RESEARCH REPORT
ANIMAL SCIENCE

Title: Nutritional strategies to reduce nursery-finisher disease severity - **#20-114 IPPA**

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Industry Summary:
Our goal was to better understand how to nutritionally manage poor-health pig flows to maximize pig performance in the face of disease pressures. Two objectives were addressed in three experimental studies. Objective #1 investigated dietary mitigation strategies to alleviate the impact of Rotavirus (and E. coli.) on nursery pig performance and mortality. Objective #2 examined the role of amino acid and energy in post disease compensatory gain. As nursery pigs are frequently faced with enteric disease challenges, Objective #1 evaluated different nutritional strategies to improve nursery pig performance in enterically challenged pig flows. These data showed that therapeutic minerals (zinc and copper) are effective at improving pig growth. Further, oat groats, soyhulls and beet pulp were all equal in pig performance. Medium chain fatty acids formulated at ~2% in the diet decreased pig performance. No differences in mortality were reported across dietary strategies examined. In objective #2, in response to PRRS virus challenge, increasing dietary Lys:ME by 115-130% at 21 days post-inoculation or infection did not increase pig performance. Thus, we conclude that the benefits of increase dietary Lys:ME are only seen when these diets are in place at the time of PRRS virus infection. Lastly, we observed no compensatory gain in post-challenge in this study. For further information, please contact Nicholas Gabler (ngabler@iastate.edu).

Key Findings:

- Medium chain fatty acids attenuated nursery pig performance, while high soybean meal, modified oats and increased branch chain amino acid diets fed in phases 1 and 2 had no longitudinal impact on pig performance or health.
- Therapeutic zinc and copper improved early nursery growth performance of enteric challenged nursery pigs.
- No differences in pig early pig performance were observed between oat groats, soyhulls and beet pulp when formulated in the diet at 5%.
- In response to PRRS virus challenge, increasing dietary Lys:ME by 115-130% 21 days post-inoculation or infection did not increase pig performance.
- The benefits of increase dietary Lys:ME are only seen when these diets are in place at the time of PRRS virus infection.

Keywords: Nutrition, health, disease, lysine, energy, nursery, finisher

Scientific Abstract:
This research was to better understand how to nutritionally manage poor-health pig flows that are prone to rotavirus and PRRS virus exposure to obtain maximal performance in the face of disease pressures. Two objectives were addressed in three experimental studies. Nursery pigs are frequently faced with disease challenges and producers are seeking nutritional strategies to help pig performance and health. In Objective 1A, we evaluate five dietary formulation strategies that may improve performance in poor health nursery flow pigs (confirmed Rotavirus A and hemolytic E. coli positive at d 14). A total of 431 weaned pigs (5.5 ± 1.25 kg BW) were assigned to pens (10-11 pigs/pen) and one of five diets (n=8 pens/treatment) over a 63-day test period consisting of 4 diet phases using a complete randomized design. In phase 1 and 2, treatments were: 1) 15-25% low soybean meal (LSBM), 2) 35-45% high soybean meal (HSBM), 3) 130% increase in valine and isoleucine branched-chain amino acids (BCAA) to Lys, 4) 2.1% combination of C8, C10 and C12 medium chain fatty acids (MCFA), and 5) 20% modified oats (MO). All pigs were fed a common diet for phases 3 and 4. Within phase, all diets were isocaloric with similar SID Lys:ME. Pen was considered the experimental unit and data were analyzed with contrast statements comparing each diet against the LSBM control. Across all phases, compared to LSBM, HSBM, BCAA and MO did not alter ADG, ADFI and G:F ($P > 0.10$). However, MCFA reduced ($P < 0.05$) ADG in phase 1 (0.20 vs 0.16 kg) and 2 (0.45 vs 0.39 kg) and phase 2 ADFI (0.66 kg vs 0.58 kg) compared to the LSBM treatment. Overall (0-63 days), compared to the LSMB, the MCFA treatment reduced ADG (0.46 vs 0.42 kg, $P = 0.004$) and ADFI (0.75 vs 0.68 kg, $P = 0.009$). Diet did not affect mortality. These data report that MCFA attenuated nursery pig performance, while HSBM, MO and BCAA diets fed in phases 1 and 2 had no longitudinal impact on pig performance or health. In objective 1B, 72 newly weaned pigs, 19-21 days of age (PIC 337 x 1050), were selected from a pig flow and determined positive for coccidia, rotavirus A, B and C, and toxigenic F18 E. coli. Pigs were housed in individual pens and randomly allotted to one of four dietary treatments (Table 3) for 14 days (n=18 pigs/trt): 1) Control, containing 5% oat groats, 2) #1 plus 3000 ppm zinc and 200 ppm copper, 3) As #1, no oats, but 5% soyhulls and 4) As #1, no oats, but 5% sugar beet pulp. Body weights and feed intake recorded to calculate ADG, ADFI and feed efficiency (G:F) on day post-weaning 0, 7 and 14. Daily feed intake was recorded by weighing feed disappearance daily. In objective 2, increasing dietary SID Lys:ME augments growth performance of Porcine Reproductive and Respiratory Syndrome virus (PRRSV) challenged pigs when diets with greater SID Lys concentrations are in place at time of infection. Our objective was to evaluate the delayed implementation of increased SID Lys:ME diets post PRRSV challenge on pig performance. 491 grower pigs (45.8 ± 7.4 kg BW) were assigned to one of three dietary strategies (n=16 pens/treatment, 10-11 pigs/pen). All pigs received a common diet from day post inoculation (dpi) -14 to dpi 21 (Phase 1), that met SID Lys:ME recommendations. From dpi 21 to 77 (market body weight), dietary treatments were implemented in two dietary phases (P2 and P3). The three treatments were 2.23 g/Mcal (100%), 2.56 g/Mcal (115%), 2.90 g/Mcal (130%) in P2; and 1.92 g/Mcal (100%), 2.21 g/Mcal (115%), 2.49 g/Mcal (130%) in P3. On dpi 0, all pigs were inoculated with PRRSV. Pig BW, feed disappearance and feed efficiency were determined in each phase. Data were analyzed with pen as the experimental unit in a complete randomized design. During P1, ADG, ADFI, or G:F did not differ ($P<0.05$). In P2 and P3, ADG, ADFI, or G:F did not differ between the 100%, 115% and 130% treatments ($P > 0.10$). Overall, ADG (0.90, 0.90 and 0.92 kg/d, $P = 0.44$) and ADFI (2.61, 2.57 and 2.57 kg/d, $P = 0.48$) did not differ between the 100%, 115% and 130% treatments, respectively. However, overall G:F was significantly higher for the 130% compared to the 100% and 115% treatments (0.36 versus 0.34 and 0.35, respectively; $P = 0.021$). Mortality was similar across treatments ($P = 0.717$). In conclusion, delayed feeding of diets with increased SID Lys:ME post infection was not beneficial to pig performance and this diet strategy needs to be in place near time of disease challenge.

