713^{ab}	0.715^{ab}	0.735^{a}	0.665^{c}	0.015
d 21 to 39[9]							
ADG, g	503^{b}	529^{ab}	535^{ab}	543^{a}	544^{a}	519^{ab}	15
ADFI, g	802^{b}	881^{a}	870^{a}	890^{a}	912^{a}	813^{b}	20
G:F	0.628^{ab}	0.602^{c}	0.616^{ac}	0.611^{bc}	0.596^{c}	0.640^{a}	0.009
d 0 to 39							
ADG, g	334^{c}	375^{a}	368^{ab}	382^{a}	387^{a}	344^{bc}	11
ADFI, g	547^{c}	599^{a}	592^{ab}	605^{a}	616^{a}	559^{bc}	13
G:F	0.611	0.625	0.622	0.631	0.629	0.614	0.010

[a,b,c] Within a row, means without a common superscript differ $P < 0.05$.

[1] A total of 1,152 nursery pigs (initial BW 5.6 kg) were used in a 39-d trial. Pigs were randomly allotted to 1 of 6 dietary treatments with 32 pigs/pen and 6 pens per treatment.

[2] Used d 0 body weight as covariate in analysis.

[3] Spray dried animal plasma; APC, Ames, IA.

[4] Select menhaden fish meal; Hubbard Feeds, Mankato, MN.

[5] Poultry meal; Hubbard Feeds, Mankato, MN.

[6] PEP2; Protein Resources, West Bend, IA.

[7] Peptone 50; Protein Resources, West Bend, IA.

[8] PEP-NS; Protein Resources, West Bend, IA.

[9] Common diet was fed from d 21 to 39.

Table 11. Effects of increasing PEP-NS on nursery pig performance[1], Exp. 3

	PEP-NS[2]							Probability, *P* <		
Item	0%	3%	6%	9%	12%	6% SMFM[3]	SEM	Linear	Quadratic	6% PEP-NS vs. 6% SMFM
d 0 to 14										
ADG, g	197	289	353	373	327	351	12	<0.01	<0.01	0.91
ADFI, g	359	401	437	455	419	459	13	<0.01	<0.01	0.52
G:F	0.550	0.721	0.808	0.819	0.797	0.781	0.018	<0.01	<0.01	0.29
d 14 to 24[4]										
ADG, g	537	506	542	508	509	546	22.08	0.44	0.95	0.89
ADFI, g	759	721	762	741	732	784	23.58	0.64	0.95	0.51
G:F	0.701	0.698	0.710	0.687	0.695	0.699	0.020	0.58	0.99	0.67
d 0 to 24										
ADG, g	367	397	447	440	417	449	13.39	<0.01	<0.01	0.95
ADFI, g	559	561	600	598	569	617	16.39	0.27	0.10	0.46
G:F	0.658	0.707	0.746	0.737	0.733	0.729	0.015	<0.01	<0.01	0.42

[1] A total of 180 nursery pigs (initial BW 6.4 kg) were used in a 24-d trial. Pigs were randomly allotted to 1 of 6 dietary treatments with 5 pigs per pen with 6 pens per treatment.

[2] PEP-NS; Protein Resources, West Bend, IA.

[3] Special select menhaden fish meal; Omega Protein Corp., Houston, TX.

[4] Common diet was fed from d 14 to 24.

Chapter 5: Effects of Liquitein on Weanling Pigs Administered a Porcine Circovirus Type 2 (PCV2) and *Mycoplasma hyopneumoniae* (M.*hyo*) Vaccine Strategy

