RESEARCH REPORT

ANIMAL SCIENCE

Title: Optimizing nutritional strategies to improve the lifetime performance of healthy compromised pigs **– NPB #18-119**

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Industry Summary: When pigs encounter a health challenge with a virus such as Porcine Reproductive and Respiratory Syndrome (PRRS) or bacteria such as *Mycoplasma Hyopneumoniae*, production efficiency is often reduced along with increased mortality, leaving an economic burden on the producer and the industry. Nutrient requirements, specifically amino acids (AA) and energy, of health challenged pigs are poorly defined compared to healthy pigs due to uncertainties in the use of AA and energy during an active disease state. We have previously reported (16-062) that increasing Standardized Ileal Digestable (SID) Lysine (Lys) to Metabolizable Energy (ME) ratios 110-130% above the requirement increased growth performance and feed efficiency in PRRSV infected pigs, and the response was similar between natural and experimental PRRSV infection. Thus, three experiments were conducted to further evaluate the effect of increasing SID Lys:ME on growth performance during a health challenge. In particular, this project aimed to address the importance of how this ratio is achieved and does this diet philosophy also work under non-viral challenge conditions. In Exp. 1, 400 mixed sex pigs (25.6 ± 4.31 kg BW) in which half of the pigs received a MLV PRRS vaccine, were then allotted to one of three diets (2.67, 3.23 and 3.22 g SID Lys:ME) for a 42-d PRRSV challenge growth study. In Exp. 2, 472 mixed sex pigs (24.05 ± 4.33 kg BW) in which half of the pigs received a killed autogenous PRRS vaccine, were then allotted to one of three diets (2.98, 3.57 and 3.57 g SID Lys:ME) for a 42-d PRRSV challenge growth study. These diets represented 100, 120 and 120% of SID Lys requirement, with the third diet in both Exp. 1 and 2 being achieved by a dilution of ME. In Exp. 1 fine grade washed sand was used to achieve a 20% dilution of energy and in Exp. 2, 8% soybean hulls were used to dilute ME 10%. In Exp. 1 after the 42-d growth study pigs were fed a common diet until they reached a targeted market weight of ~127 kg. However, after the 42-d growth study in Exp. 2, pigs were utilized for Exp. 3. In Exp. 3, 464 mixed sex pigs (79.6 ± 3.02 kg BW) in which all pigs had been previously vaccinated for *Mycoplasma Hyopneumoniae* (MHP) were allotted to one of two diets (1.95 and 2.34 g SID Lys:ME) representing 100 and 120% of NRC requirement. Thereafter, half of the pigs were exposed to a MHP challenge and all pigs fed the experimental diets until they reached targeted market weight of ~127 kg. Results from these projects can be summarized as follows:

Exp. 1:

- There were no differences in PRRS serology due to altered Lys:Me diets.
- Overall, increasing Lys:ME by 120% of requirement by either increased SID Lys or decreasing ME resulted in similar increased growth performance in PRRSV infected pigs in both vaccinated and non-vaccinated pigs compared to the control fed pigs.
- PRRS MLV vaccinated grower pigs had increased end BW after undergoing a 42 d PRRS challenge. Thus, it pays to vaccinate.
- PRRS challenged pigs ate to their energy needs when energy was diluted with an inert feedstuff (sand).
- Formulating diets with increased SID Lys:ME enhanced overall growth performance.

Exp 2:

- There were no differences in PRRS serology due to altered Lys:Me diets.
- Overall, increasing Lys:ME by 120% of requirement did not improve growth in pigs with a mild PRRS challenge (Exp. 2). These pigs were only intranasally inoculated and viremia was not as severe as reported in Exp. 1.
- Diluting the dietary ME with soyhulls did not increase feed intake during PRRS.
- Pigs that were given a killed autogenous PRRS vaccine, did not have increased performance over the PRRS challenge period.

Exp. 3:

- Although MHP reduced pig performance in late finishing, Increasing the dietary Lys:ME ratio in late finishing did not have an effect on MHP vaccinated finisher pig performance.
- Formulating diets with increased Lys:ME for bacterial challenged pigs was not beneficial in late finishing. However, this work needs exploring in younger pigs.

Keywords: Lysine, Energy, PRRS, vaccination

Scientific Abstract: The amino acid (AA) requirements and g standardized ileal digestible Lys per Mcal metabolizable energy (SID Lys:ME) for optimum performance is poorly understood in disease-challenged growing pigs. However, it has been reported that increasing g SID Lys:ME above requirement can help mitigate the reduction in growth performance due to viral challenge such as porcine reproductive and respiratory syndrome (PRRS) or Mycoplasma hyopneumoniae (MHP). Therefore, in three experiments, the objective of this study was to evaluate whether increasing the dietary ratio of SID Lys to metabolizable energy (ME) 120% above the requirement of healthy pigs could enhance growth performance in grow-finish pigs challenged with PRRSV and MHP. Experiment #1 used PRRS vaccinated (vac+; modified live vaccine [MLV] Ingelvac PRRS®) and non-vaccinated (vac-; no vaccine for PRRS) grower pigs that were subject to a PRRSV challenge. In addition, we evaluated if the dietary formulation approach to achieve a 120% ratio was significant by comparing increasing Lys relative to energy to diluting energy in relation to Lys. Within vaccine status, 195 mixed sex pigs, vac+ (35.2 ± 0.60 kg BW) and vac- (35.2 ± 0.65 kg BW) were randomly allotted to one of three dietary treatments (2.67, 3.23, and 3.22 g SID Lys:ME) for a 42 d PRRS virus challenge study representing 100, 120 (increased Lys) and 120%

(dilution of ME via dietary inclusion of sand) of requirement respectively. The pigs were randomly allotted across two barns, each containing 24 pens with 7-10 pigs per pen (8 pens/diet/vaccine status). On dpi 0, both barns were intramuscularly inoculated with live virulent PRRSV and started on experimental diets. Over the 42 d challenge period, within vaccine status PRRS viremia and serology, BW, ADG, ADFI and G:F were determined weekly. Within vaccine status, diet did not influence PRRS viremia or antibody response. In both vac+ ($P < 0.05$) and vac- ($P < 0.05$) pigs, the 120% and 120S% diets increased end BW and overall ADG compared to pigs fed the 100% diet. Overall, ADFI increased by 20% in the 120S% vac+ pigs ($P = 0.003$) and by 17% in vac- pigs ($P = 0.001$) compared to pigs fed 100% treatment. The 120% vac+ pigs had the greatest G:F compared to the 100% and 120S% pigs (0.438 versus 0.394 and 0.391 kg/kg respectively; $P < 0.01$). In summary, increasing g SID Lys:ME to 120% by either increasing Lys or decreasing ME improved growth performance of PRRSV challenged grower pigs. Furthermore, PRRSV challenged pigs ate to their energy needs as marked by the increase in ADFI in the 120S% pigs when energy was diluted. In both PRRS vac+ and vac- pigs subsequently challenged with PRRS virus, formulating diets with increased SID Lys:ME enhanced overall pig growth performance. In Exp. 2, vaccinated (vac+; mucosal killed autogenous PRRS vaccine) and non-vaccinated (vac-; no PRRS vaccine) grower pigs were subject to a PRRSV challenge. Then, in late finishing pigs were subsequently challenged with MHP (Exp. 3). In Exp. 2, a total of 464 mixed sex pigs (PRRSV vaccinated 33.6 ± 1.44 kg BW; non-vaccinated 34.7.2 ± 1.43 kg BW) were allotted to one of three dietary treatments: 1) a control diet formulated to contain 2.98 g SID Lys:ME (representing 100% of requirement), a diet containing 3.57 g SID Lys:ME achieved by increasing Lys (120% of requirement, HL) and a diet containing 3.57 g SID Lys:ME achieved by a reduction in dietary energy and increased Lys (120% of requirement, HF). Pigs were randomly allotted across two barns, each containing 24 pens with 9-10 pigs per pen (16 pens/diet and 24 pens/vaccine status). In Exp. 2, on day post inoculation (dpi) 0, all pigs were intranasally inoculated with live PRRSV and started on experimental diets. Weekly and overall challenge period pig performance were assessed. Overall, vaccination did not have an effect on overall ADG and ADFI; however, a tendency for non-vaccinated pigs to have an increase in overall G:F compared to vaccinated pigs was observed ($P < 0.10$). A tendency was also observed for HL pigs to have the greatest ADG (0.878 kg), control pigs to be intermediate (0.856 kg) and HF pigs the lowest ADG (0.830; $P < 0.10$). Overall ADFI was increased 8.6% and 3.6% in HF and HL pigs respectively compared to control ($P < 0.05$). An increase in overall G:F was observed in pigs fed control and HL diet compared to HF, 3.3% and 11.2%, respectively ($P < 0.05$). End BW did not differ between dietary treatment or vaccination status ($P > 0.05$). Eight days following the conclusion of the PRRSV challenge, Exp. 3 began with a total of 464 mixed sex pigs (79.57. ± 8.97 kg BW) allotted to one of two dietary treatments (1.95 and 2.34 g SID Lys:ME, representing 100% and 120% of requirement respectively) for a 40 d MHP challenge study with 9-10 pig per pen (12 pens/diet/MHP status). On dpi 0, one barn was inoculated with MHP, while the other barn was not inoculated (control), all pigs were started on experimental diets. Control pigs had no differences in overall ADG, ADFI, G:F or end BW due to dietary treatment ($P > 0.05$). The MHP infected pigs also had no difference in overall ADG, ADFI, G:F or end BW in response to dietary treatment ($P > 0.05$). In summary, PRRSV challenged grower pigs had increased in ADFI when energy was diluted in the (HF) diet, compared to control pigs improving growth performance. Regardless of vaccination status, pigs fed 120% Lys:ME diets had slightly improved overall growth performance in response to a PRRSV challenge. In the event of a late finishing

bacterial MHP challenge in MHP vaccinated pigs, increasing the Lys:ME had no effect on growth performance or end BW.