Introduction: The health and productive performance of the U.S. swine herd is critical for sustainable and profitable pork production. However, a continuous challenge to Iowa pork producers is the constant and inevitable pressure of bacterial and viral pathogens in the production system. These challenges may be exacerbated with the loss and restrictions of technologies used to improve growth and control disease. There is also a critical need to understand the lifetime impact of endemic diseases and how nutritional management strategies may be used to mitigate the negative effects of these disease. In suckling-nursery pigs, a major cause of gastroenteritis is Rotavirus A, B and C. This virus is endemic in our swine herds and is transmittable by oral-fecal route. Infected pigs have reduced absorptive function and capacity due to the destruction of small intestinal enterocytes or absorptive cells. Rotavirus is also seen as a co-factor of pathogenic E. coli induced disease in nursery pigs. Surprisingly, there is little information and data available to producers to guide them in nutrition and disease prevention decisions to better manage nursery pigs' positive for rotavirus. In grow-finish pigs, PRRS virus is a major endemic respiratory pathogenic agent that antagonizes growth performance and promotes secondary pathogen infection. We and others have estimated that PRRS virus costs producers $3-30 per finisher pig (Schweer et al., 2017). Our group has extensively studied how PRRS impacts growing pig longitudinal performance. We believe that utilizing compensatory growth mechanisms in today's high growth rate pigs, could be a way for producers to reduce the performance attenuations typically reported in PRRS infected grow-finish pigs. This work is even more critical in the face of reduced use of ractopamine in late finishing. Thus, the overarching goal of this research was to better manage poor-health pig flows within our industry that are prone to rotavirus and PRRS virus exposure to obtain maximal performance in the face of disease pressures. Further, the work proposed utilize pigs of negative health status, which are often overlooked, to study nutritional management and the longitudinal impacts of disease in wean to finish pigs.

Objectives: To address our overarching goal of finding ways to better feed and manage poor-health pig flows (i.e. pig flows prone to rotavirus and PRRS virus) within our industry to obtain maximum growth performance in the face of disease pressures, two objectives will be addressed:

Objective #1. Investigate dietary mitigation strategies to alleviate the impact of Rotavirus (and E. coli.) on nursery pig performance and mortality.
The rationale behind this objective was that Rotavirus A, B and C, and other enteric pathogens, are endemic in Iowa and a constant challenge to nursery pigs. This virus can cause the onset of diarrhea, usually a white to yellow color, dehydration, hairy coats, and reduced absorptive capacity of the intestinal epithelium in suckling and nursery pigs. The sub-clinical to clinical disease is most common in 3 to 6 week old pigs and ultimately leads to reduced growth performance and mortalities. Furthermore, unlike pathogenic E. coli, limited data is available as to how to best start and feed rotavirus positive/shedding pigs in the nursey. Thus, we evaluated nursery diet formulations that differ in functional ingredients that may abate enteric associated disease in commercial pigs. These diets included high and low soybean meal, medium chain fatty acids (MCFA), branch chain amino acids (BCAA), soluble fiber or therapeutic mineral formulations. In this objective, we hypothesized that increasing soluble fiber or MCFA in early nursery diets will alleviate enteric disease pressure from rotavirus and other enteric pathogens. This will translate into reduced medications and improved growth performance and wellbeing of weaned pigs.