ABSTRACT

A total of 180 nursery pigs (PIC 327 × 1050, initially 5.7 ± 0.10 kg, and 19 ± 2 d of age) were used in a 35-d study to determine the effects of Liquitein and a PCV2/*M. hyo* vaccine regimen on the growth performance of weanling pigs. Liquitein (Protein Resources; West Bend, IA) is a water soluble source of plasma serum and energy provided in the drinking water immediately after weaning. Pigs were randomly allotted to 1 of 4 treatments arranged in a 2 × 2 factorial with main effects of Liquitein (with or without) and PCV2/*M. hyo* vaccine regimen (vaccinates or non-vaccinates). There were 5 pigs per pen and 9 pens per treatment. At weaning, pigs in the vaccinate group were given a full dose (2 mL) of ResprisureOne (Pfizer Animal Health) and Circumvent (Intervet/Schering-Plough Animal Health). On d 21, pigs in the vaccinate group were administered a second full dose (2 mL) of Circumvent as per label instructions. Liquitein was administered to the pigs via water medicators for the first 5 d after arrival to the nursery. There were no vaccine × Liquitein interactions for ADG or G:F throughout the study. From d 0 to 5, non-vaccinated pigs had a tendency ($P < 0.07$) for increased ADG. From d 21 to 35, pigs previously administered Liquitein had greater ADFI ($P = 0.05$) than those not provided Liquitein. However, overall (d 0 to 35) there were no effects of Liquitein on growth performance. From d 0 to 35, vaccinated pigs had decreased ($P < 0.01$) ADG and ADFI compared to non-vaccinated pigs. In conclusion, administering Liquitein during the first 5 d in the nursery increased feed intake later in the nursery stage (d 21 to 35) but the response was not great enough to influence overall growth performance; however, pigs administered the PCV2 and M.*hyo* vaccine regimen had decreased ADG and ADFI.

Key words: growth, liquid supplement, PCV2, pigs

INTRODUCTION

Weaning poses new challenges to the young pig such as a sudden change in diet and social hierarchy (Maxwell and Carter, 2001). Consequently, the first 24 to 72 h post-weaning pigs typically do not eat large quantities of feed (Steidinger et al. 2002). This becomes problematic because sufficient nutrient intake is imperative in maintaining gut integrity (Maxwell and Carter, 2001). To further confound the issue, anecdotal field reports have indicated that producers are having increased difficulty starting and maintaining weaned pigs on feed. This correlates with the concomitant vaccination of weaned pigs for Porcine Circovirus 2 (PCV2) and *Mycoplasma hyopneumonia* (M. *hyo*) (Potter, 2010). Kane et al. (2009) found that pigs administered PCV2/M. *hyo* vaccine regimen had decreased ADFI. Perhaps, providing nutrients through the water may be an effective method in combating post vaccination feed intake reduction.

Spray dried animal plasma has been shown to improve both growth performance and feed intake in newly weaned pigs (Gatnau and Zimmerman, 1990). Previous research has indicated that providing a water soluble plasma improved growth performance in newly weaned pigs (Ward and Cook, 2000; Miller and Toplis, 2001; Steidinger et al., 2002). Recently, a new product has become available, Liquitein. Liquitein is a high density ready to use source of serum and digestible energy and is shelf stable and can be administered through water lines during the weaning period or other times of low feed intake and stress. Thus, the objective of the study was to evaluate the effects of Liquitein

and Porcine Circovirus type 2 (PCV2) and *Mycoplasma hyopneumoniae* (M. *hyo*) vaccine regimen on growth performance of nursery pigs.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee.

A total of 180 nursery pigs (C327 ×1050, PIC, Hendersonville, TN) with an initial BW of 5.7 ± 0.10 kg and 19 ± 2 d of age were used in a 35-d study. Pigs were transported approximately 7 h (623 km) from the sow farm to the Kansas State University Segregated Early Weaning facility in Manhattan. The facility is a totally enclosed, environmentally regulated, mechanically ventilated barn with 40, 1.2 m^2 pens located over metal tri-bar flooring. Each pen housed 5 pigs and provided 0.30 m^2 floor space per pig. Pigs were provided unlimited access to feed and water via a 4-hole dry self-feeder (44 cm) and 1 cup waterer. Initial temperature was maintained at 32° C for the first wk then lowered 1.5° C each wk thereafter.

