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Impact of PRRSV infection and dietary soybean meal on ileal amino acid digestibility and endogenous amino acid losses in growing pigs

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Abstract

Porcine reproductive and respiratory syndrome virus (PRRSV) is a significant disease in the swine industry, and increasing soybean meal (SBM) consumption during this disease challenge may improve performance. Our objectives were to determine the impact of SBM level on apparent total tract (ATTD) and ileal (AID) digestibility during PRRSV infection and to determine ileal basal endogenous losses (BEL) during PRRSV infection. Forty PRRSV negative gilts were fitted with a T-cannula in the distal ileum. Treatments were arranged in a 2 × 2 factorial with high and low SBM (HSBM, 29% vs. LSBM, 10%), with and without PRRSV (n = 6/treatment). The remaining pigs (n = 8/challenge status) were fed a N-free diet. Chromic oxide was used as an indigestible marker. On day post inoculation (dpi) 0, at 47.7 ± 0.57 kg BW, 20 pigs were inoculated with live PRRSV; 20 control pigs were sham inoculated. Infection was confirmed by serum PCR. Feces were collected at dpi 5 to 6 and dpi 16 to 17, and ileal digesta collected at dpi 7 to 8 and dpi 18 to 19. Feed, feces, and digesta were analyzed for DM, N, and GE. Digesta and feed were analyzed for AA. Data were analyzed in a 2 × 2 + 2 factorial design to determine main effects of diet and PRRSV and their interaction. Data from N-free fed pigs were analyzed separately to determine BEL and hindgut disappearance due to PRRSV infection. All control pigs remained PRRSV negative. There were no interactions for AID of AA; however, HSBM reduced DM, GE, Lys, and Met AID and increased Arg and Gly AID during both collection periods (P < 0.05). At dpi 7 to 8 only, PRRSV reduced DM and GE AID (P < 0.05). At 7 to 8 dpi, BEL of Arg, Ala, and Pro were reduced (P < 0.05) due to PRRSV by 64%, 39%, and 94%, respectively. At dpi 18 to 19, BEL of Thr tended (P = 0.06) to be increased in PRRSV-infected pigs; however, no other differences were observed. Pigs fed LSBM had increased Lys, Met, Thr, Trp, and Pro standardized ileal digestibility (SID), primarily at 7 to 8 dpi. At 7 to 8 dpi, PRRSV reduced Arg, Gly, and Pro SID (P < 0.01), and SID Pro continued to be reduced by 17% at dpi 18 to 19. Compared with HSBM pigs, LSBM reduced hindgut disappearance of DM and GE at dpi 5 to 8 and dpi 16 to 19, while N disappearance was reduced at dpi 5 to 8. There were no differences between control and PRRSV N-free fed pigs. Altogether, SBM inclusion impacts SID of AA and hindgut disappearance of nutrients, regardless of PRRSV. In contrast, there is minimal impact of PRRSV on BEL, and therefore, SID of most AA are not different.

Keywords

amino acids, digestibility, endogenous losses, pig, PRRS

Disciplines

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Impact of PRRSV infection and dietary soybean meal on ileal amino acid digestibility and endogenous amino acid losses in growing pigs[1]

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ABSTRACT: Porcine reproductive and respiratory syndrome virus (**PRRSV**) is a significant disease in the swine industry, and increasing soybean meal (**SBM**) consumption during this disease challenge may improve performance. Our objectives were to determine the impact of SBM level on apparent total tract (**ATTD**) and ileal (**AID**) digestibility during PRRSV infection and to determine ileal basal endogenous losses (**BEL**) during PRRSV infection. Forty PRRSV negative gilts were fitted with a T-cannula in the distal ileum. Treatments were arranged in a 2 × 2 factorial with high and low SBM (**HSBM**, 29% vs. **LSBM**, 10%), with and without PRRSV (n = 6/treatment). The remaining pigs (n = 8/challenge status) were fed a N-free diet. Chromic oxide was used as an indigestible marker. On day post inoculation (**dpi**) 0, at 47.7 ± 0.57 kg BW, 20 pigs were inoculated with live PRRSV; 20 control pigs were sham inoculated. Infection was confirmed by serum PCR. Feces were collected at dpi 5 to 6 and dpi 16 to 17, and ileal digesta collected at dpi 7 to 8 and dpi 18 to 19. Feed, feces, and digesta were analyzed for DM, N, and GE. Digesta and feed were analyzed for AA. Data were analyzed in a 2 × 2 + 2 factorial design to determine main effects of diet and PRRSV and their interaction. Data from N-free fed pigs were analyzed separately to determine BEL and hindgut disappearance due to PRRSV infection. All control pigs remained PRRSV negative. There were no interactions for AID of AA; however, HSBM reduced DM, GE, Lys, and Met AID and increased Arg and Gly AID during both collection periods (P < 0.05). At dpi 7 to 8 only, PRRSV reduced DM and GE AID (P < 0.05). At 7 to 8 dpi, BEL of Arg, Ala, and Pro were reduced (P < 0.05) due to PRRSV by 64%, 39%, and 94%, respectively. At dpi 18 to 19, BEL of Thr tended (P = 0.06) to be increased in PRRSV-infected pigs; however, no other differences were observed. Pigs fed LSBM had increased Lys, Met, Thr, Trp, and Pro standardized ileal digestibility (**SID**), primarily at 7 to 8 dpi. At 7 to 8 dpi, PRRSV reduced Arg, Gly, and Pro SID (P < 0.01), and SID Pro continued to be reduced by 17% at dpi 18 to 19. Compared with HSBM pigs, LSBM reduced hindgut disappearance of DM and GE at dpi 5 to 8 and dpi 16 to 19, while N disappearance was reduced at dpi 5 to 8. There were no differences between control and PRRSV N-free fed pigs. Altogether, SBM inclusion impacts SID of AA and hindgut disappearance of nutrients, regardless of PRRSV. In contrast, there is minimal impact of PRRSV on BEL, and therefore, SID of most AA are not different.

Key words: amino acids, digestibility, endogenous losses, pig, PRRS

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INTRODUCTION

Tissue accretion rates and performance efficiency of health-challenged pigs are reduced (Escobar et al., 2004; Curry et al., 2017; Schweer et al., 2017), suggesting an alteration in nutrient utilization and resource allocation (Rakhshandeh et al., 2010; Rauw, 2012). As such, attention has been given to nutritional intervention strategies to improve the health, well-being, and performance of pigs. Recently, one strategy has involved increasing dietary soybean meal (**SBM**), and thus reducing crystalline AA use, which has been touted to promote more rapid disease resolution and improve growth performance and feed efficiency during viral pathogen challenges (Boyd et al., 2010; Rochell et al., 2015). However, the mode of action by which these beneficial SBM effects may occur are poorly defined and may involve nutrient digestibility (Schweer et al., 2017) or bioactive compounds associated with SBM (Greiner et al., 2001a,b).