Objective #2. Examine the role of amino acid and energy nutrition in post disease compensatory gain.
In this second objective, the rationale is that PRRS attenuates growth performance of grow-finish pigs (Schweer et al., 2017; Jasper et al., 2020). Nevertheless, post-disease grow-finisher pigs may compensate for this reduced performance with "catch-up" growth. However, it is unclear if producers are providing adequate amino acids and energy nutrition at this time to maximize post-disease compensatory growth. Therefore, this objective evaluated and determine the dietary amino acid needs of pigs post-disease to maximize lean growth accretion. We have previously reported that increasing Lys:ME by 110% to 120% above NRC requirements improved performance and feed efficiency during an experimental and natural PRRSV challenges (Schweer et al., 2017; Jasper et al., 2020). Further, although lysine is considered the first limiting essential amino acid, branch chain amino acids such as leucine, isoleucine and valine have the potential to enhance protein synthesis via activating the mTOR pathway (Fan et al., 2017; Wang et al., 2018). Therefore, we hypothesis that compensatory growth post-disease can be enhanced by optimizing essential and branch chain amino acid nutrition. This will allow producers to regain lost growth during peak disease.

Materials & Methods:
Objective #1. *Nursery Study 1A.* In the first turn of nursery pigs utilizes, our objective was to evaluate five dietary strategies that may improve performance of poor health nursery pigs. A total of 431 weaned pigs (5.5 ± 1.25 kg starting BW; Maschhoffs proprietary genetics) were utilized. Post-weaning and shipping to Iowa, these pigs were randomized to pens (n=8 pens/treatment) using a completely randomized design across two barns. Pens were then randomly assigned to one of five dietary treatments that were fed in the first two phases. Four dietary phases were fed over a 63-day nursery test-period. The phases were:

Phase 1: treatment diets (d0 – d14)
Phase 2: treatment diets (d14 – d28)
Phase 3: common diet (d28 – d42)
Phase 4: common diet (d42 – d63)

In phases 1 (Table1) and 2 (Table 2), the five dietary treatments included:

- As #1 + 15-25% Low Soybean Meal (LSBM)
- 35-45% High Soybean Meal (HSBM)
- As #1 + 130% Increase in valine and isoleucine branched-chain amino acids (BCAA)
- As #1 + 0.7% of each C:8, C:10, C:12 (2.1% total) medium-chain fatty acids (MCFA) fed as a non-esterified form
- As #1 + 20% Modified Oats, high inulin (MO)

Data were collected on day post-weaning 0, 7, 14, 21, 28, 42 and 63 and included body weights and feed intake recorded to calculate ADG, ADFI and feed efficiency (G:F). Rectal-fecal swabs and blood collected for routine diagnostics within each phase. From day 0-28, fecal scores recorded on a 1-4 scale, with 1 being firm to 4 representing loose, watery diarrhea fecal consistency. Mortality and removals were recorded over the 9-week period. The nursery pigs were vaccinated for PCV2 and tested PCR positive for Rotavirus A and culture positive for Hemolytic E. coli at day 10 post placement.

Objective #1. *Nursery Study 1B.* 72 newly weaned pigs, 19-21 days of age (PIC 337 x 1050), were selected from a pig flow and determined positive for coccidia, rotavirus A, B and C, and toxigenic F18 E. coli. Pigs were housed in individual pens and randomly allotted to one of four dietary treatments (Table 3) for 14 days (n=18 pigs/trt):

1. Control, containing 5% oat groats
2. As #1 plus 3000 ppm zinc and 200 ppm copper
3. As #1, no oats, but 5% soyhulls
4. As #1, no oats, but 5% sugar beet pulp

Body weights and feed intake recorded to calculate ADG, ADFI and feed efficiency (G:F) on day post-weaning 0, 7 and 14. Daily feed intake was recorded by weighing feed disappearance daily.

Objective #2. *Grow-Finish Study.* The concept of compensatory growth has been observed to achieve body weight gain on grow-finish pigs that have experienced health challenges. However, we do not know the extent of maximizing compensatory gain post disease is largely unknown. It is unclear if nutrition is optimal to support this increased growth. In the first turn of grow-finish pigs, our objective was to evaluate and determine the dietary amino acid needs of pigs post-disease to maximize lean growth accretion. In this study design, the same Maschhoffs proprietary genetics pigs used in the nursery period were blocked by nursery treatment across three grow-finish treatment groups (16 pens/trt consisting of 9-11 pigs/pen). Starting at ~45 kg BW (~10 weeks post-weaning, dpi -14), all pigs were fed a common diet from dpi -14 to dpi 21. All pigs were challenged with a field isolate of PRRS virus (ORF5, 1-3-4) intramuscularly at dpi 0. At dpi 21 to market, 16 pens/trt were assigned to either:

i. Control (NRC requirements)
ii. 115% SID lysine:ME of control
iii. 130% SID lysine:ME of control

These diets represented either feeding pigs close to their optimal Lys:ME ration, placing them back one phase or placing back two diet phases. Diet phases changed approximately every 21-28 days until mark weight was achieved. Pig body weights and pen feed disappearance were recorded at dpi -14, 0, 7, 21, 35, 49, 64 and end, and pen ADG, ADFI and Gain:Feed recorded.