After arrival to the segregated early weaning facility, pigs were allotted to 1 of 4 treatments arranged in a 2 × 2 factorial with main effects of Liquitein (with or without) and PCV2 and *M. hyo* vaccine regimen (vaccinates or non-vaccinates). There were 5 pigs per pen and 9 pens per treatment.

Liquitein was provided to the pigs via water medicators (Select Doser 640; Genesis Instruments, Elmwood, WI) set at a ratio of 50:1 (50 parts water to 1 part Liquitein) for the first 5 d after arrival to the nursery. Liquitein is a ready to use product, which allowed for the water medicator to draw Liquitein directly out of the container

using peristaltic action to pump the product into the water. For all treatments, waterers were shut off until the pigs were finally allotted to their respective pens. After allotment, Liquitein treatments had their waterers flushed until Liquitein appeared in the cup. For the duration of the Liquitein treatment, the container containing the Liquitein was weighed daily and usage recorded. Lines distributing Liquitein were flushed daily to ensure a constant supply of product.

On d 0 (weaning), pigs in the vaccinate group were given a full dose (2 mL) each of RespriseOne (Pfizer Animal Health; New York, NY) and Circumvent (Invervet/Schering-Plough; Millsboro, DE). Again on d 21, pigs in the vaccinate group were administered a second full dose (2 mL) of Circumvent. All vaccines were administered as separate intramuscular injections according to label directions.

A common 3 phase diet was fed for the duration of the trial with each pen receiving the same diets. Phase 1 diets were fed from d 0 to 5 and were in pellet form. Phase 2 and 3 diets were fed from d 5 to 21 and d 21 to 35, respectively, and were in meal form. Pigs were weighed on d 0, 2, 5, 7, 14, 21, 23, 25 and 35. Feed disappearance was measured on d 0, 1, 2, 3, 4, 5, 7, 14, 21, 22, 23, 24, 25 and 35. The frequent weighing and feed intake measurements were done to determine the immediate effects of vaccine administration. These measurements were used to calculate average daily gain, average daily feed intake, feed efficiency, and dry matter intake.

Data was analyzed as a 2 × 2 factorial in a completely randomized design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Pen was used as the experimental unit. When significant interactions ($P < 0.05$) were observed, LSD's were the method used to separate the means. Results were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

No vaccine × Liquitein interactions were observed for ADG or G:F for the duration of the study.

One objective of our study was to evaluate ADG and ADFI immediately following administration of PCV2/M. *hyo* vaccination. To achieve this we measured ADFI daily for 5 d after the first ResprisureOne and Circumvent (d 0) and second Circumvent vaccination (d 21). By d 3 pigs in the non-vaccinate group had increased ($P < 0.05$) ADFI compared to pigs in the vaccinate group (Figure 1). On d 4, a vaccine × Liquitein interaction ($P < 0.05$) was observed for ADFI. The interaction is a result of non-vaccinated pigs that did not receive Liquitein via their drinking water having increased ADFI compared to all other treatments. On d 7, a vaccine × Liquitein interaction ($P < 0.05$) for was observed where pigs in the vaccinate group who had not been previously administered Liquitein having increased ADFI compared to all other treatments. Average daily gain (data not shown) was affected by dehydration of the pigs during transportation (approximately 7 h from IL) to the facility. From d 0 to 2, pigs gained over 300 g/d then ADG decreased to less than 100 g per d for d 2, and 5. From d 0 to 5, the period immediately following the first injection, there was a tendency ($P = 0.07$) for pigs administered PCV2/M. *hyo* vaccine regimen to have decreased ADG compared to the non-vaccinate group.

The stress associated with weaning is often characterized by a decrease in feed intake and ADG. To add to the stress of weaning it has been reported (Kane et al., 2009; Potter, 2011) that administration of a two-dose PCV2 product, Circumvent, and one dose M. *hyo* prouduct, ResprisureOne, have been shown to cause a post vaccination reduction

in ADG and ADFI. Our hypothesis was that perhaps providing additional nutrients via the drinking water would combat decreased ADG commonly seen at weaning and post vaccination. While not significant, pigs administered Liquitein during this period had a numerical tendency ($P = 0.11$) for increased ADG and DMADFI.