Introduction: Bacterial and viral pathogens impact pig survivability and performance in all stages of swine production, worldwide. In the U.S., two commonly reported respiratory pathogens that antagonize grow-finish pig performance include Porcine reproductive and respiratory virus (PRSSV) and Mycoplasma hyopneumoniae (MHP). In the case of PRRSV pathogen in the U.S., the disease of PRRS is estimated to cost swine producers upwards of $644 million per year as it antagonized all stages of production causing increased morbidity, mortality and reduced growth (Lunney et al., 2010; Holtkamp et al., 2013). Mycoplasma hyopneumoniae commonly causes enzootic pneumonia most frequently seen in grow-finish pigs causing highly variable degrees of disease (acute, chronic or clinical) due to the potential occurrence of secondary pathogens resulting in an intensified health challenge (Tao et al., 2019). The primary concern with MHP is due to its ability to suppress the immune system, resulting in co-infections of secondary pathogens of both commensal bacteria and viruses (Thacker, 2001). In commercial conditions, pigs infected with MHP will have limited outward signs of disease however, commonly they will have reduced growth rates resulting in increased market weight variation (Zimmerman, 2019). As a result, the true economic impact of MHP is not as well characterized as other bacterial and viral pathogens such as hemorrhagic Escherichia coli (E. coli) and PRRSV which cause increased morbidity, mortality and reduced growth (Fairbrother et al., 2005; Holtkamp et al., 2013).

Although advances in diagnostics, vaccinations, animal management and biosecurity in swine production have been made, disease stressors such as PRRSV and MHP still have an impact on swine production today. Therefore, nutritional strategies to help mitigate these diseases are of interest. Nutritional requirements for healthy pigs have been well established (NRC, 2012); however the nutrient requirements for pigs undergoing a health challenge (viral or bacterial) have not been well defined, specifically amino acids (AA) requirements in relation to energy. In healthy pigs the first limiting AA when feeding a corn soybean meal-based diet is Lys. The dual role of AA in metabolism and protein synthesis along with the fact that protein synthesis is a energy demanding process, is the basis for a protein-energy interaction during growth (Moughan, 2018). Thus, in practical diet formulation AA are often expressed in relation to energy as a ratio (i.e. standardized ileal digestibility (SID) Lys to metabolizable (ME) SID Lys:ME), ensuring a constant AA intake is achieved independent of dietary energy levels in feed.

Previous work from our group utilizing breakpoint analysis has reported that increasing SID Lys:ME 110% to 120% above requirement resulted in improved growth performance and feed efficiency in grower pigs subject to a PRRSV challenge, while unchallenged pigs did not benefit from and increased ratio (Schweer et al., 2018). This concept has been further validated in PRRSV challenged pigs, in which Jasper (2020) evaluated two formulation approaches to achieve a 120% Lys:ME. These two approaches included a diet containing increased Lys via increased inclusion of soybean meal (SBM) and synthetic AA and a diet in which ME was diluted, via the inclusion of fine grade sand, both diets representing 120% of requirement. However, it is unknown if altering the Lys:ME utilizing dietary fiber to reduce energy improves performance of PRRSV challenged pigs or if a non-viral challenged pig will also respond in a similar manner. Therefore, the objective of this study was to further

evaluate the formulation approach utilized to achieve a 120% Lys:ME, either by an increase in SID Lys or a reduction in dietary energy in PRRSV challenged grower pigs. As well as assessing if an increased Lys:ME is beneficial to growth performance of finishing pigs undergoing a non-viral challenge, such as MHP.

Therefore, the objective of these studies was to evaluate the importance of increasing the g SID Lys:ME in pigs undergoing a PRRSV challenge in the growing phase of both PRRS vaccinated and non-vaccinated pigs. This would allow us to determine if how the 120% g SID Lys:ME is achieved, by either increasing SID Lys or decreasing ME would result in similar increased growth performance in PRRS pigs compared to 100% g SID Lys:ME diet. Also, we wanted to determine if an increased ratio of SID Lys:ME would be beneficial for vaccinated finishing pigs undergoing a *Mycoplasma Hyopneumoniae* (MHP) challenge.

Objectives from original proposal: The objectives of this project are to determine and compare dietary synthetic amino acid and exogenous enzyme use in nursery pigs divergent in health status. We also plan to validate our recent lysine:energy ratio findings (NPB# 16-062) in poor health nursery-grower pigs. Importantly, we will evaluate how nursery-grower pig diet by health interactions impact lifetime productivity (i.e. wean-market performance). In addition, we plan to determine if reducing energy in nursery diets by including non-fermentable fiber sources plus exogenous enzymes will stimulate feed intake and thereby improve performance and reduce mortality. Specifically, in two turns of commercial Maschhoffs Pork Group nursery pigs, we aim to:

1. Optimizing AA and energy utilization to improve performance and reduce mortality of PRRSV+ nursery grower pigs.
    a. Does increasing amino acid to energy ratios to 110% of requirement improve growth performance and reduce mortality in nursery grower pigs?
    b. Does amino acid source (soybean meal or synthetic amino acid) impact performance and mortality differently?
    c. Can feed intake and pig performance be improved under reduced energy and exogenous enzyme usage?

2. Evaluate the impact of diet and PRRSV vaccine on lifetime performance and health of nursery-grower pigs.
    a. Does increasing amino acid to energy ratio profiles of the diet improve growth performance and vaccine response?
    b. Can diets with increased non-fermentable fiber and exogenous enzymes improve performance upon challenge with vaccine and/or live PRRSV?

Materials & Methods:

Animal Housing and Experimental Design

All procedures adhered to the ethical and humane use of animals for research and were approved by the Iowa State University Institutional Animal Care and Use Committee (IACUC# 18-158).

Exp. 1: Four hundred non-vaccinated, mixed sex (purebred Maschhoffs proprietary line Duroc sires by commercial Yorkshire-Landrace F1 females; 5.4 ± 1.23 kg BW), 19-21 d old freshly weaned PRRS naïve pigs were randomly selected and transported to Ames, IA. Upon arrival, all weaned pigs were randomly split by litter across two barns with identical configuration (i.e. ventilation, temperature setpoints, pen configuration, feeders and waterers). Each barn had 24 pens, however only 12 pens in each barn were utilized for the nursery acclimation phase and each pen was double stocked to contain 15-17 pigs. All pens measured to be 3.66 m long x 2.44 m wide, with fully slated cement flooring and two water cups. On day one post placement, one barn was PRRS vaccinated intramuscularly with 1 mL of Boehringer Ingelheim Inglevac PRRS® modified live vaccine (St. Joseph, MO). The other barn was not PRRSV vaccinated. Throughout the 42 d nursery acclimation period all pigs were fed identical diets in three nursery dietary phases and these diet met or exceeded the nutritional requirements of the pig (NRC, 2012).

On d 42 post-weaning (25.6 ± 4.31 kg BW) pig numbers were reduced in all nursery pens. This was achieved by randomly selecting 7-10 pigs within pen and barn (vaccine status) and placing them into clean unused pens within the same barn. The grow-finish study now consisted of 48 identical pens (3.66 m long x 2.44 m wide, with fully slated floors), containing a double sided 0.36 m feeder and two nipple waters. Within vaccine status there were 24 pens in which all pigs received a common corn-soybean meal-based grower diet that met or exceeded the nutritional requirement (NRC, 2012) for this size pig for 14 d prior to PRRSV inoculation.

After a 14 d acclimation period (d 56 post-weaning) to the grower pens, all pigs in both barns (vaccinated 35.2 ± 0.60 kg BW; non-vaccinated 35.2 ± 0.65 kg BW) were randomly allotted to one of three dietary treatments with 8 pens per treatment per vaccine status. The three treatments per vaccination status were: 1) A control diet formulated to contain 2.69 g SID Lys:ME (control diet representing, 100% Lys:ME based on NRC 2012); 2) a diet containing 3.23 g SID Lys:ME achieved via increased inclusion of soybean meal and synthetic AA (120% ratio from control; high lysine [HL]) and 3) a diet containing 3.22 g SID Lys:ME achieved by reducing dietary ME via the inclusion of 18% fine grade, washed and dried sand (120S% ratio from control; low energy [LE]). The three diets (Table 1) were formulated to contain 2.69, 3.23, and 3.22 g SID Lys:ME, representing 100%, 120%, and 120% of the NRC (2012) requirements for 25-50 kg pigs, as verified internally by the Maschhoffs system and Schweer, et al., (2018). The three diets were formulated to contain similar total calcium, STTD phosphorus and ratios of SID Thr, Trp, Met, Ile, and Val to SID Lys to avoid secondary AA deficiencies (Table 1).

On d 56 post-weaning, all pigs in both barns were inoculated with a live PRRSV isolate open reading frame (ORF) 5 sequence 1-18-4 (day post inoculation [dpi] 0) administer with a single intramuscular 1 mL injection of saline diluted serum containing 10^6 genomic PRRSV units per mL. For the next 42 dpi, pig BW, pen feed intake and feed efficiency performance parameters were collected and calculated weekly on dpi 0, 7, 14, 21, 28, 35, and 42. Pigs were allowed unrestricted access to feed and water throughout the 42 d PRRSV challenge.