Results and Discussion:

Previous research has demonstrated the efficacy of novel feed ingredients in modulating pathogen loads. For instance, MCFA have been reported to mitigate the severity of Porcine Epidemic Diarrhea virus (PEDV) in feed (Dee et al., 2016; Cochrane et al., 2020; Gebhardt et al., 2020; Jackman et al., 2020). Further, we have shown that dietary soluble fiber, derived from the increased inclusion of sugar beet pulp, improved growth performance, decreased the incidence of diarrhea, fecal shedding and adherence of E. coli to the ileal epithelium in F18 enterotoxigenic Escherichia coli (ETEC) challenged nursery pigs (Li et al., 2019). However, more bioassays need to be conducted to test the true benefit of modified diets on nursery pig performance and health in the presence of enteric pathogenic burden. To address this, Objective #1 evaluated different nutritional strategies to improve nursery pig performance in naturally enterically challenged pig flows that were prone to rotavirus and hemolytic E. coli.

Objective #1A. When compared to the LSBM, the HSBM treatment, despite a higher fecal score (Figure 1), did not differ in ADG, ADFI, and G:F (Table 4). Increasing the BCAA content of phase 1 and 2 diets by 130% did not show evidence of increased protein accretion through growth performance (Table 4). The use of modified oats high in inulin did not alter nursery pig performance (Table 4) or reduce fecal scores (Figure 1). Surprisingly, our preliminary analysis reported that inclusion of C:8, C:10, & C:12 (1:1:1) at 2.1% inclusion negatively impacted pig performance (Table 4). We speculate that the use of the non-esterified free fatty acid forms may have reduced palatability of the feed and thus ADG. No differences in mortalities/pulls across dietary treatments (4-5%) were reported.

Objective #1. *Nursery Study 1B.* Pooled fecal diagnostics of incoming pigs showed that the population was positive for rotavirus (Ct values of 23, 26 and 18 for rotavirus A, B and C, respectively). Further, bacterial cultures were moderate for Salmonella growth and had high hemolytic E. coli growth. The E. coli was F18 pilus positive and LT, STb, STx2, STx2e and EAST toxin positive. Over the 14-day test period, daily feed intake (Figure 1) did not significantly differ by diet ($P > 0.05$), but increased over time ($P < 0.05$). However, soyhull fed pigs were numerically slower to get on feed post-weaning ($P > 0.10$). Thus, day 0-14 QADFI did not differ between treatments ($P = 0.148$, Table 5). Over the test period, therapeutic zinc and copper treatment increased ADG over the control by 250%, while soyhulls and beat pulp diets were intermediate ($P > 0.05$, Table 5). Although highly variable, day 0-14 Gain to Feed ratios did not differ between dietary treatments.

Objective #2. *Grow-Finish Study.* All performance data are reported in Table 6. As expected, from dpi -14 to 0 and dpi 0-21, all pigs performed similarly on the same diets. Further, ADG and ADFI were reduced by 36 to 48% due to the PRRS virus challenge. Post dpi 21, when the three Lys:ME dietary treatments were fed, at any time point (dpi 21-35, 35-49, 49-end), no differences were reported in ADG, ADFI or Gain:Feed ($P> 0.05$; Table 6). However, Gain:Feed was significantly higher from dpi 0-end when pigs were fed Lys:ME ratio's 130% higher than recommended. Overall, grow-finish mortality rates were not different due to diet strategy, ranging from 6-9% mortality (Table 6). We have previously reported that increasing Lys:ME by 110% to 120% above NRC requirements improved performance and feed efficiency during an experimental and natural PRRSV challenges when diets were given at the time of the challenge (dpi 0) (Schweer et al., 2017; Jasper et al., 2020).

Conclusion:

Upon evaluation of dietary strategies to improve nursery pig performance (Objective 1), feeding a more complex diet to low health nursery pigs did not improve growth in phases 1 and 2. Only therapeutic zinc and copper improved early nursery growth performance of enteric challenged nursery pigs. No differences in pig early pig performance were observed between oat groats, soyhulls and beet pulp when formulated in the diet at 5%. The most cost-effective strategy for producers facing enteric disease pressure within their nursery flow is to feed a low or high soybean meal diets. In Objective #2, these data highlight that practically increasing Lys:ME by placing pigs back one phase or placing them back two diet phases to increase Lys:ME 115-130% at 21 dpi, did not enhance pig growth or compensatory gain based of the performance data collected. Thus, increasing the dietary Lys:ME appears best when implemented close to the challenge initiation.