Porcine reproductive and respiratory syndrome virus (**PRRSV**) is one of the most economically significant swine diseases in the world, costing the U.S. pork industry more than $660 million annually (Holtkamp et al., 2013). In growing pigs, PRRSV reduces growth performance and feed efficiency (Escobar et al., 2004; Schweer et al., 2016b). Reduced apparent total tract digestibility (**ATTD**) of nutrients and energy in grow-finisher pigs challenged with PRRSV has also been reported (Schweer et al., 2017); however, in nursery pigs, it has been shown that PRRSV did not alter ATTD or apparent ileal digestibility (**AID**) of nutrients, energy, or AA after experimental infection (Schweer et al., 2016b).

Interestingly, basal endogenous AA losses (**BEL**) have not been quantified in relation to a PRRSV challenge, and thus, it is not known if standardized ileal digestibility (**SID**) of N or AA would be different. Even so, limited studies have determined the BEL of AA due to a pathogen or vaccine challenge in pigs or other livestock species. In nursery and growing pigs, *Salmonella* Typhimurium increased BEL of several AA (Lee, 2012). In contrast, use of a mild coccidial vaccine in broilers reduced BEL of several AA (Adedokun et al., 2012). Therefore, the objectives of this study were to determine how PRRSV infection affects the digestibility of nutrients and energy in high and low SBM diets and to determine BEL of AA in response to PRRSV infection in growing pigs.

MATERIALS AND METHODS

Animals, Housing, and Experimental Design

All animal work was approved by the Iowa State University Institutional Animal Care and Use Committee (IACUC# 1-16-8156-S) and adhered to the ethical and humane use of animals for research.

The experiment was performed in 2 identical replicates consisting of 20 gilts each. In total, 40 gilts (38.6 ± 0.70 kg BW), negative for PRRSV as determined by PRRS PCR and X3 ELISA (Iowa State University Veterinary Diagnostic Laboratory, Ames, IA), were selected and surgically fitted with a T-cannula in the distal ileum as previously described (Stein et al., 1998). After surgery, pigs were moved to individual pens (1.8 × 1.9 m) and allowed to recover for 10 to 14 d. Following the recovery period, pigs were semi-sedated with 1.1 mg/kg BW of a tiletamine-zolazepam–ketamine–xylazine (Fort Dodge Animal Health, Fort Dodge, IA) combination for safe transport to the BSL2 Livestock Infectious Disease Isolation Facility (**LIDIF**) at the Iowa State Veterinary College (Ames, IA). Pigs were individually penned (1.4 × 1.5 m) with each disease status having a separate room (Control or PRRSV) to prevent viral cross-infection. Following a 4-d adaptation period at the LIDIF, on day post inoculation (**dpi**) 0, the PRRSV room (n = 10 pigs/rep) was inoculated with 2 mL (1 mL i.m. and 1 mL intranasal; 10^6 genomic units per mL) of a live PRRSV (open reading frame 5 sequence 1-3-4), while the Control room (n = 10 pigs/rep) received a sham saline inoculation. At the start of the first and second collection period, grower pigs with a BW of 47.7 ± 0.57 and 50.2 ± 0.99 kg, respectively, were used.

Diets and Feeding

Dietary treatments were arranged in a 2 × 2 + 2 factorial with 2 SBM dietary inclusion (10% vs. 29.7%) by PRRSV challenge status (with or without) as factorial variables plus a N-free (**NF**) diet with or without PRRSV as an added variable. Dietary treatments included a high SBM (**HSBM**, 29.7% SBM; n = 6 pigs/challenge status) and low SBM (**LSBM**, 10.0% SBM; n = 6 pigs/challenge status) diet (Table 1) that met or exceeded requirements for nutrients and energy (NRC, 2012). The 29.72% SBM was chosen and considered high because this inclusion rate met all the essential AA requirements without the addition of crystalline AA for this size pig. Furthermore, going beyond

Table 1. Diet composition, as-fed basis

Ingredient, %	HSBM	LSBM	N free
Corn	67.22	83.90	–
Cornstarch	–	–	78.95
Soybean meal, 46.5% CP	29.72	10.00	–
Dextrose	–	–	10.00
Solka floc	–	–	4.00
Soybean oil	–	–	3.00
Casein	–	2.17	–
Monocalcium phosphate	0.79	0.85	1.35
Limestone	0.97	1.09	1.00
Salt	0.50	0.50	0.50
L-Lys·HCl	–	0.43	–
L-Thr	–	0.13	–
L-Trp	–	0.03	–
Chromic oxide	0.40	0.40	0.40
Potassium carbonate	–	–	0.40
Vitamin premix[1]	0.15	0.15	0.15
Mineral premix[2]	0.15	0.15	0.15
Magnesium oxide	–	–	0.10

HSBM = high soybean meal; LSBM = low soybean meal.

[1]Provided per kilogram of diet: 6,125 IU vitamin A, 700 IU vitamin D_3, 50 IU vitamin E, 30-mg vitamin K, 0.05-mg vitamin B_{12}, 11-mg riboflavin, 56-mg niacin, and 27-mg pantothenic acid.

[2]Provided per kilogram of diet: 22-mg Cu (as $CuSO_4$), 220-mg Fe (as $FeSO_4$), 0.4-mg I (as $Ca(IO_3)_2$), 52-mg Mn (as $MnSO_4$), 220-mg Zn (as $ZnSO_4$), and 0.4-mg Se (as Na_2SeO_3).

this inclusion rate of SBM would promote excess N excretion and wastage. Soybean meal inclusion was limited to 10% in the LSBM diet and supplemented with L-Lys·HCl. Diets were formulated to be isocaloric (ME basis) and contain similar SID Lys concentrations (Table 1). At inoculation, a subset of pigs (n = 8 pigs/challenge status) were allotted to an NF diet (Table 1) to determine BEL associated with PRRSV. All diets contained 0.40% chromic oxide as an indigestible marker. Pigs were allotted to diets based on BW, and diets were fed starting postsurgery. Pigs on the HSBM and LSBM diets were fed the same diet for the duration of the experiment. The NF diet was fed at 0 to 8 and 12 to 19 dpi (4- to 5-d diet adaptation followed by a 4-d collection). A 50/50 blend of HSBM and LSBM diets (Table 1) was fed after collection on 8 to 11 dpi.