Exp. 2: Four hundred and seventy-two mixed sex (purebred Maschhoffs proprietary line Duroc sires by commercial Yorkshire-Landrace F1 females; 5.57 ± 1.22 kg BW) 21 d old freshly weaned PRRS naïve pigs were transported to Ames, IA. Prior to weaning and arrival to Ames, IA. Upon arrival, all weaned pigs were randomly split across two barns with identical configuration (i.e. ventilation, temperature setpoints, pen configuration, feeders and waterers). Each barn had 24 pens, however only 12 pens in each barn were

utilized for the nursery acclimation phase and each pen was double stocked to contain 18-20 pigs. All pens measured to be 3.66 m long x 2.44 m wide, with fully slated cement flooring and two water cups. On day one and 23 post placement, half of the pigs (6 pens/barn) were intranasally vaccinated with 2mL of Aptimmune Barricade Mucosal killed autogenous mucosal PRRS vaccine (Diamond Animal Health, Des Moines, IA). Throughout the 42 d nursery acclimation period pigs were fed two phases of experimental nursery diets (Phase 1: 15 to 35% soybean meal; Phase 2: 25 to 45% soybean meal) and a third phase of common nursery diet that all pigs received. All of these diets either met or exceeded nutritional requirements of the pig (NRC, 2012).

On d 42 post-weaning (24.05 ± 4.33 kg BW) pig numbers were reduced in all nursery pens. This was achieved by randomly selecting 10 pigs within pen and barn and placing them into clean unused pens within the same barn. The grow-finish study now consisted of 48 identical pens (3.66 m long x 2.44 m wide, with fully slated floors), containing a double sided 0.36 m feeder and two nipple waters. All pigs received a common corn-soybean meal-based grower diet that met or exceeded the nutritional requirement (NRC, 2012) for this size pig for 14 d prior to PRRSV inoculation.

After the 14 d acclimation period (d 56 post-weaning) to the grower pens, all pigs in both barns (vaccinated 33.6 ± 1.44 kg BW; non-vaccinated 34.7.2 ± 1.43 kg BW) were randomly allotted to one of three dietary treatments with 8 pens per treatment per vaccine status. The three treatments per vaccination status were: 1) A control diet formulated to contain 2.98 g SID Lys:ME (Control, diet representing 100% Lys:ME based on NRC 2012); 2) a diet containing 3.57 g SID Lys:ME achieved via increased inclusion of soybean meal (120% ratio from control; high lysine [HL]) and 3) a diet containing 3.57 g SID Lys:ME achieved by reducing dietary ME 8% via the inclusion of soybean hulls and increasing Lys 12% via soybean meal (120S% ratio from control; high fiber [HF]). The three diets (Table 2) were formulated to contain 2.98, 3.57 and 3.57 g SID Lys:ME, representing 100%, 120%, and 120% of the NRC (2012) requirements for 25-50 kg pigs, as verified internally by the Maschhoffs system and Schweer, et al., (2018). The three diets were formulated to contain similar total calcium, STTD phosphorus and ratios of SID Thr, Trp, Met, Ile, and Val to SID Lys to avoid secondary AA deficiencies (Table 2).

On d 56 post-weaning, all pigs in both barns were inoculated with a live PRRSV isolate open reading frame (ORF) 5 sequence 1-18-4 (day post inoculation [dpi] 0) administer with a single intranasal 2 mL injection of saline diluted serum containing 10^6 genomic PRRSV units per mL. For the next 42 dpi, pig BW, pen feed intake and feed efficiency performance parameters were collected and calculated weekly on dpi 0, 7, 14, 21, 28, 35, and 42. Pigs were allowed unrestricted access to feed and water throughout the 42 d PRRSV challenge. After Exp. 2 42-d growth study pigs were utilized for Exp. 3.

Exp. 3: For a 40 d *Mycoplasma Hyopneumoniae* (MHP) study, 464 mixed sex pigs (79.6 ± 3.02 kg BW) in which all pigs had been previously vaccinated MHP were allotted to one of two diets (1.95 and 2.34 Lys:ME) representing 100 and 120% of NRC requirement. One of the two barns (MHP+) was inoculated with MHP via aerosol fogging on d 106 post placement, while the other barn was not exposed to MHP (MHP-). Confirmation of MHP status in both barns was performed on dpi -6, 12, 27 and 41 via deep tracheal swabbing of 10 pigs/barn at each timepoint. The MHP + barn tested PCR positive for MHP at dpi 12 while the MHP- remained PCR negative for MHP through the 40 d study. Pig BW, pen feed intake and feed efficiency parameters were collected and calculated on dpi 0, 12, 28 and 40. Pigs were allowed unrestricted access to feed and water throughout the 42 d PRRSV challenge.

Diet Analysis

The experimental diets used during the PRRSV and MHP challenge were analyzed for energy and nutrient composition. Proximate analysis of dietary gross energy (GE) was determined using bomb calorimetry (Oxygen Bomb Calorimeter 6200, Parr Instruments, Moline, IL). Diet samples were analyzed for dietary dry matter (DM) using method 934.01 according to AOAC (2007). Dietary AA and N analysis were conducted by University of Missouri Experimental Station Chemical Laboratories (Columbia, MO). Amino acid and N analysis were performed using method 994.12, 999.13, and 990.03 according to AOAC (2007) methods, and CP was calculated (N × 6.25).

Blood collection and Analysis

In both Exp. 1 and 2 two pigs in each pen were randomly select and these same two pigs were snare restrained and bled on dpi -7, 0, 7, 14, 21, 28, 35 and 42. Blood samples (8-10 mL) were collected from the jugular vein into serum tubes (BD Vacutainer, Franklin Lakes, NJ) for routine diagnostics. Blood samples from pigs at 0 dpi were collected immediately before inoculation. All blood samples were allowed to clot then serum separated by centrifugation (2,000 × *g*, 15 min at 4°C) pooled within dietary treatment and vaccine status, and stored at -80˚C until analysis. Serum aliquots were submitted to the Iowa State University Veterinary Diagnostic Laboratory (Ames, IA) for routine diagnostics. Real-time polymerase chain reaction (RT-PCR) and serum antibody testing for PRRSV was performed using commercial reagents (VetMAX™ NA and EU PRRSV real-time RT-PCR, Thermo Fisher Scientific, Waltham, MA) and a commercial ELISA kit (HerdCheck® PRRS X3, IDEXX Laboratories, Inc., Westbrook, ME), respectively. A negative serum viremia cycle threshold (**Ct**) was ≥ 37 and serology antibody was considered negative with a S:P ≤ 0.40.

Statistical analysis

In all three experiments, least square (LS) means were determined using the LS means statement and differences in LS means were produced using the pdiff option. Tukey's multiple comparison adjustment was used on each LS mean pairwise comparison. Data was reported as LS means and standard error of the mean (SEM). Differences were considered significant when $P < 0.05$ and a tendency when $0.05 < P < 0.10$.For Exp. 1, within vaccine status and with pen considered the experimental unit, all data was analyzed using the PROC MIXED procedure of Statistical Analysis System (SAS) 9.4 (SAS Inst. Inc., Cary, NC). All performance data was analyzed for the fixed effects of dietary treatment consisting of 100%, 120% and 120S% Lys:ME, representing 2.69, 3.23 and 3.22 g SID Lys:ME respectively. For Exp. 2, pen was considered the experimental unit, all data was analyzed using the PROC MIXED procedure in SAS 9.4 (SAS Inst. Inc., Cary, NC). All performance data was analyzed for the fixed effects of dietary treatment, vaccine and their interaction with barn being a random effect in the model. Dietary treatment consisted of 100%, 120% and 120S% Lys:ME representing 2.98, 3.57 and 3.57 g SID Lys:ME respectively. In Exp. 3 within MHP status and with pen considered the experimental unit, all data was analyzed using the PROC MIXED procedure of Statistical Analysis System (SAS) 9.4 (SAS Inst. Inc., Cary, NC). All performance data was analyzed for the fixed effects of dietary treatment consisting of 100% and 120% Lys:ME, representing 1.95 and 2.34 g SID Lys:ME respectively.

Results:

Diet analysis

During the PRRSV challenge period in Exp 1, the diets were formulated to contain 2.69, 3.23 and 3.22 g SID Lys per Mcal ME (Table 1). Proximate and AA analysis of the diets were conducted to verify that the diets were formulated similar to the predicted values (Table 1). Analyzed GE of the diets were 3.87, 3.86 and 3.01 Mcal/kg, representing the control, HL and LE dietary treatments, respectively. These results confirmed the formulated 20% reduction in dietary energy LE in comparison to the control and HL diets. Experimental diets were formulated to contain 2.98, 3.57, 3.57 and 1.95 and 2.34 g SID Lys per Mcal ME in Exp. 2 and 3, respectively (Table 2 and 3, respectively). Proximate analysis of the experimental diets determined that diets were formulated similar to the predicted values.

Experiment 1 health, serology and performance

Serum samples were pooled within dietary treatment and vaccine status to confirm weekly PRRSV viremia and antibody titers (dpi 0-42). The serology responses to the PRRS vaccine and the PRRSV challenge are reported in Table 4. Prior to PRRSV inoculation, PRRSV viremia was not detected in pigs irrespective of vaccine status based on serum Ct values ≥ 37. As expected, the PRRSV vaccinated pigs had detectable PRRSV antibodies 56 days post-vaccination, while the non-vaccinated pigs were deemed negative for PRRSV antibodies with S:P ≤ 0.40. The success of the PRRSV challenge was confirmed via PCR over the 42 d challenge period. By 7 dpi, irrespective of diet and vaccination status, PRRS viremia Ct values were reported in the range of 16 to 26 (considered positive if < 37; Table 4). As expected, PRRSV Ct values increased (i.e. viremia decreased) as pigs seroconverted. Vaccinated pigs had detectable PRRSV antibodies (S:P ratio) prior to PRRSV inoculation, and PRRSV antibody levels increased throughout the challenge period and plateaued at 28 dpi, at which time all vaccinated pigs were considered non-viremic (Ct > 37; Table 4). As expected, nonvaccinated pigs experienced a longer duration and magnitude of PRRSV viremia based on diagnostics. Following PRRSV inoculation, antibody titers for nonvaccinated pigs increased throughout the challenge period (Table 4).