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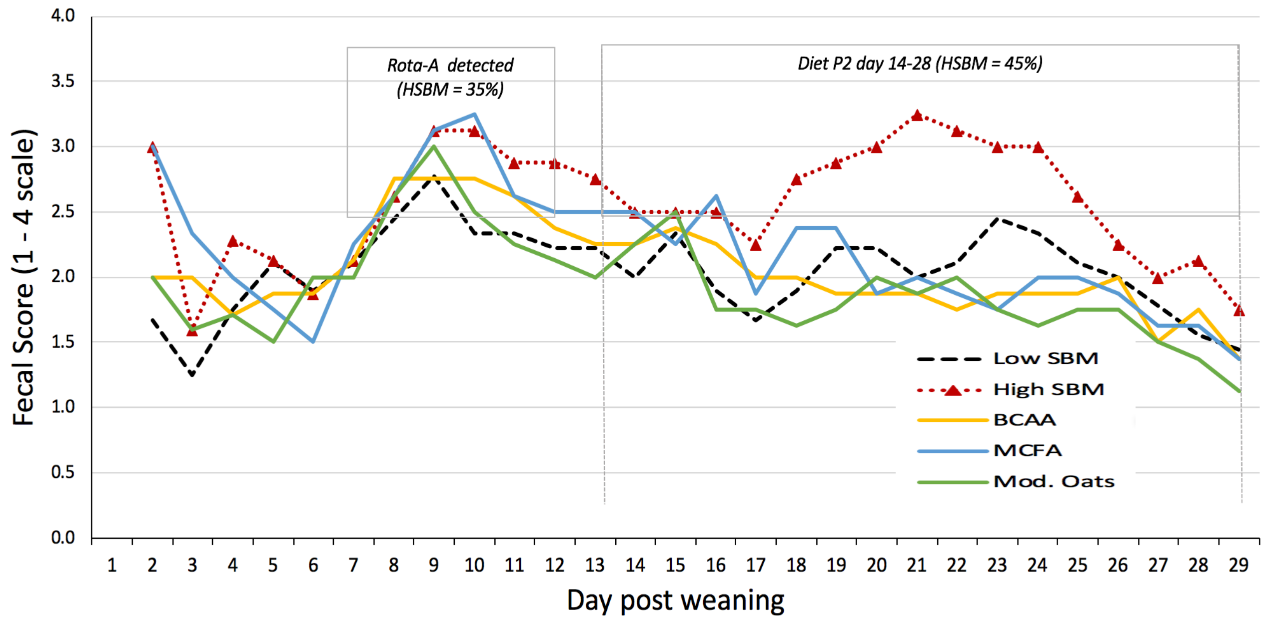

Figure 1. Objective #1A Day 0-28 post-weaning fecal scores.