Previous research evaluating the effects of plasma protein administered via the water has shown a greater improvement in growth performance (Ward and Cook, 2000; Miller and Toplis, 2001; Steidinger et al., 2002) then what was seen in the present study. Miller and Toplis (2001) evaluated adding plasma to the feed, water, or both feed and water. They found that all 3 sources of plasma were effective in increasing growth rate the first wk after weaning. However, they noted that there was no additional benefit of adding plasma to both the feed and water. In the present study all pigs received a common early weaning diet containing 5% spray dried animal plasma (SDAP) during the period in which they received the Liquitein treatment, which could be a reason behind why no significant difference in growth rate was observed between pigs who received Liquitein and those who did not receive Liquitein. A difference between previously tested water-soluble plasma products and Liquitein is the blood fractions that each contain. The previously tested products contain SDAP, serum, and the globulin fraction of plasma, whereas, Liquitein solely contains serum as the only plasma fraction. The difference in blood fractions contained in the different products could be another reason behind the difference in results. Pierce et al. (2005) observed that the fraction of plasma that was responsible for the increased growth and feed intake commonly seen when feeding SDAP was the globulin fraction. Perhaps, the addition of globulin to the previously tested products could be the reason behind the increased ADG seen during those studies.

From d 5 to 21 and 0 to 21, pigs administered PCV2/M. *hyo* vaccine regimen had decreased ($P < 0.05$) ADG compared to pigs in the non-vaccinate group. No significant differences were observed for Liquitein.

From d 21 to 25, pigs administered PCV2/M. *hyo* vaccine regimen had lower ($P < 0.01$) ADG and ADFI compared to pigs in the non-vaccinate group. These results are similar to that of Potter et al. (2010) where pigs in the vaccinate group who received a second dose of PCV2 product, Circumvent, on d 21 had a decrease in ADG and ADFI. As a result of the reduced feed intake there was a tendency ($P < 0.07$) for pigs administered PCV2/M. *hyo* vaccine regimen to have decreased G:F compared to pigs in the non-vaccinate group. No significant differences were observed for Liquitein.

One factor that could have exacerbated the effects of the second injection could have been that the pigs were switched from a phase 2 diet to the phase 3 diet on the same day that the second Circumvent injection was given (d 21). The main difference between these two diets is their complexity as the phase 2 diet contained specialty protein and lactose sources (6% PEP-NS and 10% dried whey), while phase 3 was a less complex corn-soybean meal-based diet. Switching diets at the same time the second injection was given may have caused an increase in stress and contributed to the performance differences seen. Hyun et al. (1998) noted that multiple stressors have an additive effect and that by removing a single stressor could positively impact growth performance. Potter (2011) suggested that perhaps altering vaccination timing as a means of removing a single stressor could reduce the negative impacts on seen on growth performance. Perhaps the stress of diet change and vaccination could explain the decrease in growth performance seen from d 21 to 23 and 23 to 25, where pigs administered PCV2/M. *hyo*

vaccine regimen had decreased ($P < 0.05$) ADG compared to pigs in the non-vaccinate group (Figure 2). On d 23 and 35, pigs in the non-vaccinate group had increased ($P < 0.05$) ADFI compared to pigs in the vaccinate group (Figure 3).

From d 21 to 35, pigs administered PCV2/M. *hyo* vaccine regimen had decreased ($P < 0.01$) ADG and ADFI compared to pigs in the non-vaccinate group. Pigs previously administered Liquitein had increased ($P < 0.05$) ADFI compared to pigs that were not provided Liquitein. It is unclear why we saw that pigs previously administered Liquitein had increased ADFI during this period. However, other studies that have evaluated Liquitien have also observed the same post administration increase in ADFI (unpublished data). Several theories have evolved regarding the increase in ADFI observed post Liquitein administration. Perhaps Liquitein aids in maintaining the gut brush border helping to boost immunity and consequently improving the piglet's ability to handle the stress of the second vaccination.