Diagnostic testing also indicated that all pigs, irrespective of PRRS vaccination status, became naturally infected with Porcine Circovirus 2 (PCV2) between dpi 7 and 14, as confirmed by PCR; all pigs had not received PCV2 vaccinations prior to this experiment. As a result of this PRRSV and PCV2 co-infection, the PRRSV vaccinated and non-vaccinated barns experienced 11 and 22 mortalities, respectively, equating to 5.6 and 11.3% mortality over the test period. However, mortality was not different across dietary treatment (data not shown). A common cause of mortality, as reported by necropsy and diagnostics via the ISUVDL, was attributed to systemic effects of PRRSV and PCV2, with *Streptococcus suis* sepsis resulting in rapid death. Due to the severity of disease from unintended PCV2 infection, intentional PRRSV challenge, and secondary bacterial infections, all pigs were placed on water amoxicillin (Vet Rx Pharmacy, St. Peter, MN) from 14 to 21 dpi to decrease the impact of opportunistic secondary bacterial pathogens. From 22 to 30 dpi, all pigs received sodium salicylate (Aurora Pharmaceutical LLC., Northfield, MN) through the water with a daily target dose of 50 mg/kg body weight to help mitigate any febrile response associated with the multifactorial infection.

Prior to the disease challenge period (dpi 0) all pigs were fed a common nursery diet and no differences in pig performance parameters within the vaccinated pens were detected ($P > 0.10$; Table 5). From 0 to 7 dpi, there was a tendency ($P = 0.071$) for

average daily gain to be increased by 150% in the HL pigs compared to the control treatment, while LE was not different from either treatment ($P > 0.05$). Growth rates were similar between treatments for all other weekly weigh periods ($P > 0.10$; 7 to 42 dpi). An increase ($P < 0.05$) in average daily feed intake was observed weekly throughout the challenge period, with the exception of dpi 14 to 21 in which a tendency for ADFI was observed ($P < 0.10$) as a result of the LE treatment compared to the control and HL dietary treatments. From 28 to 35 dpi, feed efficiency (gain-to-feed) was greatest for pigs fed the HL dietary treatment, lowest for pigs fed the LE treatment, and intermediate for those fed control diet; however, G:F differences were not detected in any other weekly growth periods ($P > 0.05$).

For the overall challenge period (Table 5), increasing SID Lys:ME to 120% of NRC (2012) requirement during the 42 d PRRSV challenge period increased ADG ($P < 0.01$), regardless of how the 120% ratio was achieved by either increasing g SID Lys (HL) or decreasing ME (LE). Overall ADFI increased 19.8% as a result of LE dietary treatment compared to control ($P < 0.01$), whereas the HL treatment was similar to the control. When expressing overall ADFI on a ME intake per day, the HL pigs had significantly higher ME intakes compared to the LE ($P < 0.05$), with the control pigs being intermediate (Table 5). An increase in overall G:F was observed in pigs fed the HL treatment compared to pigs fed the control and LE treatments ($P < 0.01$), which were not different from each other. End BW of pigs fed HL and LE treatments were improved 6.9 kg and 4.2 kg, respectively, in comparison to the control ($P < 0.05$).

In the non-vaccinated pigs, prior to the disease challenge period (dpi 0) there were no differences in pig performance parameters ($P > 0.10$; Table 6). Throughout the challenge period, pigs remained PRRSV seropositive until 42 dpi (Table 4), confirming PRRSV inoculation was successful. Weekly growth performance results are shown in Table 6. From 0 to 7, 21 to 28, and 28 to 35 dpi ADG increased in pigs fed the HL and LE dietary treatments relative to control ($P < 0.05$), with no differences between treatment during the other weekly weigh periods. There were no differences ($P > 0.05$) in ADFI between treatments during the first 4 weekly weigh periods. An increase in ADFI was observed from 28 to 35 and 35 to 42 dpi as an effect of LE dietary treatment ($P < 0.01$). From 0 to 7, 21 to 28, and 28 to 35 dpi, G:F was increased in pigs fed the HL and LE diets compared to control ($P < 0.05$); with no other G:F differences observed between treatments throughout other weekly growth periods.

Overall growth performance results for Exp 1 are shown in Table 7. Overall, increasing SID Lys:ME to 120% of NRC (2012) requirement during the 42 d PRRSV challenge period increased ADG ($P < 0.05$), regardless of how the 120% ratio was achieved by either increasing g SID Lys or decreasing ME. Overall ADFI increased 16.6% as a result of LE dietary treatment with respect to control ($P < 0.01$); with no difference seen between HL and control ($P > 0.05$). Further, during the overall challenge period daily ME intake (Mcal/d) tended ($P = 0.077$) to differ, with the LE pigs having the lowest ME intake per day compared to the control and HL pigs (Table 7). Dietary treatment had no effect on overall G:F ($P > 0.10$). End BW of pigs fed HL and LE treatments were improved 5.4 and 5.2 kg, respectively, in comparison to control ($P < 0.05$).

Experiment 2 and 3 vaccination and nursery performance

Expt. 2 and 3 growth performance data throughout the 42 d nursery period is shown in Table 9. Throughout the nursery period vaccine and dietary treatment by vaccine interaction did not have an effect on phase or overall growth performance ($P > 0.05$). During Phase 1, average daily gain (ADG) and average daily feed intake (ADFI)

was greatest in high SBM fed pigs, with medium SBM pigs being intermediate and low SBM fed pigs having the lowest ADG and ADFI ($P < 0.05$). However, throughout phase 1, feed efficiency (gain-to-feed, G:F) and end BW were not different due to dietary treatment ($P > 0.05$). Throughout phase 2, there was a tendency for ADG to be increased in low SBM fed pigs compared to medium and high SBM pigs ($P < 0.10$). Low SBM fed pigs had an increased G:F compared to medium and high SBM pigs ($P < 0.05$). End BW and ADFI did not differ throughout phase 2 in response to dietary treatment ($P > 0.05$). Throughout phase 3 (common diet to all pigs), no growth performance parameters differed between previous treatment groups ($P > 0.05$). When analyzing the overall nursery period, an interaction between dietary treatment and vaccination status was observed for ADG ($P < 0.05$). However, the remaining overall growth performance parameters for the 42 d nursery period did not differ between dietary treatments or vaccination status ($P > 0.05$). Thus, high SBM inclusion rates in phase 1 and 2 did not hinder pig performance (Data not shown).

Experiment 2

No mortalities were recorded due to the PRRSV challenge in this period. The serology responses to the PRRS vaccine and the PRRSV challenge are reported in Table 8. Prior to PRRSV inoculation, all pigs were negative for viremia and both the PRRSV vaccinated ad non-vaccinated pigs did not have detectable PRRSV antibodies. The success of the viral challenge was assessed via PCR weekly throughout the 42 d challenge period. By 7 dpi, irrespective of dietary treatment and vaccination status, PRRSV viremia Ct values were considered positive and increased with time (i.e. viremia decreased) as pigs seroconverted. Irrespective of vaccination status, PRRSV antibody levels increased throughout the challenge period and plateaued between dpi 25 and 42, at which time all pigs were considered non-viremic (Table 8).

During the 13 d acclimation period to grower pens, no differences in ADG or G:F were observed ($P > 0.05$; Table 9). However, during this period ADFI was increased in the non-vaccinated pigs in comparison to vaccinated ($P < 0.05$; Table 9). Weekly growth performance during the PRRSV challenge period is reported in Table 10. From 0 to 7 dpi, ADFI increased in the HF fed pigs compared to the control pigs ($P = 0.05$), while the HL did not differ from either treatment. Also, in this time period non-vaccinated pigs had a tendency for increased ADFI in comparison to vaccinated pigs ($P = 0.067$). On d 0 and 7 non-vaccinated pigs had increased BW compared to vaccinated pigs ($P < 0.01$). Growth rates between dietary treatments were similar from dpi 7 to 14 ($P > 0.10$); however, G:F of vaccinated pigs was increased 0.093 kg above non-vaccinated pigs ($P < 0.05$). In week 3, ADFI increased 10.7% and 17.2% in pigs fed HL and HF diets, respectively in comparison to control ($P < 0.05$). All other performance parameters during this time period were similar across dietary treatments and vaccination status. During the third week post inoculation, a tendency for G:F and end BW to increase in HL fed pigs in comparison to control with HF differing from neither diets ($P < 0.10$). From dpi 28 to 35 both ADG was greatest in control pigs, intermediate in HL pigs and lowest in HF pigs ($P < 0.05$); with no differences in ADFI seen. However, G:F was greatest in control and HL pigs compared to HF pigs ($P < 0.05$). In the last week of the PRRSV challenge, ADG increased 18.9% and 5.7% in control and HL fed pigs, respectively in comparison to HF pigs ($P < 0.05$). The HF pigs had the greatest ADFI, while HL pigs were intermediate and control having the lowest ADFI ($P < 0.05$). The greatest G:F reported during the sixth week was the control pigs in comparison to HL and HF pigs ($P < 0. 05$). Additionally, a tendency for

nonvaccinated pigs to have increased ADFI in comparison to vaccinated pigs was also observed ($P < 0.10$).