Pigs were restrictively fed to ensure the entire meal was eaten during the collection periods. Pigs were weighed before each collection period, and the amount of feed provided at each meal was recorded. For 5 d before collections, pigs were fed 2.5 times the estimated energy requirement for maintenance (2.5 × 197 kcal of ME per $BW^{0.60}$; NRC, 2012). The daily feed allotment was provided in 2 equal meals at 0700 and 1700 h.

Blood Collection and Analysis

To confirm PRRS viremia or the absence thereof, blood samples (10 mL) were collected from all pigs at dpi 0, 7, 14, and 21 via jugular venipuncture in vacutainer serum tubes (BD, Franklin Lakes, NJ), while pigs were restrained by a snare. After clotting, serum was separated by centrifugation (2,000 × g, 15 min at 4 °C), aliquoted, and submitted to the Iowa State Veterinary Diagnostic Laboratory (Ames, IA) for PRRSV real-time RT-PCR and serology analysis. Testing for PRRSV was performed using commercial reagents (VetMAX NA and EU PRRSV real-time RT-PCR, Thermo Fisher Scientific, Waltham, MA). A commercial ELISA kit (HerdCheck PRRS X3, IDEXX Laboratories, Inc., Westbrook, ME) was used to detect anti-PRRSV antibody per manufacturer's instruction.

Digesta and Fecal Sample Collection, Analysis, and Calculations

A representative feed sample from each diet was obtained from both replicates and pooled for subsequent analysis. In order to determine how peak viremia and seroconversion of PRRSV altered digestibility, digesta and feces were collected at 2 different periods. Feces were collected from all pigs on dpi 5 to 6 and dpi 16 to 17 and pooled by pig within period. Ileal digesta was collected from 0800 to 1600 h on dpi 7 to 8 and dpi 18 to 19 by attaching a 207-mL plastic bag (Whirl-Pak; Nasco, Fort Atkinson, WI) to the opened cannula with a cable tie. Bags were removed when they were filled with digesta or every 30 min, whichever occurred first. All fecal samples were stored at −20 °C until further analysis. Digesta samples were stored on dry ice at the BSL2 facility during collections and transferred to −20 °C after each collection day.

At the end of each sampling period, ileal and fecal samples were thawed and mixed thoroughly within pig and sampling period. A subsample of ileal digesta was collected, stored at −20 °C and lyophilized (Model 10–100; Virtis Co. Ltd., Gardiner, NY) to a constant weight. Fecal samples were dried in a mechanical convection oven at 100 °C. Feed, fecal, and digesta samples were ground through a 1-mm screen (Model ZM1; Retsch Inc., Newton, PA) prior to analysis. Proximate analysis of feed, feces, and ileal digesta samples were analyzed as previously described (Stein et al., 2007; Oresanya et al., 2008). Briefly, all samples were analyzed for

DM (method 930.15; AOAC, 2007), chromic oxide as described by Fenton and Fenton (1979), N using TruMac N (Leco Corporation, St. Joseph, MO), and GE using bomb calorimetry (Oxygen Bomb Calorimeter 6200, Parr Instruments, Moline, IL). Amino acid composition of diet and digesta samples was determined by the Agricultural Experiment Station Chemical Laboratories at the University of Missouri–Columbia (Columbia, MO) by cation-exchange HPLC (L8900 Amino Acid Analyzer, Hitachi High-Technologies Corporation, Tokyo, Japan).

The AID (%) and ATTD (%) of each dietary component were calculated using the following equations (Oresanya et al., 2008):

$$\text{AID or ATTD} = 100 - [100 \times (\text{concentration of } Cr_2O_3 \text{ in diet} \times \text{concentration of component in feces or digesta} \div \text{concentration of } Cr_2O_3 \text{ in feces or digesta} \times \text{concentration of component in diet})]$$

The BEL of AA and N (g/kg DMI) were calculated using the following equation (Stein et al., 2007):

$$\text{BEL} = [\text{AA or N in digesta} \times (Cr_2O_3 \text{ in diet} \div Cr_2O_3 \text{ in digesta})]$$

Standardized ileal digestibility values for each AA were calculated by correcting the AID for BEL using the equation (Stein et al., 2007):

$$\text{SID} = [\text{AID} + (\text{BEL} \div \text{AA in diet})]$$

As this was not a crossover design, each pig could not serve as its own control for SID determination; therefore, statistical analysis was performed on the BEL values and the reported treatment averages were used to determine SID values.

Disappearance of DM (g/d), N (g/d), and GE (Mcal/d) in the hindgut was calculated using the following equation (Pilcher et al., 2013):

$$\text{Hindgut disappearance} = \text{amount remaining at terminal ileum} - \text{amount excreted in feces}$$

Statistical Analysis

Forty pigs were assigned to a 2 × 2 + 2 factorial design. Start BW were equal among treatments, and the data were analyzed as a completely randomized design using the MIXED procedure of SAS version 9.4 (SAS Institute Inc., Cary, NC). A 2 × 2 factorial design was used to compare the fixed effects of SBM inclusion (10% vs. 29.7% dietary SBM), PRRSV (challenge vs. nonchallenge), and their interaction on AID, SID, and hindgut disappearance of nutrients and energy near peak PRRS viremia (dpi 5 to 8) and seroconversion (dpi 16 to 19). Control and PRRSV pigs fed NF diets were analyzed separately from the factorial design using the same completely randomized design to determine the impact of PRRSV on BEL and hindgut disappearance of nutrients and energy. Pig was considered the experimental unit for all analyses. Replicate was used as a random effect. All data are reported as least squares means ± SEM and considered significant if $P \leq 0.05$ and a trend if $P \leq 0.10$.