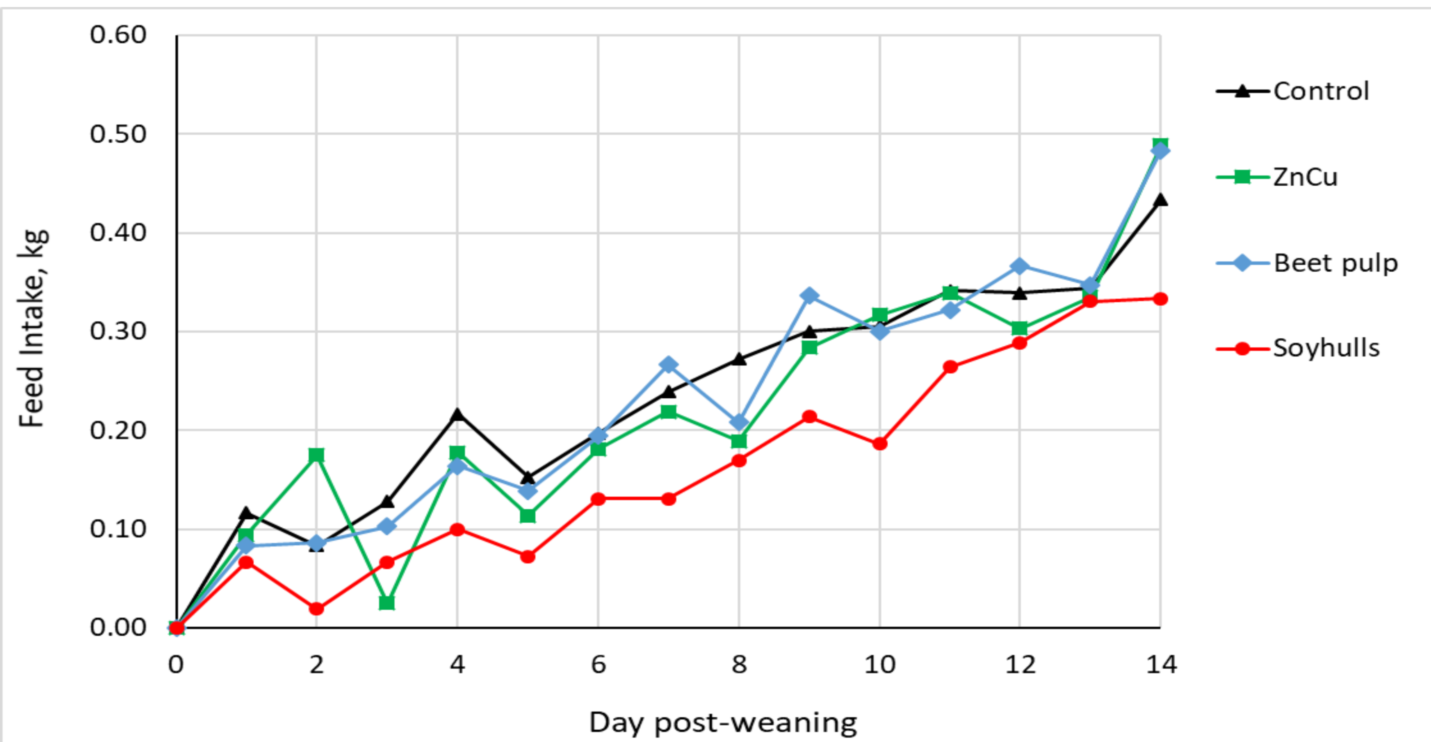

Figure 2. Objective #1B daily feed intake 0-14 days post-weaning

Table 1. Objective 1A phase 1 diets, as fed

Ingredient	Low SBM	High SBM	BCAA	MCFA	Modified Oats
Corn, yellow dent	44.73	33.65	44.22	39.87	24.22
Soybean meal, 46.5% CP	15.01	35.00	15.00	15.00	15.00
Whey, dried	24.26	24.25	24.25	24.25	24.25
HP300	10.00	1.80	10.00	10.00	10.00
Plasma spray-dried	0.75	0.75	0.75	0.75	0.75
Soybean oil	0.50	0.82	0.50		1.23
MCFA	-	-	-	2.10	-
L-lysine HCl	0.40	0.08	0.40	0.39	0.38
DL-methionine	0.25	0.15	0.25	0.26	0.26
L-threonine	0.18	0.04	0.18	0.18	0.17
L-tryptophan	0.02	-	0.02	0.02	0.01
L-valine	0.12	-	0.43	0.10	0.09
Monocalcium phosphate 21%	1.39	1.13	1.39	1.40	1.38
Limestone	0.99	0.96	0.99	0.93	0.89
Salt	0.78	0.75	0.75	0.75	0.75
Optiphos 5000	0.01	0.01	0.01	0.01	0.01
TML Vitamin Premix	0.05	0.05	0.05	0.05	0.05
TML Trace Mineral Premix	0.10	0.10	0.10	0.10	0.10
Zinc oxide, 72% Zn	0.39	0.39	0.39	0.39	0.39
Copper sufate, 25.2% Cu	0.07	0.07	0.07	0.07	0.07
L-isoleucine	-	-	0.25	-	-
Soybean hulls	-	-	-	3.38	-
Inulin/Oat-based Blend	-	-	-	-	20.00
Calculated Composition					
ME - kcal/lb.	1500	1500	1506	1510	1500
g SID Lys: Mcal ME	4.11	4.08	4.07	4.05	4.08
Crude Protein %	24.11	24.28	24.45	24.08	24.31
ADF %	2.58	3.24	2.56	3.81	3.73
NDF %	6.27	6.86	6.22	7.71	7.96
SID Lys %	1.36	1.35	1.35	1.35	1.35
SID AA ratio to Lys					
Thr	0.65	0.65	0.66	0.65	0.65
Met+Cys	0.60	0.61	0.61	0.61	0.61
Trp	0.18	0.21	0.19	0.19	0.19
Ile	0.59	0.70	0.77	0.59	0.59
Val	0.72	0.74	0.94	0.70	0.70
Leu	1.17	1.33	1.17	1.16	1.15
Total Calcium %	0.85	0.85	0.85	0.85	0.85
Phos. Available, %	0.67	0.67	0.69	0.7	0.69
Copper, ppm	200	200	200	200	200
Zinc, ppm	3000	3000	3000	3000	3000