Overall, no significant differences were observed for Liquitein. Pigs administered PCV2/M. *hyo* vaccine regimen had decreased ($P < 0.01$) ADG and ADFI compared to pigs in the non-vaccinate group. Our findings coincide with those of Potter (2011), Kane et al., (2009), and Shelton et al., (2009) where pigs administered a PCV2/M. *hyo* vaccine regimen had decreased nursery growth performance and feed intake. The reasoning behind the decreased growth performance associated with PCV2/M. *hyo* vaccines is not completely understood. However, it has been thought that perhaps the adjuvants associated with vaccines may elicit the reduction in growth performance. Aucouturier et al., 2001 stated that adjuvants affect growth performance and reproduction rate as well as impact animal comfort and carcass quality. The two products evaluated in the present

studies utilize water-in-oil emulsions which have been shown to be damaging to tissues due to the high oil content (Aucouturier et al., 2001) causing an increased inflammatory response that reduces feed intake and growth rate (Potter, 2010).

Another possibility behind the decrease in growth performance following vaccination could be due to immune stimulation. It is possible that immune system activation causes a redirection of nutrients from productive growth to development of protective immunity or immune response necessary counteract disease processes (Colditz, 2002). Schinckel et al., (1995) observed that when numerous antigens were administered to early-weaned nursery pigs growth rate and feed intake were negatively affected. Perhaps, the decrease in performance post-vaccination could be attributed to the added metabolic cost of building immunity (Potter, 2010).

IMPLICATIONS

No benefit of administering Liquitein the first 5 d post-weaning was observed. However, we did note an increase in ADFI from d 21 to 25 in pigs previously administered Liquitein. Our findings coincide with previous research where pigs vaccinated a with Circumvent/Resprisure One vaccine regimen had decreased growth performance during the nursery period (d 0 to 35). Further research needs to be done to evaluate both Liquitein's and PCV2/M. *hyo* effects on nursery pig growth performance

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

Item	SEW[2]	Phase 2[3]	Phase 3[4]
Ingredient, %			
Corn	38.50	53.45	62.80
Soybean meal (46.5% CP)	25.00	25.85	32.25
Spray-dried animal plasma	5.00	---	---
Select menhaden fish meal	---	---	---
PEP-NS	---	6.00	---
Spray-dried whey	25.00	10.00	---
Soybean oil	3.00	1.00	1.00
Monocalcium P (21% P)	1.18	1.15	1.25
Limestone	1.03	0.93	1.05
Salt	0.35	0.35	0.35
Zinc oxide	0.25	0.25	0.25
Vitamin premix[5]	0.25	0.25	0.25
Trace mineral premix[5]	0.15	0.15	0.15
L-lys HCl	0.16	0.30	0.33
DL-met	0.13	0.15	0.14
L-thr	0.03	0.13	0.13
Phytase[6]	---	0.05	0.05
Total	100.00	100.00	100.00
Calculated analysis			
Standardized ileal digestible amino acids, %			
Lys	1.40	1.30	1.26
Ile:lys	59	60	61
Met:lys	29	35	34
Met & Cys:lys	58	58	59
Thr:lys	63	63	63
Trp:lys	18.9	17.1	17.5
Val:lys	69	67	68
Total lys, %	1.55	1.46	1.39
CP, %	22.1	21.1	20.8
ME kcal/kg	3,140	3,331	3,349
Ca, %	0.90	0.75	0.76
P, %	0.79	0.68	0.66
Available P, %	0.55	0.47	0.34

[1] A total of 180 nursery pigs (C327 ×1050, PIC, Hendersonville, TN) with an initial BW of 5.7 kg and 19 ± 2 d of age were used in a 35-d study.

[2] The SEW diet was a common diet fed the first 7 days post weaning and was in pellet form.

[3] Phase 2 diets were fed from d 0 to 14 and were in meal form.

[4] Phase 3 diet was a common diet fed from d 14 to 24 and was in meal form.