RESULTS AND DISCUSSION

Previous research completed by our group (Schweer et al., 2016b, 2017) and others (Greiner et al., 2000; Escobar et al., 2004) have reported reduced growth performance and feed efficiency due to PRRSV infection. Additionally, protein and fat accretion are reduced during a PRRSV challenge both acutely (Escobar et al., 2004) and throughout the entire finishing period (Schweer et al., 2017). Dietary strategies are of interest to recover lost growth performance and promote earlier clearance of virus in pathogen-challenged pigs. One such strategy has been the use of increasing dietary SBM. It has been reported in a commercial production environment, that increasing dietary SBM to 32% inclusion can improve growth performance during a natural inflammatory-pathogen challenge in the finishing period of pigs (Boyd et al., 2010). Similarly, in an experimental setting, increasing dietary SBM from 17% to 29%, reduced serum viremia load and improved growth in nursery pigs (Rochell et al., 2015). However, it remains unclear if improved performance and viral clearance is a result of increased digestibility of CP and AA, or by increasing the bioactive antioxidant compounds (i.e., isoflavones) that are found within SBM. Therefore, the objectives of the experiment presented herein were aimed to determine if increasing SBM level improved ileal digestibility of AA and to quantify BEL of AA during a PRRSV challenge. This allowed for AA SID coefficient calculation and then compared the SID AA values between healthy (NRC, 2012) and PRRSV-challenged pigs.

In the first replicate of the experiment, 1 pig in the control HSBM treatment was removed from the study after the first collection period due to a cannula malfunction. In the second replicate, 3 pigs

in the PRRSV NF treatment were removed from the study. Two of these pigs were euthanized due to severe interstitial pneumonia secondary to acute PRRSV infection as determined by a veterinary diagnostician, and the other pig was removed due to excessive BW loss as defined in the IACUC. Data from these removed pigs were not used in the analysis. The calculated and analyzed nutrient concentrations in each diet are presented in Table 2. As expected due to diet formulation, the HSBM diet had increased CP (18.46% vs. 13.04%) compared with the LSBM diet; however, analyzed total dietary Lys was similar in both diets (1.12% vs. 1.10%, respectively) due to the use of crystalline AA.

Viremia and Antibody

All pigs were negative for PRRS virus and antibody prior to inoculation as determined by serum PCR and ELISA. As desired, control pigs remained PRRSV negative throughout the 21-d experimental period, and all PRRSV-inoculated pigs had detectable levels of PRRS virus and antibody at 7, 14, and 21 dpi (Table 3). Expectedly, viremia decreased, and antibody increased from 7 to 21 dpi, respectively ($P < 0.001$), indicating pigs were clearing the virus and seroconverting antibodies. In the current study, all PRRSV-infected pigs, including PRRSV-inoculated NF pigs, demonstrated a classical PRRS viremia and antibody (seroconversion) response based on the timing of viremia (by 7 to 14 dpi) and seroconversion (14 to 21 dpi). This is similar to what has been previously reported in growing pigs infected with PRRSV (Greiner et al., 2000; Zimmerman et al., 2012; Schweer et al., 2016b). Interestingly, there was no effect of dietary SBM inclusion ($P > 0.10$) on serum PRRS viremia or antibody response. This is in contrast with Rochell et al. (2015), who report HSBM diets decreased serum PRRS viral load at 14 dpi as determined by PCR Ct values; although these were younger pigs, the inclusion of SBM was similar to the current study, 29.0% vs. 29.7%, respectively.

Apparent Total Tract and Ileal Digestibility

To understand how viremia and seroconversion may alter digestibility of energy and nutrients, 2 collections were chosen at 5 to 8 dpi and 16 to 19 dpi to coincide with peak PRRS viremia and

Table 2. Calculated and analyzed nutrient composition of experimental diets, as-fed basis

	Calculated			Analyzed		
Parameter	HSBM	LSBM	N free	HSBM	LSBM	N free
DM, %	89.2	89.5	–	94.6	94.6	96.3
Energy, Mcal/kg[1]	3.31	3.33	3.71	4.00	3.88	3.82
CP, %	19.4	14.2	0.20	18.5	13.0	0.73
Indispensable AA, %						
Arg	1.17	0.66	0.01	1.15	0.60	0.01
His	0.48	0.34	0.01	0.49	0.33	0.02
Ile	0.72	0.48	0.01	0.80	0.51	0.02
Leu	1.51	1.26	0.03	1.60	1.20	0.05
Lys	0.92	0.92	0.00	1.12	1.10	0.03
Met	0.28	0.31	0.00	0.27	0.29	0.01
Met + Cys	0.55	0.52	0.00	0.55	0.47	0.10
Phe	0.85	0.60	0.01	0.94	0.62	0.02
Thr	0.61	0.56	0.01	0.71	0.60	0.01
Trp	0.21	0.16	0.00	0.19	0.14	0.00
Val	0.79	0.60	0.01	0.89	0.61	0.02
Dispensable AA, %						
Ala	–	–	–	0.93	0.65	0.03
Asp	–	–	–	1.90	1.05	0.03
Cys	0.27	0.21	0.00	0.28	0.18	0.09
Glu	–	–	–	3.28	2.26	0.06
Gly	–	–	–	0.77	0.45	0.01
Pro	–	–	–	1.03	0.90	0.03
Ser	–	–	–	0.81	0.54	0.02
Tyr	0.55	0.45	0.01	0.50	0.29	0.01

HSBM = high soybean meal; LSBM = low soybean meal; N free = nitrogen free.

[1]Calculated composition = Mcal ME/kg; analyzed composition = Mcal GE/kg.

Table 3. PRRS viremia and antibody titers of pigs fed high and low soybean meal diets or nitrogen-free diet during PRRSV infection

	Complete diet					*P*-value[1]			Nitrogen-free diet			*P*-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	Diet	dpi	Diet × dpi	Control	PRRS	SEM	Diet	dpi	Diet × dpi
PRRS viremia[2]														
7 dpi	≥37	20.1	≥37	19.5	1.29	0.205	<0.001	0.567	≥37	19.3	0.91	<0.001	<0.001	<0.001
14 dpi	≥37	27.3	≥37	24.7					≥37	26.2	1.08			
21 dpi	≥37	32.6	≥37	30.6					≥37	32.4	1.08			
PRRSX3 antibody[3]														
7 dpi	<0.40	0.97	<0.40	0.97	0.36	0.550	<0.001	0.400	<0.40	0.94	0.01	<0.001	<0.001	<0.001
14 dpi	<0.40	2.42	<0.40	2.27					<0.40	2.03	0.13			
21 dpi	<0.40	2.04	<0.40	2.57					<0.40	2.17	0.13			

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, day post inoculation (dpi), and interaction of diet × dpi.

[2]Ct ≥ 37 denotes negative PRRS outcome.