For the overall 42 d PRRSV challenge period, vaccination did not have an effect on ADG and ADFI (Table 10); however, a tendency for vaccinated pigs to have increased G:F compared to non-vaccinated pigs was observed ($P < 0.10$). A tendency was also observed for HL pigs to have the greatest ADG, compared to the control pigs being intermediate and the HF pigs having the lowest ($P < 0.10$). Overall ADFI was increased 8.6 and 3.6% in HF and HL pigs, respectively compared to control ($P < 0.05$). An increase in overall G:F was observed in pigs fed control and HL diet compared to HF, with a 13.3% and 11.2% increase, respectively ($P < 0.05$). Body weights at dpi 42 did not differ between dietary treatment or vaccination status ($P > 0.05$; Table 9).

Experiment 3

In Exp. 3, deep tracheal swabs were collected on dpi -7, confirming that both barns were in fact MHP negative (Ct ≥ 37.0). Swabs were collected again on dpi 12 and 27 dpi confirming that the MHP inoculated barn was positive (Ct values of 28.0 and 24.7, respectively; Ct ≥ 37.0 represents MHP negative), indicating a successful MHP inoculation. The control barn was also was confirmed negative (Ct ≥ 37.0) on dpi 12 and 40, confirming that a negative MHP status was maintained for the entirety of the 40 d challenge period in the control group. Within inoculation status, growth performance response to the 100% and 120% Lys:ME diets throughout the 40 d MHP challenge period is presented in Table 11. No differences in ADG, ADFI or G:F were reported due to dietary treatment in the non-challenged pigs ($P > 0.05$; Table 11). Within the MHP challenged pigs, increasing the dietary Lys:ME also resulted in no differences in ADG, ADFI or G:F during the 40 d period ($P > 0.05$).

Discussion:

Viral and bacterial pathogens impact pig survivability and performance in all stages of swine production worldwide. In the U.S., two commonly reported respiratory pathogens that antagonize grow-finish performance are PRRSV and *Mycoplasma hyopneumoniae* (MHP). It has been reported that more than 50% of U.S. grow-finish sites have had a PRRRS incidence and over 55% of U.S. grow-finish sites have had MHP incidence (NAHMS, 2012). In the case of PRRSV pathogen, Porcine reproductive and respiratory syndrome (PRRS) in the U.S. alone is estimated to cost swine producers upwards of $644 million per year, as it antagonizes all stages of production causing increased morbidity, mortality and reduced growth (Lunney et al., 2010; Holtkamp et al., 2013; Nathues et al., 2017). However, even with endemic diseases such as PRRS and MHP, feeding and managing these challenged pig flows (populations) as well as knowing their nutritional requirements for health recovery and growth performance have remained elusive. Nutritional requirements for healthy pigs are well established by the National Research Council (NRC, 2012); however, nutrient requirements for pigs undergoing a health challenge are widely unknown, including amino acids (AA) requirements. In a healthy pig, Lys is the first limiting AA when feeding corn-soybean meal-based diets. However, the AA utilization of swine with an activated immune system is not as well understood (NRC, 2012).

In the context of feeding health challenged pigs, one nutritional strategy that has been studied to promote earlier viral clearance and recovery, in addition to enhancing pig performance, is the increased inclusion of soybean meal (SBM) (Boyd, 2014). Soybean meal is the main protein and essential AA source in corn SBM-based diets. Rochell et al. (2015) reported in nursery pigs challenged with PRRSV that

increasing SBM from 17.5% to 29% reduced viremia load and improved growth performance over a 14 d challenge period. However, it is unclear if the improved performance is due to increased dietary crude protein (CP) and AA, or the increase in bioactive antioxidant compounds (i.e. isoflavones) found within SBM. The latter has yielded mixed results in modulating PRRSV in challenged pigs (Greiner et al., 2000; Cornelison et al., 2018; Smith et al., 2019). Furthermore, based on previous work from our group, we determined that the potential benefits of feeding increased SBM during a PRRSV challenge is likely not related to digestibility of nutrients or AA (Schweer et al., 2018b). This work also highlighted that basal endogenous losses of AA were only nominally different in PRRSV challenged pigs compared to healthy control pigs and this translated to minimal differences in standardized ileal digestibility of most AA (Schweer et al., 2018b).

To further examine the impact of SBM, the impact of the relationship of Lys to energy in PRRSV challenged pigs was evaluated. Utilizing break point analysis Schweer et al. (2018a) reported that increasing dietary Lys:ME to 110% to 120% of requirement improved growth and feed efficiency in PRRSV challenged pigs. The increase in Lys:ME was primarily achieved in the diet with the use of intact protein sources, with synthetic AA levels remaining relatively constant across diets. The relationship of Lys to energy was evaluated because when formulating diets AA requirements are expressed in relation to energy as a ratio (i.e. SID Lys:ME). This ensures that a constant AA intake is achieved by the pig independent of the dietary energy level fed and related adjustment to feed intake, which is key in supporting optimal feed intake and growth. However, stimulation of the immune system due to a pathogen challenge can result in reduced voluntary feed intake, and as a result, lower energy and AA intake (Johnson, 2002; Doeschl-Wilson et al., 2009) causing growth rate suppression (Greiner et al., 2001; Rochell et al., 2015; Schweer et al., 2018a). In addition, it has been suggested that under unrestricted feeding conditions, healthy pigs will attempt to consume the amount of feed required to satisfy their requirement for energy and nutrients (Schiavon et al., 2018). However, it is unclear if pigs are able to adjust their feed intake to meet their energy needs under stressors such as disease. Therefore, the overall objective of these studies herein were to evaluate the importance of increasing dietary SID Lys:ME ratio above requirement (i.e. targeting 120% of requirement) in pathogen challenged pigs to improve growth performance. Further, we also evaluated the formulation approaches used to achieve this increased ratio. To address this objective, three research experiments were conducted.

In the first experiment (Exp 1), our objective was to evaluate the effects of increasing SID Lys:ME on growth performance in PRRSV vaccinated and nonvaccinated pigs facing a subsequent PRRSV challenge. Furthermore, we hypothesized that irrespective of how the increased Lys:ME ratio (i.e. 120%) was achieved, either by an increase in g SID Lys (HL) or a reduction in ME (LE), would result in increased growth performance in PRRSV infected pigs compared to pigs fed a 100% Lys:ME ratio (i.e. at optimal requirement for healthy pigs). Additionally, the reduction in feed intake during a disease challenge reduces nutrient availability to tissues, particularly muscle (Helm et al., 2019), thus being the primary cause of reduced lean tissue accretion observed during a viral challenge (Schweer et al., 2017). Therefore, we also hypothesized that decreasing dietary energy concentration may be beneficial in pigs with an activated immune system resulting in improving feed intake, highlighting the pig's ability to eat to meet their energy needs.

In Exp 1, overall, in both PRRSV vac+ and vac- pigs, increasing SID Lys:ME to 120% of requirement during the 42 d PRRSV challenge period increased average daily

gain, regardless of how the 120% ratio was achieved by either increasing g SID Lys (HL) or decreasing ME (LE). Overall average daily feed intake increased 17% and 20% as a result of LE dietary treatment with respect to control in vac+ and vac- pigs, respectively. In vac+ pigs, dietary treatment had no effect on overall gain-to-feed, however in vac- pigs an increase in overall G:F was observed in pigs fed the HL treatment compared to pigs fed the control and LE treatments, which were not different from each other. In vac+ pigs, end BW of pigs fed HL and LE treatments were improved 5.4 and 5.2 kg, respectively, in comparison to control. Additionally, in vac- pigs, end BW increased in pigs fed HL and LE treatments 6.9 kg and 4.2 kg, respectively, in comparison to control. This study validates Schweer et al. (2018a) studies and proved that during a controlled PRRSV challenge (also naturally co-challenged with PCV2), increasing the dietary SID Lys:ME to 120% in grower pigs aids in augmenting growth performance. Additionally, irrespective of vaccination status, diluting ME by 20% with inert sand to achieve a 120% Lys:ME in the diet resulted in increased feed intake, translating to an increase in ADG and end BW in comparison to control throughout a PRRSV challenge. The use of sand in diet formulations to dilute dietary energy is not a practical approach or feedstuff from a farm management standpoint. Although sand is an inert in terms of ME, if the sand is too fine it may cause ulcers in pigs and may settle to the bottom of the pit causing management issues in confinement facilities.

To further evaluate diet formulation strategies to achieve a 120% Lys:ME ratio, PRRSV challenged pigs were fed a diet with reduced dietary energy via dietary fiber source (Exp 2). It is unknown if altering the Lys:ME by reducing ME utilizing dietary fiber improves performance of PRRSV challenged pigs similarly to the results previously seen in Exp 1. In the second experiment, on dpi 0, 464 pigs (~34 kg BW) were randomly allotted to one of three dietary treatments and inoculated intranasally with a live PRRSV isolate (open reading frame 5, 1-18-4), administer with a single intranasal 2 mL dose of saline diluted serum containing 10^6 genomic PRRSV units per mL live virulent PRRSV. The three dietary treatments per vaccination status were: 1) control, a diet formulated to contain 2.98 g SID Lys:ME (representing 100% Lys:ME requirement); 2) high Lys (HL), a diet containing 3.57 g SID Lys:ME achieved via increased inclusion of SBM (120% ratio from control) and 3) high fiber (HF), a diet containing 3.57 g SID Lys:ME achieved by reducing dietary ME 8% via the inclusion of 8.3% soy hulls and increasing Lys 112% via SBM (120% ratio from control). All pigs had confirmed PRRSV viremia at dpi 7, confirming a successful PRRSV inoculation. Overall (Exp 2), during the 42 d PRRSV challenge period, a tendency was observed for HL pigs to have the greatest ADG (0.878 kg/d), control pigs to be intermediate (0.856 kg/d) and HF pigs the lowest ADG (0.830 kg/d). Overall ADFI was increased 8.6 and 3.6% in HF and HL pigs respectively compared to control, indicating that the HF fed pigs were able to adjust their voluntary feed intake to achieve a higher ADFI than control pigs, in an effort to reach their energy needs; similarly to the result in Exp 1. Additionally, an increase in overall G:F was observed in pigs fed control and HL diet compared to HF, 13.3 and 11.2% increase respectively. However, end BW at the conclusion of the 42 PRRSV challenge period did not differ between dietary treatments. In summary, experiment 2 supports that during an experimental PRRSV challenge, increasing SID Lys:ME to 120% in grower pigs aids in the mitigation of negative growth performance throughout the challenge period (Schweer et al., 2018a). However, in the current study a mild PRRSV response was seen (i.e. a moderate growth performance reduction) as a result of intranasal PRRSV inoculation. Consequently, overall ADG and end BW did not differ between dietary treatments.