[5] Provided (per kilogram of complete diet) 11,025 IU of Vitamin A; 1,654 IU of Vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin k (as menadione dimethylpyrimidinol bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as D- calcium pantothentate); 9.9 mg of riboflavin; 0.044 mg of vitamin B_{12}; 16.5 mg of Cu as $CuSO_45H_2O$; 165.4 mg of Fe as $FeSO_4H_2O$; 39.7 mg of Mn as $MnSO_4H_2O$; 0.30 mg of Se Na_2SeO_3; 165.4 mg of Zn as ZnO; and 0.30 mg of I as $C_2H_2(NH_2)_22HI$.

[6] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 231 FTU/kg, with a release of 0.10 available P.

Table 2. Effects of Liquitein and vaccine regimen on nursery pig performance[1]

	Liquitein[2]		No-Liquitein					
Item	No	PCV2/M. *hyo*	No	PCV2/ M. *hyo*	SEM	V × L[4]	Vaccine	Liquitein
d 0 to 5								
ADG, g	175	160	162	135	11		0.07	0.11
ADFI, g	107	103	110	89	9	0.60	0.17	0.52
DMADFI, g	103	100	98	79	8	0.30	0.17	0.10
G:F	1.675	1.599	1.489	1.529	0.09	0.31	0.85	0.18
DM G:F[3]	1.722	1.635	1.669	1.714	0.09	0.54	0.82	0.89
d 5 to 21						0.48		
ADG, g	316	287	303	298	9		0.04	0.85
ADFI, g	415	396	412	394	14	0.31	0.19	0.86
G:F	0.764	0.728	0.751	0.757	0.016	0.98	0.34	0.60
d 0 to 21						0.19		
ADG, g	214	199	208	186	9		0.05	0.30
ADFI, g	232	217	226	207	11	0.72	0.15	0.48
G:F	0.925	0.918	0.927	0.904	0.025	0.83	0.54	0.82
d 21 to 25						0.76		
ADG, g	410	280	351	281	19		<0.01	0.13
ADFI, g	643	476	587	499	24	0.11	<0.01	0.49
G:F	0.638	0.585	0.597	0.566	0.023	0.10	0.07	0.20
d 21 to 35						0.63		
ADG, g	500	443	475	411	21		<0.01	0.18
ADFI, g	865	757	816	726	20	0.87	<0.01	0.05
G:F	0.579	0.586	0.582	0.568	0.024	0.66	0.87	0.76
d 0 to 35						0.65		
ADG, g	370	330	354	320	11		<0.01	0.21
ADFI, g	551	496	530	483	13	0.83	<0.01	0.23
G:F	0.671	0.666	0.669	0.664	0.016	0.78	0.76	0.88

[1] A total of 180 nursery pigs (C327 ×1050, PIC, Hendersonville, TN) with an initial BW of 5.7 kg and 19 ± 2 d of age were used in a 35-d study to evaluate the effects of Liquitein and Porcine Circovirus type 2 (PCV2) and *Mycoplasma hyopneumoniae* (M. *hyo*) vaccine regimen on growth performance of nursery pigs.

[2] Liquitein (Protein Resources; West Bend, IA) was added to the water lines at a ratio of 50:1. Liquitein disappearance was measured by weighing the container and was 0.50, 0.77, 2.36, 0.18, and 0.73 kg for days 1, 2, 3, 4, 5, respectively.

[3] Calculated by dividing ADG by DM intake from both feed and liquid.

[4] V × L = Vaccine x Liquitein interaction.