[3]PRRSX3 antibody S/P ratio < 0.40 denotes PRRS negative.

seroconversion, respectively. Apparent total tract digestibility of DM, N, and GE was assessed from dpi 5 to 6 (Table 4) and dpi 16 to 17 (Table 5) by fecal grab sample. There was no diet × PRRSV interaction ($P > 0.10$) at either time point or any effect of PRRSV on any ATTD coefficients evaluated. No effect of PRRSV on ATTD coefficients is in agreement with a previous study from our group (Schweer et al., 2016b); however, this is in contrast with another study from our group (Schweer et al., 2017). In the later study, pigs were housed in a commercial barn and not in a BSL2 facility, and could have been exposed to secondary pathogens. Together, this would have had a higher immunological burden that would have contributed to the reduction in ATTD coefficients reported in this field study. Expectedly, there was an effect of diet at both time points postinoculation where ATTD of N was reduced in LSBM compared with HSBM ($P < 0.01$). This is in agreement with previous reports demonstrating that as dietary CP decreases, so does N digestibility (Yu et al., 2017). Also, at 5 to 6 dpi, ATTD of GE was reduced in the LSBM diet compared to HSBM ($P < 0.01$). This is in contrast with previous studies that reported no difference between high protein and low protein, AA-supplemented diets on energy digestibility (Kerr and Easter, 1995); however, these pigs were younger and not housed in BSL2 facilities.

Apparent ileal digestibility of DM, N, and GE was also assessed from dpi 7 to 8 (Table 4) and dpi 18 to 19 (Table 5). No diet × PRRSV interactions were found at either collection period ($P > 0.10$). During both collection periods, LSBM diets resulted in an increased DM AID compared to HSBM diets ($P < 0.05$). Similarly, at 7 to 8 dpi AID of GE was increased in LSBM-fed pigs compared to HSBM ($P = 0.027$). There was an effect of PRRSV at 7 to 8 dpi for AID of DM and GE ($P < 0.04$). Dry matter AID was reduced by PRRSV in the HSBM fed pigs by 8.4% and LSBM pigs by 3.1%, while GE AID was reduced by 7.7% and 3.4% in the HSBM and LSBM pigs, respectively. At 18 to 19 dpi, DM and GE AID were not reduced due to PRRSV, which our group has previously reported in nursery age pigs (Schweer et al., 2016b).

Apparent ileal digestibility of AA was determined from dpi 7 to 8 and dpi 18 to 19 (Tables 4 and 5, respectively). At 7 to 8 dpi, AID of Arg was minimally reduced in HSBM pigs infected with PRRSV (85.91% vs. 84.14%) and increased in LSBM pigs infected with PRRSV (80.81% vs. 83.07%, respectively) leading to a tendency for a diet × PRRSV interaction ($P = 0.063$). This trend, however, did not continue at 18 to 19 dpi. Similarly, during the first collection period, there was a tendency ($P = 0.099$) for PRRSV to reduce AID of Thr; however, this trend was not seen at 18 to 19 dpi. The AID of Lys, Met, and Thr were increased at 7 to 8 dpi in LSBM pigs ($P < 0.03$). Interestingly, only the AID of Met was significantly increased ($P = 0.023$) in LSBM pigs at 18 to 19 dpi, while AID of Lys showed a strong tendency ($P = 0.052$) to be increased. There was a significant reduction ($P < 0.05$) in the AID of Arg and Gly and a tendency ($P < 0.10$) for Tyr to be reduced in LSBM-fed pigs at both collection periods. There was also a reduction ($P < 0.05$) in AID of Asp and Pro at dpi 7 to 8, Ser at dpi 18 to

Table 4. Apparent total tract and ileal digestibility coefficients (%) in pigs fed high and low soybean meal diets at 5 to 8 dpi PRRSV infection

						P-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	PRRS	Diet	PRRS × Diet
ATTD[2], %								
DM	88.52	87.92	87.32	87.83	3.30	0.930	0.220	0.283
N	85.91	85.55	81.65	80.35	4.14	0.533	0.002	0.720
GE	86.58	86.23	84.14	84.55	3.12	0.958	0.004	0.550
AID[3], %								
DM	72.08	66.01	76.58	74.15	3.43	0.030	0.003	0.327
N	77.49	73.87	76.65	76.00	3.16	0.220	0.706	0.388
GE	73.02	67.39	75.98	73.38	3.87	0.040	0.027	0.425
Indispensable AA, %								
Arg	85.91	84.14	80.81	83.07	2.28	0.812	0.007	0.063
His	83.52	81.17	79.16	81.17	2.24	0.910	0.163	0.163
Ile	80.75	80.78	78.45	79.66	2.07	0.574	0.134	0.594
Leu	82.21	81.85	81.75	83.47	1.95	0.527	0.589	0.340
Lys	82.57	85.12	87.52	88.34	1.18	0.170	0.003	0.475
Met	84.11	85.54	88.14	89.55	1.37	0.138	<0.001	0.995
Phe	81.91	81.68	80.50	81.80	1.99	0.615	0.548	0.480
Thr	76.72	70.90	78.76	77.82	2.66	0.099	0.033	0.223
Trp	81.00	78.60	82.17	80.82	1.98	0.266	0.311	0.752
Val	76.87	76.04	74.66	75.42	2.29	0.984	0.321	0.573
Dispensable AA, %								
Ala	78.40	79.41	76.71	78.30	2.06	0.335	0.303	0.827
Asp	81.87	82.36	79.15	79.57	1.45	0.688	0.023	0.975
Cys	75.35	70.17	69.27	69.73	3.68	0.270	0.134	0.190
Glu	85.09	84.88	84.32	86.20	1.60	0.368	0.766	0.262
Gly	67.37	62.80	57.79	59.71	4.78	0.603	0.020	0.206
Pro	73.51	75.30	81.58	82.57	3.47	0.644	0.022	0.894
Ser	81.57	78.41	79.00	79.15	1.50	0.327	0.547	0.283
Tyr	79.14	76.82	74.37	75.55	2.86	0.716	0.067	0.272

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, PRRS, and interaction of PRRS × diet.

[2]ATTD = apparent total tract digestibility.

[3]AID = apparent ileal digestibility.

19, and a tendency ($P = 0.081$) for reduction of Cys at dpi 18 to 19 due to the LSBM diet.