We concluded that pigs fed increased SID Lys:ME during a PRRS challenge augmented growth performance, in agreeance with Schweer et al. (2018a). However, it is unclear if this dietary mitigation strategy would also provide beneficial effects on growth performance in non-viral challenged pigs. Therefore, a third experiment was conducted (Exp 3) to determine if an increased SID Lys:ME ratio would improve growth performance in pigs undergoing an MHP challenge in late finishing. *Mycoplasma hyopneumoniae* is a bacterial pathogen commonly seen in the U.S. swine industry, as it antagonizes growth rates resulting in increased market weight variation (Zimmerman, 2019). In an effort to control MHP occurrence, pigs are commonly vaccinated for MHP as a wide array of vaccines are commercially available. Vaccination has shown to reduce clinical signs and lung lesions thus improving growth performance; however, studies have also shown that vaccination may result in limited reductions of MHP transmission (Maes et al., 2018). For this work, pigs from Exp 2 were utilized 40 d prior to marketing. At ~80 kg BW, one barn was inoculated with aerosolized MHP infected lung homogenate, while the second barn remained MHP negative, serving as the control, MHP naïve group. Within barn, one of two dietary treatments were assigned resulting in 12 pen per dietary treatment per MHP status. The two treatments were: 1) A control diet formulated to contain 1.95 g SID Lys:ME (representing 100% Lys:ME) and 2) A high Lys:ME (120% ratio) diet containing 2.34 g SID Lys:ME achieved via the increased inclusion of SBM. Overall, during the 40 d MHP challenge period, the 120% Lys:ME ratio had no effect on growth performance or end BW in late finishing pigs in comparison to control fed pigs, in either MHP challenged or MHP naïve pigs. Protein deposition (PD) in swine is dependent on various factors such as genetics, BW, sex and environmental stressor present (NRC, 2012). Various swine genotypes have a limit to daily protein deposition (PD_{max}) and deposit the excess dietary protein in the body as lipid (Moughan et al., 2006). Consequently, leading us to hypothesis that the results of experiment 3 may be attributed to the late finishing pigs reaching their PD_{max} during the experiment. Thus, feeding an increased Lys diet would not be as beneficial as in early growing stages (Exp 1 and 2) when PD is more prevalent. Additionally, the pigs in Exp 3 had received vaccination against MHP prior to weaning, possibly reduced the impact of MHP inoculation on pig growth performance. However, vaccines available for MHP have had varying vaccine efficacies reported (Tao et al., 2019).

In conclusion, study reported that during a controlled PRRSV challenge (also naturally co-challenged with PCV2), increasing SID Lys:ME to 120% in grower pigs aids in the mitigation of negative growth performance associated with mixed infections including PRRSV challenge (Schweer et al., 2018a). Additionally, the ability of the pig to alter their voluntary feed intake to meet their energy needs was expressed during a health challenge. Thus, increased feed intake was observed in pigs fed a diet with reduced dietary energy, which translated to increased ADG and end BW. This work is important to determining the requirements of health challenged pigs, as they can be employed in the swine industry today to better feed pigs encountering a viral challenge. However, as shown in this work, in the event of a non-viral MHP challenge no benefit was observed when feeding 120% SID Lys:ME, in late finishing. Indicating that further research is needed to evaluate possible nutritional mitigation strategies to better feed non-viral challenged pigs. Altogether, these findings further emphasize the importance of understanding and defining nutrient requirements of health challenged pigs.

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Table 1. Experiment 1 diet composition, as fed basis, 35-70 kg

	g SID[1] Lys:Mcal ME (% of NRC)		
Ingredients, %	**2.69 (100%)**	**3.23 (HL)**	**3.22 (LE)**
Corn	75.91	68.89	56.22
Soybean meal, 48% CP	19.35	26.46	21.95
Limestone	0.94	0.93	0.84
Monocalcium phosphate, 21%	0.74	0.60	0.90
Salt	0.46	0.46	0.47
Sand	-	-	18.00
AV Blend fat	1.68	1.62	0.84
Biolys 70	0.52	0.55	0.41
L-Threonine	0.11	0.12	0.09
DL-Methionine	0.11	0.16	0.12
Valine	0.02	0.03	0.01
Vitamin Premix[2]	0.03	0.03	0.03
Trace Mineral Premix[3]	0.08	0.08	0.08
Copper sulfate (25.2%)	0.06	0.06	0.06
Ronozyme HiPhos 2500GT 500FTU/KG	0.01	0.02	0.00
Calculated composition			
DM, %	86.28	85.45	88.88
CP, %	14.77	17.60	14.48
ME, Mcal/kg	3.31	3.31	2.67
Total Calcium, %	0.58	0.58	0.58
STTD Phosphorus, %	0.24	0.24	0.24
Lys, Total %	0.99	1.18	0.96
SID AA			
Lys	0.89	1.07	0.86
Thr:Lys	0.61	0.61	0.61
Met+Cys:Lys	0.57	0.57	0.57
Trp:Lys	0.16	0.17	0.18
Ile:Lys	0.56	0.58	0.59
Val:Lys	0.65	0.65	0.65
SID Lys:ME, g/Mcal	2.69	3.23	3.22
Analyzed composition			
DM, %	87.03	87.06	87.05
CP, %	14.29	16.74	17.05
GE, Mcal/kg	3.87	3.86	3.08
Lys, Total %	0.77	1.22	1.08
Total AA:Lys			
Thr:Lys	0.86	0.56	0.53
Met+Cys:Lys	0.78	0.56	0.61
Ile:Lys	0.81	0.58	0.58
Val:Lys	0.88	0.65	0.64

[1]SID = standardized ileal digestibility

[2]Provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 5,291 IU as vitamin A acetate; vitamin D3, 827 IU as vitamin D-activated animal sterol; vitamin E, 26 IU as α-tocopherol acetate; menadione, 1.5 mg as menadione dimethylpyrimidinol bisulfite; vitamin B12, 0.02 mg; riboflavin, 6.0 mg; pantothenic acid, 22 mg as calcium pantothenate; niacin, 30 mg.

[3]Provided the following quantities of trace minerals per kilogram of complete diet: Fe, 124 mg as iron sulfate; Zn, 124 mg as zinc oxide; Mn, 29 mg as manganese sulfate; Cu, 12 mg as copper sulfate; I, 0.22 mg as calcium iodate; and Se, 0.22 mg as sodium selenite.

Table 2. Experiment 2 diet composition, as fed basis, 35-70 kg

	SID[1] Lys:ME (g/Mcal)		
Ingredients, %	2.98 (Control)	3.57 (HL)	3.57 (HF)
Corn	58.22	50.00	50.07
Soybean meal, 48% CP	20.51	29.09	23.89
DDGS	15.00	15.00	15.00
Soy hulls	-	-	8.34
Limestone	1.19	1.19	1.07
Monocalcium phosphate, 21%	0.35	0.16	0.29
Salt	0.40	0.40	0.41
AV Blend fat	3.41	3.19	0.00
Biolys 70	0.58	0.58	0.58
L-Threonine	0.06	0.07	0.07
DL-Methionine	0.08	0.13	0.11
Engage M	0.05	0.05	0.05
Vitamin Premix[2]	0.03	0.03	0.03
Trace Mineral Premix[3]	0.08	0.08	0.08
Copper Chloride (25.2%)	0.03	0.03	0.03
Ronozyme HiPhos 2500GT 500FTU/KG	0.01	0.02	0.01
Calculated composition			
DM, %	87.25	87.41	87.18
CP, %	18.30	21.68	20.27
ME, Mcal/kg	3.31	3.31	3.04
ADF, %	4.17	4.43	7.56
NDF, %	9.80	9.86	14.04
Total Calcium, %	0.63	0.63	0.63
STTD Phosphorus, %	0.31	0.31	0.31
Lys, Total %	1.13	1.35	1.26
SID AA			
Lys	0.99	1.18	1.09
Thr:Lys	0.60	0.60	0.60
Met+Cys:Lys	0.57	0.57	0.57
Trp:Lys	0.17	0.19	0.17
Ile:Lys	0.60	0.62	0.61
Val:Lys	0.68	0.68	0.67
SID Lys:ME, g/Mcal	2.98	3.57	3.57
Analyzed composition			
DM, %	89.65	89.77	89.61
CP, %	18.99	21.69	21.01
GE, Mcal/kg	4.06	4.07	3.92
Lys, Total %	1.03	1.00	1.06
Total AA:Lys			
Thr:Lys	0..67	0.71	0.70
Met+Cys:Lys	0.71	0.67	0.72
Ile:Lys	0.74	0.77	0.80
Val:Lys	0.86	0.87	0.93

[1]SID = standard ileal digestibility

[2]Provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 5,291 IU as vitamin A acetate; vitamin D3, 827 IU as vitamin D-activated animal sterol; vitamin E, 26 IU as α-tocopherol acetate; menadione, 1.5 mg as menadione dimethylpyrimidinol bisulfite; vitamin B12, 0.02 mg; riboflavin, 6.0 mg; pantothenic acid, 22 mg as calcium pantothenate; niacin, 30 mg.