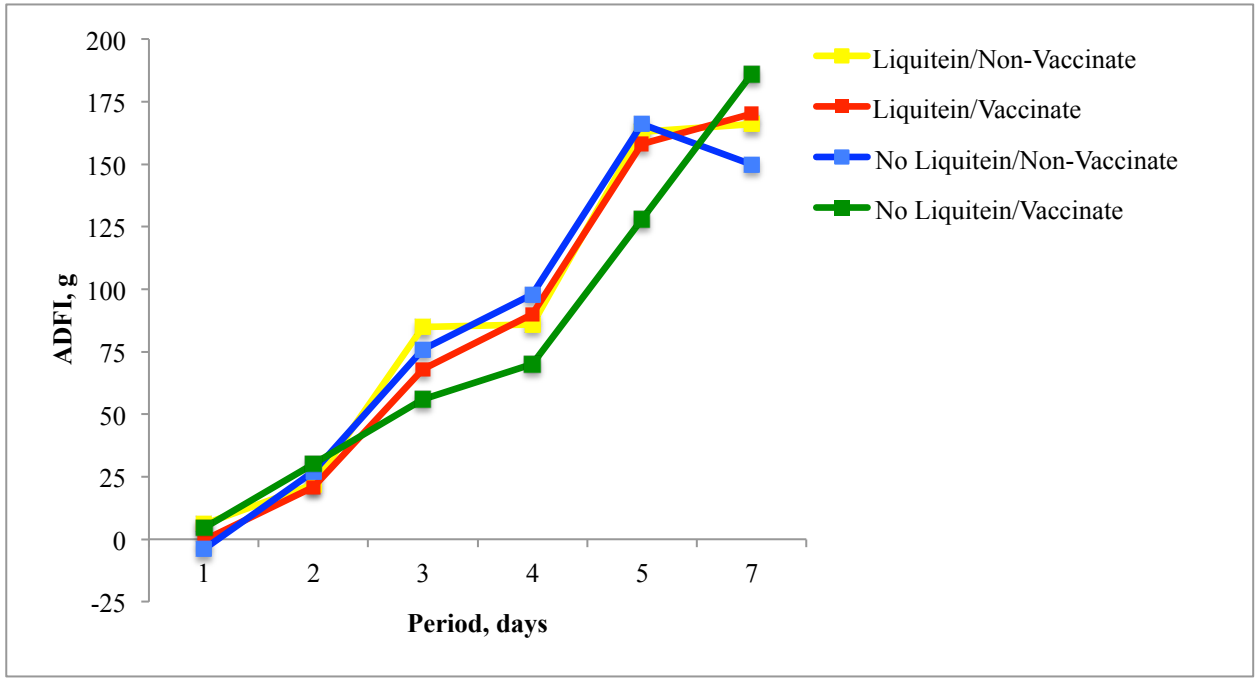

Figure 1: Effects of Liquitein and PCV2/M. *hyo* vaccine strategy on ADFI.
* $P < 0.05$, main effect of vaccine.
** $P < 0.05$, vaccine × Liquitein.