Table 2. Objective 1A phase 2 diets, as fed

Ingredient	Low SBM	High SBM	BCAA	MCFA	Modified Oats
Corn, yellow dent	66.01	50.76	65.40	59.60	45.58
Soybean meal, 46.5% CP	25.00	45.00	25.00	25.00	25.00
Soybean oil	0.47	0.83	0.50		0.89
MCFA	-	-	-	2.10	-
HP300	4.00	-	4.00	4.00	4.00
L-isoleucine	0.02		0.24	0.02	0.01
L-lysine HCl	0.50	0.03	0.50	0.49	0.50
DL-methionine	0.23	0.08	0.23	0.24	0.23
L-threonine	0.22	0.02	0.22	0.23	0.22
L-tryptophan	0.04	-	0.04	0.04	0.04
L-valine	0.12		0.41	0.13	0.12
Monocalcium phosphate 21%	1.35	1.39	1.47	1.50	1.46
Limestone	1.06	0.91	1.01	0.94	0.97
Salt	0.50	0.50	0.50	0.50	0.50
Optiphos 5000	0.01	0.01	0.01	0.01	0.01
TML Vitamin Premix	0.05	0.05	0.05	0.05	0.05
TML Trace Mineral Premix	0.10	0.10	0.10	0.10	0.10
Zinc oxide, 72% Zn	0.25	0.25	0.25	0.25	0.25
Copper sufate, 25.2% Cu	0.07	0.07	0.07	0.07	0.07
Soybean hulls	-	-	-	4.73	-
Inulin/Oat-based Blend	-	-	-		20.00
Calculated Composition					
ME - kcal/lb.	1497	1495	1502	1497	1497
g SID Lys: Mcal ME	3.94	3.94	3.93	3.94	3.94
Crude Protein %	21.7	25.21	22	21.75	21.81
ADF %	3.59	4.29	3.57	5.32	4.16
NDF %	9.04	9.44	8.99	11.1	9.88
SID Lys %	1.3	1.3	1.3	1.3	1.3
SID AA ratio to Lys	0.84	0.84	0.84	0.84	0.84
Thr	0.65	0.65	0.65	0.65	0.65
Met+Cys	0.60	0.60	0.60	0.60	0.60
Trp	0.18	0.22	0.18	0.18	0.18
Ile	0.56	0.73	0.73	0.56	0.56
Val	0.70	0.79	0.91	0.70	0.70
Leu	1.18	1.45	1.18	1.16	1.17
Total Calcium %	0.75	0.75	0.75	0.75	0.75
Phos. Available, %	0.52	0.53	0.53	0.53	0.52
Copper, ppm	200	200	200	200	200
Zinc, ppm	2000	2000	2000	2000	2000

Table 3. Objective 1B diets, as fed

	Control	ZnCu	Beet Pulp	Soyhulls
Corn, yellow dent	58.22	57.35	57.01	56.47
Soybean meal, 46.5% CP	12.00	12.00	12.00	12.00
Casein	5.51	5.58	5.81	5.67
Oats, groats	5.00	5.00	-	-
Beet pulp	-	-	5.00	-
Soybean hulls	-	-	-	5.00
Whey, dried	13.89	13.89	13.89	13.89
Soybean oil	1.12	1.45	2.04	2.70
Limestone	0.84	0.83	0.72	0.75
Monocalcium phosphate 21%	1.01	1.02	1.09	1.09
Salt	0.40	0.40	0.40	0.40
L-lysine HCl	0.60	0.59	0.58	0.59
DL-methionine	0.22	0.22	0.23	0.23
L-threonine	0.22	0.22	0.22	0.22
L-tryptophan	0.07	0.07	0.07	0.07
L-valine	0.40	0.41	0.43	0.42
L-isoleucine	0.12	0.12	0.13	0.13
Optiphos 2500	0.03	0.03	0.03	0.03
Vitamin Premix	0.20	0.20	0.20	0.20
Trace Mineral Premix	0.15	0.15	0.15	0.15
Copper sufate, 25.2% Cu	-	0.40	-	-
Zinc oxide, 72% Zn	-	0.08	-	-
Calculated composition				
Dry Matter %	90.7	90.8	90.8	90.9
ME - kcal/lb.	1540	1540	1540	1540
Crude Protein %	18.0	18.0	18.0	18.0
ADF %	2.30	2.28	3.21	3.49
NDF %	5.54	5.47	7.15	7.32
Lactose %	10.0	10.0	10.0	10.0
SID Lys %	1.40	1.40	1.40	1.40
g SID Lys:ME	4.12	4.12	4.12	4.12
Total calcium, %	0.65	0.65	0.65	0.65
Av. Phos, %	0.55	0.55	0.55	0.58