[3]Provided the following quantities of trace minerals per kilogram of complete diet: Fe, 124 mg as iron sulfate; Zn, 124 mg as zinc oxide; Mn, 29 mg as manganese sulfate; Cu, 12 mg as copper sulfate; I, 0.22 mg as calcium iodate; and Se, 0.22 mg as sodium selenite.

Table 3. Experiment 3 diet composition, as fed basis, 80-123 kg

	g SID[1] Lys:Mcal ME (% of NRC)	
Ingredients, %	**1.95 (100%)**	**2.34 (120%)**
Corn	74.93	69.80
DDGS	15.00	15.00
Soybean meal	7.07	12.27
Limestone	1.12	1.10
AV blend	0.75	0.75
Biolys 70	0.49	0.50
Salt	0.44	0.34
Trace Mineral Premix[3]	0.08	0.08
Threonine	0.05	0.07
Copper chloride (58%)	0.03	0.03
Vitamin Premix[2]	0.03	0.03
Tryptophan	0.02	0.01
Ronozyme HiPhos 2500GT 500FTU/KG	0.01	0.01
Methionine-DL	-	0.02
Calculated composition		
DM, %	86.64	86.74
CP, %	13.24	15.31
ME, Mcal/kg	3.83	3.83
Total Calcium, %	0.48	0.49
STTD Phosphorus, %	0.21	0.23
Lys, Total %	0.76	0.90
SID AA		
Lys	0.64	0.77
Thr:Lys	0.64	0.64
Met+Cys:Lys	0.59	0.57
Trp:Lys	0.18	0.18
Ile:Lys	0.60	0.61
Val:Lys	0.73	0.71
SID Lys:ME, g/Mcal	1.95	2.34
Analyzed composition		
DM, %	87.29	87.32
CP, %	14.22	14.73
GE, Mcal/kg	4.00	3.89
Lys, Total %	0.72	0.97
Total AA:Lys		
Thr:Lys	0.68	0.56
Met+Cys:Lys	0.64	0.52
Ile:Lys	0.72	0.61
Val:Lys	0.82	0.73

[1]SID = standard ileal digestibility

[2]Provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 5,291 IU as vitamin A acetate; vitamin D3, 827 IU as vitamin D-activated animal sterol; vitamin E, 26 IU as α-tocopherol acetate; menadione, 1.5 mg as menadione dimethylpyrimidinol bisulfite; vitamin B12, 0.02 mg; riboflavin, 6.0 mg; pantothenic acid, 22 mg as calcium pantothenate; niacin, 30 mg.

[3]Provided the following quantities of trace minerals per kilogram of complete diet: Fe, 124 mg as iron sulfate; Zn, 124 mg as zinc oxide; Mn, 29 mg as manganese sulfate; Cu, 12 mg as copper sulfate; I, 0.22 mg as calcium iodate; and Se, 0.22 mg as sodium selenite.

Table 4. Overall effects of increasing the ratio of standard ileal digestible (SID) lysine and reduced metabolizable energy (ME) on PRRSV viremia and antibody titers in PRRSV infected pigs, Exp. 1

Parameter[1]	g SID[1] Lys:Mcal ME (% of NRC)					
	2.69 (100%)		3.23 (HL)		3.22 (LE)	
Vaccine	+	-	+	-	+	-
PRRSV Ct value[2]						
dpi 0	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0
dpi 7	25.8	17.6	25.3	16.5	24.1	19.6
dpi 14	32.0	25.4	26.8	25.3	32.1	26.2
dpi 21	35.4	27.3	35.6	20.1	≥37.0	26.8
dpi 28	≥37.0	31	>=37	30.1	≥37.0	29.8
dpi 42	≥37.0	≥37.0	≥37.0	36.7	≥37.0	≥37.0
PRRSV S/P ratio[3]						
dpi 0	2.025	-0.006	1.890	-0.008	1.881	-0.005
dpi 7	2.005	0.304	1.773	0.154	1.949	0.220
dpi 14	2.011	1.266	1.943	1.158	1.995	1.307
dpi 21	1.919	1.380	2.016	1.217	1.941	1.181
dpi 28	2.185	1.273	2.049	1.242	1.859	1.279
dpi 42	1.978	1.685	1.894	1.285	1.940	1.571

[1]pooled serology within treatment and vaccine status
[2]Cycle threshold (Ct), Ct ≥ 37.0 denotes PRRS negative.
[3]PRRSX3 antibody sample to positive (S/P) ratio, ≤ 0.40 denotes PRRS negative.

Table 5. Effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on growth performance in PRRSV infected, vaccinated growing pigs, Exp. 1

	g SID[1] Lys:Mcal ME (% of NRC)				
Parameter	**2.69 (100%)**	**3.23 (HE)**	**3.22 (LE)**	**SEM**	***P-Value***
Nursery[1]					
Start BW, kg	5.5	5.4	5.3	0.115	0.318
ADG, kg	0.482	0.490	0.478	0.017	0.883
ADFI, kg	0.755	0.798	0.760	0.018	0.277
G:F	0.720	0.708	0.709	0.022	0.911
End BW, kg	25.7	25.9	25.1	0.647	0.651
PRRSV Challenge[2]					
dpi 0 to 7					
ADG, kg	0.416	0.633	0.511	0.062	0.071
ADFI, kg	1.120[b]	1.411[a]	1.324[ab]	0.063	0.014
G:F	0.375	0.452	0.396	0.050	0.534
dpi 7 to 14					
ADG, kg	0.407	0.506	0.520	0.087	0.615
ADFI, kg	1.221[b]	1.462[ab]	1.494[a]	0.073	0.033
G:F	0.327	0.336	0.344	0.061	0.980
dpi 14 to 21					
ADG, kg	0.790	0.966	0.949	0.092	0.348
ADFI, kg	1.729	1.745	2.027	0.090	0.052
G:F	0.458	0.536	0.467	0.041	0.355
dpi 21 to 28					
ADG, kg	0.968	1.016	1.090	0.092	0.647
ADFI, kg	2.102[b]	2.221[ab]	2.525[a]	0.092	0.013
G:F	0.474	0.459	0.445	0.036	0.846
dpi 28 to 35					
ADG, kg	0.912	1.045	0.967	0.072	0.434
ADFI, kg	2.398[c]	2.438[b]	2.792[a]	0.078	0.004
G:F	0.376[b]	0.430[a]	0.346[c]	0.021	0.035
dpi 35 to 42					
ADG, kg	0.873	1.073	1.070	0.083	0.178
ADFI, kg	2.456[c]	2.590[b]	3.053[a]	0.068	<.0001
G:F	0.354	0.415	0.350	0.026	0.181

[1] Nursery period (-56 to -14 dpi), all pigs fed common diet; n = 4 pens/treatment and 15 to 17 pigs/pen

[2] Challenge period (0 to 42 dpi), all pigs fed experimental diets; n=8 pens/treatment and 7 to 10 pigs/pen

Table 6. Effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on growth performance in PRRSV infected, non-vaccinated growing pigs, Exp. 1

	g SID[1] Lys:Mcal ME (% of NRC)				
Parameter	**2.69 (100%)**	**3.23 (HL)**	**3.22 (LE)**	**SEM**	***P-Value***
Nursery[1]					
Start BW, kg	5.3	5.3	5.5	0.245	0.777
ADG, kg	0.478	0.472	0.488	0.009	0.506
ADFI, kg	0.749	0.743	0.777	0.013	0.201
G:F	0.774	0.730	0.731	0.025	0.431
End BW, kg	25.4	25.1	26.1	0.487	0.350
PRRSV Challenge[2]					
dpi 0 to 7					
ADG, kg	-0.022[b]	0.119[ab]	0.275[a]	0.064	0.014
ADFI, kg	0.839	0.879	1.001	0.052	0.083
G:F	-0.011[b]	0.121[ab]	0.270[a]	0.070	0.034
dpi 7 to 14					
ADG, kg	0.265	0.319	0.340	0.061	0.669
ADFI, kg	0.826	0.804	0.938	0.052	0.183
G:F	0.342	0.385	0.369	0.066	0.898
dpi 14 to 21					
ADG, kg	0.759	0.667	0.617	0.094	0.569
ADFI, kg	1.412	1.463	1.587	0.069	0.209
G:F	0.528	0.451	0.390	0.050	0.180
dpi 21 to 28					
ADG, kg	0.587[b]	0.782[ab]	0.894[a]	0.069	0.017
ADFI, kg	1.848	1.872	2.130	0.093	0.087
G:F	0.317[b]	0.414[ab]	0.425[a]	0.028	0.023
dpi 28-35					
ADG, kg	0.842[b]	1.086[a]	0.937[ab]	0.058	0.025
ADFI, kg	2.153[b]	2.283[b]	2.551[a]	0.045	<.001
G:F	0.392[b]	0.477[a]	0.366[b]	0.026	0.018
dpi 35 to 42					
ADG, kg	1.003	1.109	1.056	0.074	0.607
ADFI, kg	2.297[b]	2.423[ab]	2.724[a]	0.087	0.009
G:F	0.439	0.454	0.388	0.023	0.139

[1] Nursery period (-56 to -14 dpi), all pigs fed common diet; n = 4 pens/treatment and 15 to 17 pigs/pen