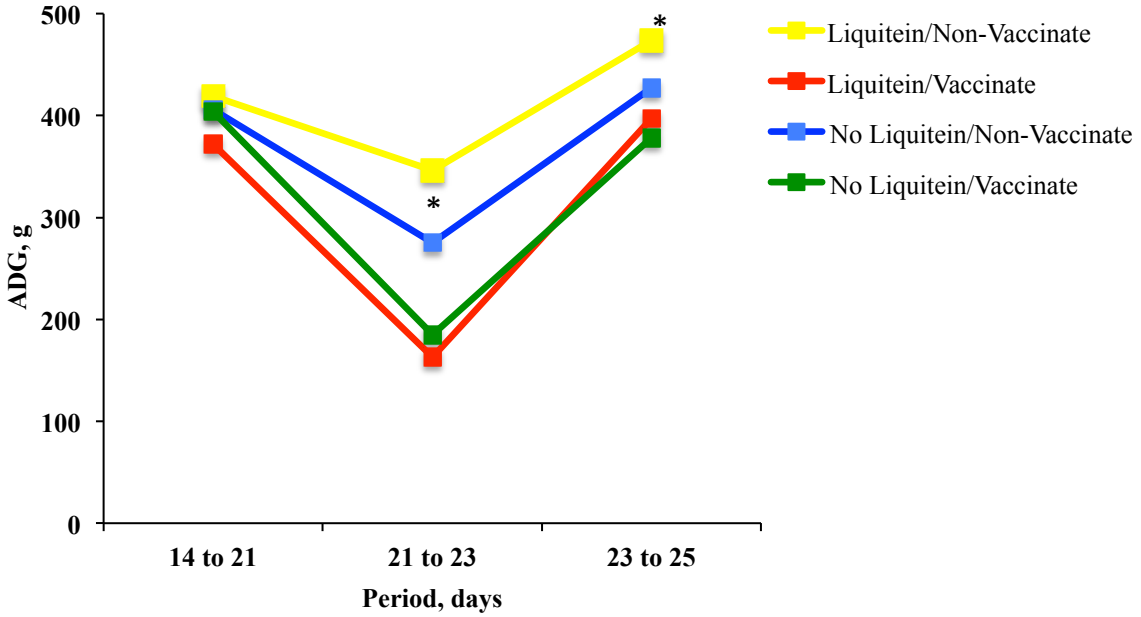

Figure 2: Effects of Liquitein and PCV2/M. *hyo* vaccine strategy on ADG.
* $P < 0.05$, main effect of vaccine.

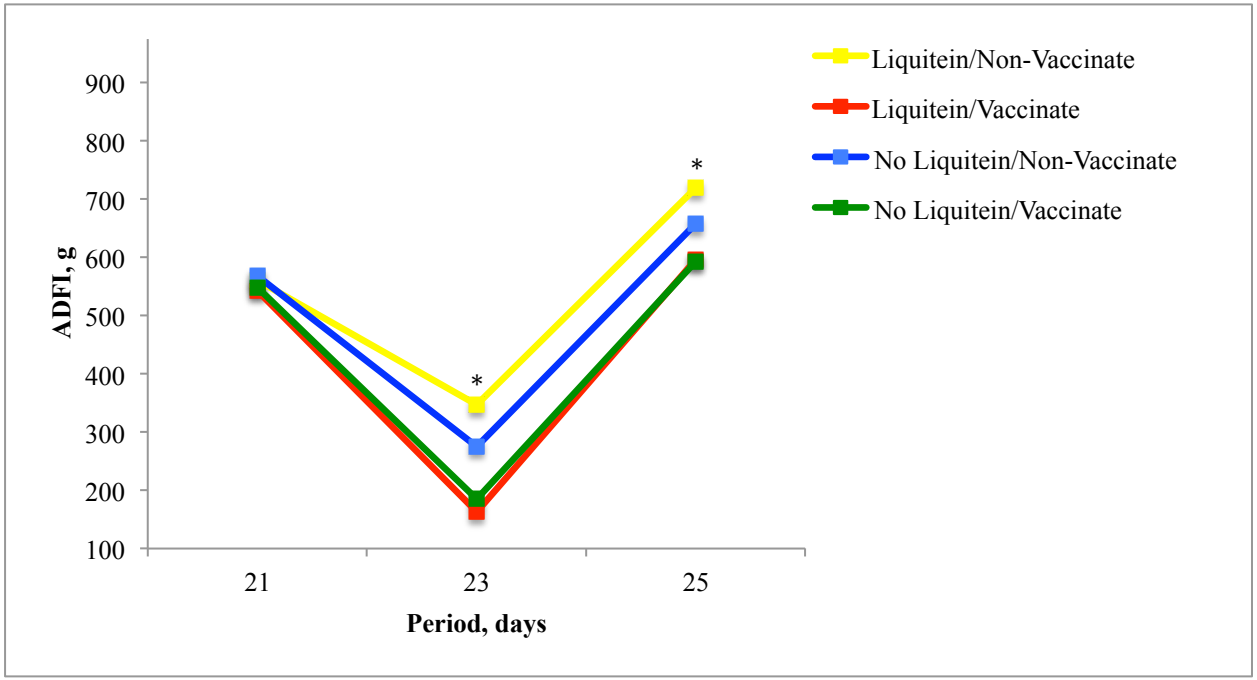

Figure 3: Effects of Liquitein and PCV2/M. *hyo* vaccine strategy on ADFI.
* $P < 0.05$, main effect of vaccine.