Table 4. Objective 1A Nursery performance data

Item	Low SBM	High SBM	BCAA	MCFA	Modified Oats	SEM	P-value
Day 0, kg	5.55	5.76	5.51	5.20	5.54	0.433	0.148
Day 14, kg	8.35[a]	8.79[a]	8.22[a]	7.41[b]	8.55[a]	0.287	0.001
Day 28, kg	14.66[a]	14.73[a]	14.24[a]	12.82[b]	14.60[a]	0.354	0.002
Day 42, kg	23.92[a]	23.74[a]	23.52[a]	21.94[b]	23.92[a]	0.501	0.042
Day 63, kg	42.17[a]	41.67[a]	41.28[a]	39.80[b]	41.17	1.022	0.298
Phase 1							
ADG, kg/d	0.20[a]	0.22[a]	0.19[a]	0.16[b]	0.21[a]	0.016	0.001
ADFI, kg/d	0.24	0.25	0.22	0.21	0.23	0.015	0.322
Gain:Feed	0.87	0.89	0.89	0.80	0.95	0.087	0.436
Phase 2							
ADG, kg/d	0.45[a]	0.43[a]	0.43[a]	0.39[b]	0.43[a]	0.025	0.065
ADFI, kg/d	0.66[a]	0.63[a]	0.66[a]	0.59[b]	0.67[a]	0.021	0.055
Gain:Feed	0.69	0.68	0.66	0.66	0.65	0.034	0.538
Phase 3							
ADG, kg/d	0.66	0.64	0.66	0.65	0.67	0.030	0.955
ADFI, kg/d	1.04[x]	0.99[x]	1.01[x]	0.96[y]	1.01[x]	0.042	0.442
Gain:Feed	0.63	0.66	0.66	0.68	0.66	0.024	0.703
Phase 4							
ADG, kg/d	0.87	0.85	0.85	0.85	0.82	0.034	0.772
ADFI, kg/d	1.68[a]	1.60[a]	1.61[a]	1.55[b]	1.62[a]	0.072	0.218
Gain:Feed	0.52	0.53	0.52	0.55	0.51	0.016	0.403
Overall							
ADG, kg/d	0.46[a]	0.45[a]	0.46[a]	0.42[b]	0.47[a]	0.010	0.016
ADFI, kg/d	0.75[a]	0.72[a]	0.73[a]	0.68[b]	0.74[a]	0.024	0.090
Gain:Feed	0.71	0.70	0.72	0.69	0.74	0.028	0.224

Phase 1, post-weaning day 0-14.
Phase 2, post-weaning day 15-24.
Phase 3, post-weaning day 29-42.
Phase 4, post-weaning day 43-63.
Overall, post-weaning day 0-63.
Within row, different superscript a, b indicates $P < 0.05$

Table 5. Objective 1A Nursery performance data

	Control	ZnCu	Beet Pulp	Soyhulls	SEM	*P*-value
BW day 0, kg	5.64	5.74	5.51	5.42	0.879	0.706
BW day 7, kg	5.58	6.45	5.63	5.79	0.757	0.256
BW day 14, kg	6.55[a]	8.62[b]	7.27[ab]	7.14[ab]	0.761	0.045
0-14 d						
ADG, kg	0.073[a]	0.203[b]	0.123[ab]	0.129[ab]	0.0266	0.019
ADFI, kg	0.237	0.246	0.241	0.173	0.0323	0.148
G:F	0.308	0.825	0.510	0.746	0.314	0.419

N = 18 pigs/trt
Within rows, different letters a,b $P < 0.05$

Table 6. Grow-Finish pig performance during a PRRS virus challenge.

Item	100% Lys:ME	115% Lys:ME	130% Lys:ME	SEM	*P*-value
BW, kg					
Dpi -14[1]	45.3	46.0	46.3	0.509	0.325
Dpi 0[1]	60.6	59.8	60.6	0.594	0.565
Dpi 7[1]	62.3	62.3	63.0	0.622	0.642
Dpi 21[1]*	71.3	70.6	72.3	1.088	0.332
Dpi 35[2]	88.2	87.9	89.6	1.442	0.352
Dpi 49[2]	104.5	104.7	105.7	0.961	0.646
Dpi 64[3]	123.0	123.9	124.4	0.977	0.576
End[3]	129.1	130.0	128.4	0.959	0.747
dpi -14 – 0[1]					
ADG, kg	1.10	0.99	1.03	0.049	0.008
ADFI, kg	2.50	2.43	2.49	0.030	0.221
Gain:Feed	0.44	0.41	0.41	0.017	0.018
dpi 0 – 21[1]					
ADG, kg	0.53	0.51	0.58	0.028	0.141
ADFI, kg	1.59	1.55	1.59	0.055	0.672
Gain:Feed	0.33	0.33	0.36	0.011	0.100
dpi 21 – 35 [2]*					
ADG, kg	1.15	1.19	1.21	0.039	0.296
ADFI, kg	2.82	2.79	2.79	0.032	0.722
Gain:Feed	0.41	0.43	0.43	0.012	0.166
dpi 35 – 49 [2]					
ADG, kg	1.16	1.14	1.13	0.060	0.672
ADFI, kg	3.16	3.12	3.08	0.048	0.244
GF	0.37	0.37	0.36	0.022	0.972
dpi 49 – end[3]					
ADG, kg	1.03	1.04	1.04	0.029	0.879
ADFI, kg	3.24	3.20	3.19	0.045	0.700
Gain:Feed	0.32	0.32	0.33	0.008	0.472
Overall, dpi 0 – end[3]					
ADG, kg	0.95	0.95	0.97	0.014	0.471
ADFI, kg	2.70	2.66	2.66	0.035	0.426
Gain:Feed	0.35	0.35	0.36	0.003	0.038
Mortality, %	7.97	8.09	6.21	2.778	0.717

[1]Phase 1 fed from dpi -14 to 21
[2]Phase 2 fed from dpi 21-49
[3]Phase 3 fed dpi 49-end
*Start of treatment feeding
n=16 pens/trt with 9-11 pigs/pen
dpi = day post-inoculation with PRRS virus