[2] Challenge period (0 to 42 dpi), all pigs fed experimental diets; n=8 pens/treatment and 7 to 10 pigs/pen

Table 7. Overall effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on growth performance in PRRSV infected pigs, Exp. 1

	g SID[1] Lys:Mcal ME (% of NRC)				
Parameter[1]	**2.69 (100%)**	**3.23 (HL)**	**3.22 (LE)**	**SEM**	***P-Value***
Vaccinated[2]					
Start BW, kg	34.7	36.1	34.7	0.600	0.178
End BW, kg	66.6^{b}	73.5^{a}	70.8^{a}	1.194	0.003
ADG, kg	0.728^{b}	0.873^{a}	0.851^{a}	0.033	0.013
ADFI, kg	1.838^{b}	1.978^{b}	2.202^{a}	0.054	0.001
G:F	0.394^{b}	0.438^{a}	0.391^{b}	0.010	0.005
Non-vaccinated[2]					
Start BW, kg	35.4	36.1	34.0	0.647	0.104
End BW, kg	60.4^{b}	65.8^{a}	65.6^{ab}	1.245	0.021
ADG, kg	0.572^{b}	0.680^{a}	0.687^{a}	0.030	0.024
ADFI, kg	1.563^{b}	1.621^{b}	1.823^{a}	0.047	0.003
G:F	0.334	0.384	0.368	0.014	0.135

[1] n = 8 pens/treatment and 7 to 10 pigs/pen

[2] Overall challenge period (0 to 42 dpi), pigs fed experimental diets

Table 8. Overall effects of increasing the ratio of standard ileal digestible (SID) lysine and reducing metabolizable energy (ME) on PRRSV viremia and antibody titers in PRRSV infected pigs, Exp. 2

Parameter[1]	g SID[1] Lys:Mcal ME					
	2.98 (Control)		3.57 (HL)		3.57(HF)	
Vaccine	+	-	+	-	+	-
PRRSV Ct value[2]						
dpi 0	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0
dpi 7	23.8	31.0	28.9	27.7	32.1	34.3
dpi 14	25.8	23.8	24.4	23.3	23.2	22.8
dpi 21	29.4	30.6	31.1	26.9	29.2	30.2
dpi 28	33.6	32.9	35.3	36.6	34.5	32.5
dpi 35	≥37.0	≥37.0	≥37.0	≥37.0	36.6	≥37.0
dpi 42	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0	≥37.0
PRRSV S/P ratio[3]						
dpi 0	0.013	0.032	0.013	0.010	0.158	0.039
dpi 7	0.008	0.005	0006	0.004	0.071	0.008
dpi 14	0.712	0.784	0.503	1.102	0.285	0.423
dpi 21	1.758	1.553	1.692	1.712	1.617	1.690
dpi 28	1.834	1.746	1.774	1.695	1.599	1.681
dpi 35	1.820	1.703	1.754	1.752	1.774	1.611
dpi 42	1.694	1.698	1.823	1.788	1.668	1.695

[1]pooled serology within treatment and vaccine status; n=8
[2]Cycle threshold (Ct), Ct ≥ 37.0 denotes PRRS negative.
[3]PRRSX3 antibody sample to positive (S/P) ratio, ≤ 0.40 denotes PRRS negative.

Table 9. Effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on BW performance in PRRSV infected, growing pigs, Exp. 2

Parameter[1]	g SID[1] Lys:Mcal ME						SEM	*P-Value*		
	2.98 (Control)		3.57 (HL)		3.57 (HF)			TRT	VAC	TRT X VAC
Vaccine	+	-	+	-	+	-				
Nursery[2]										
Start BW, kg	5.47	5.61	5.54	5.53	5.63	5.61	0.171	0.848	0.764	0.854
End BW, kg	23.76	23.74	24.08	24.75	23.69	24.83	0.501	0.388	0.152	0.510
PRRS challenge[3]										
dpi0 BW, kg	33.45	33.92	33.65	33.05	33.70	35.11	0.510	0.301	0.012	0.574
dpi7 BW, kg	39.94	40.28	40.21	42.01	39.90	41.93	0.850	0.288	0.014	0.394
dpi14 BW, kg	43.95	44.04	44.94	46.09	44.30	45.22	1.075	0.194	0.290	0.798
dpi 21 BW, kg	48.87	48.90	50.04	51.11	49.18	50.67	1.115	0.118	0.192	0.647
dpi 28 BW, kg	54.17	53.85	55.58	56.65	54.74	56.54	1.077	0.053	0.241	0.482
dpi 35 BW, kg	62.28	62.53	63.91	64.58	62.44	63.54	1.247	0.177	0.409	0.912
dpi 42 BW, kg	69.31	70.19	70.86	71.58	68.66	70.41	1.456	0.285	0.238	0.888

[1] n =8 pen/diet/vaccine status. Pens contained 9-10 pigs each from dpi 0 to 42

[2] 42 d nursery period (dpi -56 to -14)

[3] PRRS infection period (dpi 0 to 42) Lys:ME diets were fed from dpi 0 to 42. All pigs inoculated intranasally with 2 mL of ORF 1-18-4 isolate.

Table 10. Effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on growth performance in PRRSV infected, growing pigs, Exp. 2

Parameter[1]	g SID[1] Lys:Mcal ME						SEM	*P-Value*		
	2.98 (Control)		3.57 (HL)		3.57 (HF)			TRT	VAC	TRT X VAC
Vaccine[2]	+	-	+	-	+	-				
dpi 0 to 7										
ADG, kg	0.926	0.978	0.936	0.994	0.886	0.974	0.080	0.836	0.187	0.949
ADFI, kg	1.586	1.708	1.690	1.734	1.741	1.833	0.065	0.050	0.067	0.785
G:F	0.581	0.573	0.552	0.578	0.503	0.532	0.036	0.150	0.539	0.807
dpi 7 to 14										
ADG, kg	0.525	0.591	0.676	0.585	0.629	0.470	0.058	0.309	0.210	0.181
ADFI, kg	1.218	1.374	1.361	1.426	1.349	1.405	0.099	0.621	0.277	0.874
G:F	0.430	0.431	0.503	0.420	0.463	0.335	0.035	0.208	0.023	0.220
dpi 14 to 21										
ADG, kg	0.705	0.730	0.729	0.718	0.696	0.743	0.044	0.991	0.564	0.786
ADFI, kg	1.424	1.443	1.627	1.547	1.675	1.684	0.059	0.001	0.725	0.655
G:F	0.503	0.507	0.451	0.457	0.418	0.463	0.029	0.100	0.380	0.779
dpi 21 to 28										
ADG, kg	0.758	0.675	0.800	0.791	0.766	0.819	0.048	0.153	0.730	0.348
ADFI, kg	1.927	1.867	1.865	1.869	1.944	2.054	0.081	0.207	0.771	0.542
G:F	0.392	0.363	0.427	0.430	0.394	0.403	0.024	0.049	0.727	0.604
dpi 28 to 35										
ADG, kg	1.160	1.240	1.181	1.132	1.099	0.897	0.070	0.011	0.300	0.121
ADFI, kg	2.259	2.253	2.280	2.282	2.444	2.385	0.084	0.118	0.745	0.917
G:F	0.519	0.552	0.520	0.496	0.449	0.375	0.025	<0.001	0.311	0.122
dpi 35 to 42										
ADG, kg	1.004	1.173	0.993	0.943	0.890	0.942	0.053	0.009	0.208	0.155
ADFI, kg	2.345	2.548	2.489	2.504	2.591	2.700	0.082	0.019	0.067	0.425
G:F	0.432	0.461	0.399	0.378	0.345	0.350	0.021	0.001	0.781	0.513
Overall[3]										
ADG, kg	0.854	0.857	0.886	0.870	0.827	0.833	0.028	0.090	0.903	0.847
ADFI, kg	1.810	1.842	1.886	1.898	1.955	2.010	0.049	0.002	0.337	0.879
G:F	0.477	0.472	0.473	0.460	0.426	0.411	0.009	<0.001	0.069	0.768

[1] [1] n =8 pen/diet/vaccine status. Pens contained 9-10 pigs each from dpi 0 to 42

[2] Aptimmune Barricade mucosal vaccination status. Pigs vaccinated at day 1 post weaning and 24 days post weaning

[3] Overall PRRS virus infection period (dpi 0 to 42) Lys:ME diets were fed from dpi 0 to 42. All pigs inoculated intranasally with 2 mL of ORF 1-18-4 isolate

Table 11. Overall effects of increasing the ratio of standard ileal digestible (SID) lysine to metabolizable (ME) on growth performance in *Mycoplasma Hyopneumoniae* infected pigs, Exp. 3

	g SID[1] Lys:Mcal ME (% of NRC)			
Parameter[1]	**1.95 (100%)**	**2.34 (120%)**	**SEM**	***P-Value***
Control [2]				
Start BW, kg	80.22	79.64	0.946	0.672
End BW, kg	125.08	123.58	1.124	0.358
ADG, kg	1.117	1.168	0.054	0.515
ADFI, kg	3.307	3.296	0.043	0.862
G:F	0.338	0.354	0.016	0.460
M. Hyopneumoniae [3]				
Start BW, kg	78.93	79.60	0.829	0.570
End BW, kg	122.64	122.53	0.981	0.939
ADG, kg	1.082	1.067	0.020	0.594
ADFI, kg	3.308	3.322	0.048	0.835
G:F	0.327	0.322	0.006	0.493

[1] n = 12 pens/treatment and 8 to 10 pigs/pen; all pigs fed experimental diets (0 to 40 dpi)
[2] Confirmed PCR MHP negative throughout the challenge period
[3] Confirmed PCR MHP positive 12 and 27 dpi