Irrespective of challenge, increased digestibility of Lys, Met, Thr, and Trp in the LSBM diet was expected, as the diet was supplemented with crystalline AA, which are considered 100% digestible (Chung and Baker, 1992). Although there was a tendency for Thr AID to be reduced by PRRSV in the first collection period, differences in AID of AA were not expected based on a previous study where AID of AA were not different at 21 dpi of PRRSV challenge (Schweer et al., 2016b). The previous study, however, utilized younger pigs and a different, less virulent PRRSV isolate. Similarly, when pigs were challenged with lipopolysaccharide to elicit immune system stimulation, no AID differences were reported (Rakhshandeh et al., 2010). After 24 h of *Salmonella* Typhimurium infection, only AID of Gly was reduced, and at 72 h after infection, AID of Lys, Phe, Thr, and Ser were reduced (Lee, 2012), suggesting that health challenge or immune stimulation has little impact on AID coefficients.

Basal Endogenous Losses

One of the primary objectives of this paper was to determine if a PRRSV challenge altered BEL of N and AA in grower pigs. Surprisingly, BEL of N and AA are very poorly understood and defined across health compromised livestock species. In a limited number of studies, endogenous secretions are altered due to the enteric challenges *Salmonella* Typhimurium (Lee, 2012) and

Table 5. Apparent total tract and ileal digestibility coefficients (%) in pigs fed high and low soybean meal diets at 16 to 19 dpi PRRSV infection

						P-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	PRRS	Diet	PRRS × Diet
ATTD[2], %								
DM	86.01	85.22	86.05	85.51	1.32	0.239	0.762	0.825
N	84.55	83.85	80.23	82.02	1.41	0.670	0.024	0.325
GE	84.92	84.06	83.77	83.85	1.79	0.557	0.312	0.477
AID[3], %								
DM	67.85	68.95	74.90	71.76	4.90	0.635	0.033	0.329
N	74.09	75.69	72.98	73.35	5.03	0.650	0.433	0.775
GE	69.32	71.00	74.84	72.19	4.69	0.826	0.141	0.330
Indispensable AA, %								
Arg	85.05	86.75	79.69	82.06	3.74	0.227	0.008	0.840
His	82.95	83.76	79.09	81.98	4.88	0.277	0.112	0.539
Ile	79.02	79.99	79.17	78.01	3.16	0.952	0.574	0.497
Leu	80.68	81.45	80.94	81.91	3.91	0.606	0.831	0.951
Lys	82.75	83.14	86.11	86.85	5.30	0.740	0.052	0.918
Met	83.70	85.29	87.38	88.54	2.97	0.324	0.023	0.876
Phe	80.34	81.09	81.19	80.94	3.07	0.860	0.815	0.729
Thr	74.61	73.93	76.07	76.68	4.66	0.987	0.312	0.750
Trp	79.44	79.57	80.22	82.57	3.29	0.392	0.208	0.448
Val	74.21	75.64	71.66	73.16	4.90	0.521	0.286	0.987
Dispensable AA, %								
Ala	75.58	77.71	77.14	76.19	3.23	0.748	0.992	0.404
Asp	79.63	79.71	76.07	77.68	4.57	0.657	0.161	0.689
Cys	73.85	71.68	67.37	69.02	6.44	0.916	0.081	0.444
Glu	83.72	81.40	83.21	83.46	4.39	0.518	0.636	0.431
Gly	63.53	66.24	55.49	57.21	8.37	0.485	0.017	0.875
Pro	72.37	75.14	75.89	81.66	4.60	0.300	0.230	0.724
Ser	80.86	81.12	77.38	77.47	3.42	0.915	0.043	0.958
Tyr	78.28	78.50	74.71	74.85	3.35	0.916	0.057	0.980

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, PRRS, and interaction of PRRS × diet.

[2]ATTD = apparent total tract digestibility.

[3]AID = apparent ileal digestibility.

Brachyspira hyodysenteriae (Wilberts et al., 2014; Quintana-Hayashi et al., 2015), but in general, they are not well characterized. Basal endogenous loss of AA and N in healthy control pigs and pigs infected with PRRSV at 7 to 8 dpi and 18 to 19 dpi were determined using the NF method (Table 6). At 7 to 8 dpi, significant reductions ($P \leq 0.05$) in BEL of Arg, Ala, and Pro were detected, with no other differences noted ($P > 0.10$). Interestingly, BEL of N tended ($P = 0.087$) to be reduced in PRRS pigs; however, total tract basal N losses were increased in PRRS pigs (3.44 vs. 2.50 g/kg DMI, $P < 0.001$). At 18 to 19 dpi, there was a strong tendency ($P = 0.057$) for BEL of Thr to be increased. There were also numerical reductions in BEL of Arg, Ala, and Pro during this collection period, but because of high variability, significance was not detected. This high variability could be a result of variance associated with host–pathogen interactions, pathogen virulence and clearance rates, or small sample size. Similarly, ileal and total tract basal N losses were not different at 18 to 19 dpi.

When using an NF diet, BEL of Pro and Gly are generally overestimated (de Lange et al., 1989; Moughan et al., 1992), and there is an increase in BEL of Pro when pigs are offered NF diets for extended periods (Jansman et al., 2002); however, at both collection periods, BEL of Pro and Ala were reduced in PRRSV-infected pigs. This could suggest that infected pigs require more Ala and Pro than noninfected pigs. Collagen is abundant in the lungs, forming the bronchovascular skeleton and is also found in the lining of basal membranes, and is rich in Ala, Pro, and hydroxyproline (Eyre

Table 6. Basal endogenous loss of N and AA (g/kg DMI) due to PRRSV infection

	7 to 8 dpi				18 to 19 dpi			
Parameter	Control	PRRS	SEM	*P*-value	Control	PRRS	SEM	*P*-value
Fecal N	2.50	3.44	1.71	<0.001	2.83	3.05	0.70	0.637
Ileal N	3.43	2.21	1.22	0.087	4.05	2.46	1.54	0.302
Indispensable AA								
Arg	0.90	0.32	0.30	0.022	1.18	0.42	0.53	0.214
His	0.25	0.22	0.08	0.587	0.21	0.19	0.09	0.736
Ile	0.41	0.34	0.16	0.408	0.33	0.36	0.14	0.730
Leu	0.66	0.64	0.27	0.876	0.52	0.63	0.26	0.437
Lys	0.74	0.45	0.27	0.131	0.56	0.56	0.35	0.971
Met	0.11	0.09	0.05	0.406	0.08	0.10	0.04	0.643
Phe	0.41	0.39	0.17	0.841	0.33	0.41	0.17	0.363
Thr	0.64	0.72	0.24	0.482	0.49	0.77	0.25	0.057
Trp	0.13	0.14	0.05	0.627	0.10	0.13	0.05	0.287
Val	0.63	0.59	0.23	0.745	0.51	0.63	0.21	0.323
Dispensable AA								
Ala	0.75	0.46	0.29	0.050	0.79	0.48	0.36	0.329
Asp	0.98	0.78	0.37	0.314	0.82	0.85	0.38	0.888
Cys	0.28	0.25	0.10	0.620	0.19	0.23	0.09	0.171
Glu	1.21	0.96	0.51	0.335	1.00	0.99	0.46	0.970
Gly	1.92	1.37	0.68	0.310	2.48	1.38	1.05	0.264
Pro	7.59	0.43	2.13	0.009	8.17	3.51	2.29	0.188
Ser	0.61	0.51	0.19	0.299	0.50	0.52	0.20	0.764
Tyr	0.29	0.26	0.11	0.650	0.23	0.26	0.10	0.657

dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

and Muir, 1975). Girard et al. (2001) reported that PRRSV increases collagenase activity in the lung at 7 and 14 dpi, which could increase the need for Ala and Pro. Basal endogenous loss of Arg was also reduced due to PRRSV. Arginine can be readily converted to Glu, a preferred energy substrate of activated immune cells (Maciolek et al., 2014), or Pro which is involved in collagen synthesis, as previously mentioned. Nitric oxide (**NO**), a derivative of Arg, exhibits antiviral activity; however, there are contrasting reports on the ability of NO to inhibit PRRSV replication (Pampusch et al., 1998; Jung et al., 2010; Yan et al., 2017). This could be a result of insufficient Arg causing NO inhibition, which leads to increased reactive oxygen species and ultimately apoptosis (Lee and Kleiboeker, 2007).

The tendency for reduced BEL of N in PRRSV-challenged pigs could suggest a reduction in the secretion of endogenous proteins such as mucins or trefoil factors, although mucins were not different at 21 dpi in a previous study (Schweer et al., 2016a). Digestive enzyme secretion could also be reduced, and although this requires further exploration, we have seen no reduction in sucrase, maltase, or aminopeptidase activities in the jejunum of PRRSV-infected nursery pigs (Schweer et al., 2016a). Differences in total tract endogenous N loss could likely be related to microbial density and activity in the cecum and colon. Total microbial diversity can be reduced, while proteolytic species (e.g., Proteobacteria) can increase in pigs severely impacted by PRRSV challenge (Niederwerder et al., 2016). Similarly, increased microbial diversity and density in the gut can reduce coughing, lung lesion scores, and respiratory cytokines during *Mycoplasma hyopneumoiniae* challenge (Schachtschneider et al., 2013). Changes in pig gut microbial density or diversity have not been described in other viral respiratory challenges.

Standardized Amino Acid Digestibility

The SID of AA was determined by correcting the AID coefficients for BEL at 7 to 8 dpi and 18 to 19 dpi (Tables 7 and 8, respectively). There was a tendency for interaction ($P = 0.061$) at 7 to 8 dpi for the SID of Pro, where it was lower in HSBM pigs compared to LSBM and reduced by PRRSV in a similar manner (43% and 46% reduction, respectively) in both diets. At 18 to 19 dpi, no interactions were detected. A reduction ($P < 0.05$) in the SID of Arg, Gly, Pro, Ala ($P = 0.09$), and Ser ($P = 0.06$) from PRRSV infection was detected at 7 to 8 dpi. At 18 to 19 dpi only, a reduction in the SID of Pro ($P = 0.001$) was reported. An increase ($P < 0.05$) in SID of Lys, Met, and Trp in LSBM

pigs was detected at both time points, while SID of Thr was increased ($P < 0.01$) at 7 to 8 dpi and tended ($P = 0.10$) to be increased at 18 to 19 dpi. Also, at 7 to 8 dpi, SID of Pro was significantly increased ($P < 0.001$), while Leu ($P = 0.096$) and Glu ($P = 0.077$) tended to increase in pigs fed the LSBM diet.

Interestingly, very few studies have examined the relationship between AA SID and infection in livestock species. In the current study, SID values were determined from AID values through the use of an NF diet and determination of BEL. As previously mentioned, BEL of some AA can be overestimated using an NF diet. Therefore, it is possible that some SID values can be overestimated. Proline determination can be variable; even so, there was a tendency for interaction in the current study. Decreased SID of Arg and Pro due to PRRSV infection are likely due to the decreased BEL of each of these AA. In a repeated lipopolysaccharide injection model, Rakhshandeh et al. (2014) reported no difference in SID of Met and Cys; however, SID values were calculated from BEL values described by Jansman et al. (2002). To the author's knowledge, there are only 2 studies that report both BEL and SID values in pigs utilizing a *Salmonella* Typhimurium challenge model in nursery and grower pigs. In nursery pigs, Lee (2012) used a comparative slaughter technique and reported a tendency for SID of Arg to be reduced at 24- and 72-h postchallenge. In the same study, and in contrast to the current study, SID of Gly was increased by more than 2-fold at 24 h but was not different at 72-h postchallenge. No differences in Pro, Ala, or Ser were reported in the study. Using the T-cannula method, SID of all AA were significantly reduced or tended to be reduced between 8 and 24 h after inoculation in growing pigs; however, by 56-h postinoculation SID values had recovered to preinoculation values (Lee, 2012). In the same study, the greatest reduction was seen in Gly (53% reduction), which is in agreement with the current study, but contrasts the previous study by Lee, which utilized younger pigs. As *Salmonella* Typhimurium is a bacterial pathogen that impacts the intestinal tract, it likely has a different impact than a respiratory virus like PRRSV, probably leading to differences in the 2 studies.

Expectedly, SID of Lys, Met, Thr, and Trp were increased in the LSBM diet due to the use of crystalline AA, which are assumed to be 100% digestible (Chung and Baker, 1992). Increased SID of Pro, Leu, and Glu in LSBM diets may be related

Table 7. Standardized ileal digestibility coefficients (%) in pigs fed high and low soybean meal diets at 7 to 8 dpi PRRSV infection

						P-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	PRRS	Diet	PRRS × Diet
N	78.15	74.30	77.27	76.41	3.16	0.177	0.718	0.386
Indispensable AA, %								
Arg	93.44	88.01	95.12	88.24	1.89	<0.001	0.317	0.448
His	88.67	88.44	86.62	87.84	1.62	0.724	0.354	0.606
Ile	85.56	84.80	85.99	85.97	2.07	0.728	0.475	0.740
Leu	86.08	85.61	86.92	88.49	1.95	0.609	0.096	0.347
Lys	88.79	88.95	93.85	92.25	1.18	0.548	0.002	0.463
Met	87.96	88.67	91.72	92.47	1.37	0.437	0.001	0.985
Phe	86.01	85.62	86.72	87.78	1.99	0.752	0.192	0.501
Thr	85.24	80.50	88.85	89.18	2.66	0.269	0.005	0.206
Trp	87.59	85.77	91.12	90.55	1.98	0.472	0.020	0.707
Val	83.58	82.36	84.46	84.64	2.29	0.712	0.271	0.618
Dispensable AA, %								
Ala	86.06	84.06	87.68	84.95	2.06	0.090	0.354	0.788
Asp	86.77	86.26	88.02	86.63	1.45	0.405	0.476	0.698
Cys	84.67	78.55	83.76	82.78	3.68	0.104	0.434	0.232
Glu	88.59	87.66	89.40	90.23	1.60	0.955	0.077	0.341
Gly	90.15	78.26	97.32	81.65	7.56	0.002	0.188	0.630
Pro	137.49	77.89	160.59	86.34	5.05	<0.001	<0.001	0.061
Ser	88.66	84.31	89.63	88.00	1.50	0.060	0.136	0.376
Tyr	84.64	81.83	83.86	84.19	2.86	0.433	0.616	0.322

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, PRRS, and interaction of PRRS × diet.

Table 8. Standardized ileal digestibility coefficients (%) in pigs fed high and low soybean meal diets at 18 to 19 dpi PRRSV infection

						P-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	PRRS	Diet	PRRS × Diet
N	87.49	86.08	91.18	88.70	3.29	0.408	0.201	0.820
Indispensable AA, %								
Arg	95.35	93.33	97.79	92.98	2.34	0.133	0.656	0.538
His	87.17	87.62	87.26	88.18	3.79	0.602	0.812	0.856
Ile	82.87	84.02	84.75	84.46	3.23	0.789	0.492	0.653
Leu	83.73	84.84	84.82	86.62	4.04	0.387	0.403	0.838
Lys	87.51	87.86	90.95	91.64	5.28	0.758	0.047	0.917
Met	86.62	88.50	90.12	91.58	3.08	0.232	0.029	0.882
Phe	83.43	84.80	83.60	86.39	4.05	0.234	0.615	0.684
Thr	80.90	82.27	83.22	87.31	5.54	0.205	0.100	0.524
Trp	84.33	85.24	86.55	90.65	3.62	0.119	0.025	0.312
Val	79.55	81.69	79.03	82.39	5.15	0.239	0.969	0.791
Dispensable AA, %								
Ala	83.68	84.20	85.53	84.18	3.51	0.859	0.702	0.692
Asp	83.73	83.86	82.95	85.33	4.51	0.517	0.861	0.564
Cys	80.10	78.69	76.51	80.41	6.71	0.619	0.714	0.300
Glu	86.62	84.27	87.21	87.65	4.35	0.554	0.237	0.395
Gly	94.67	89.90	100.26	92.88	6.48	0.193	0.367	0.777
Pro	152.21	127.07	163.17	134.13	11.54	0.001	0.189	0.774
Ser	86.65	87.08	85.58	86.56	3.43	0.670	0.641	0.868
Tyr	82.69	83.17	81.66	83.13	3.47	0.589	0.776	0.786

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, PRRS, and interaction of PRRS × diet.

to dietary N. Zhai and Adeola (2011) reported a negative linear relationship between the digestibility of several AA and dietary CP, with SID of AA decreasing as CP increased. Included in this were Leu and Glu, and although not significant, Pro decreased as well. Decreases may be related to an oversupply of AA in the HSBM diet that would saturate AA transporters in the small intestine.

Hindgut Disappearance

Hindgut disappearance was calculated from AID and ATTD values for all pigs at 5 to 8 dpi and 16 to 19 dpi to determine differences attributed to diet, PRRS, or their interaction (Table 9). No diet × PRRS interaction was detected at either collection period. At 5 to 8 dpi, PRRS increased ($P < 0.03$) hindgut disappearance of DM and GE by 21% and 23%, respectively, in pigs fed a complete diet. Interestingly, there was a tendency ($P = 0.10$) for PRRS to reduce DM disappearance in the hindgut at 16 to 19 dpi. The increase in hindgut DM and GE disappearance is likely related to an increase in microbial density in the cecum and colon of PRRSV-challenged pigs (Niederwerder et al., 2016).

Diet significantly ($P < 0.001$) influenced all parameters at 5 to 8 dpi. In pigs fed HSBM diets, hindgut disappearance of DM, N, and GE were all increased compared with pigs fed LSBM diets. Similarly, at 16 to 19 dpi, DM disappearance was significantly increased ($P = 0.023$), while N and GE disappearance tended to be increased ($P = 0.082$ and $P = 0.051$, respectively) in pigs fed HSBM diet. Increased disappearance of nutrients and energy in the hindgut of pigs fed HSBM diets was likely due to the increased CP content in the diet, and therefore, increased protein reaching the cecum and colon promoting microbial growth. Although pigs cannot readily absorb and utilize N from the hindgut for protein deposition (Rérat, 1978), energy used by the hindgut can contribute to maintenance energy and improve feed efficiency (Dierick et al., 1990).

Hindgut disappearance was also determined in the NF pigs to determine differences between control and PRRSV-challenged pigs. Surprisingly, no differences ($P > 0.10$) were detected at 5 to 8 dpi or 16 to 19 dpi. A numerical increase in DM disappearance at both collection periods (62% and 55%, respectively) was seen in PRRSV pigs compared with control pigs; however, due to high variation,

Table 9. Hindgut disappearance of nutrients and energy in pigs fed high and low soybean meal diets after PRRSV infection

						P-value[1]		
Parameter	HSBM−	HSBM+	LSBM−	LSBM+	SEM	PRRS	Diet	PRRS × Diet
Complete diet								
5 to 8 dpi								
DM, g/d	244	312	158	197	19.7	0.014	<0.001	0.462
N, g/d	3.93	4.94	1.22	1.28	0.83	0.293	<0.001	0.353
GE, Mcal/d	0.84	1.05	0.48	0.65	0.08	0.026	<0.001	0.771
16 to 19 dpi								
DM, g/d	286	219	196	172	50.1	0.100	0.023	0.417
N, g/d	4.89	2.79	1.45	1.96	1.43	0.491	0.082	0.266
GE, Mcal/d	1.01	0.70	0.64	0.56	0.19	0.114	0.051	0.339
Nitrogen-free diet	Control	PRRS	SEM	*P*-value				
5 to 8 dpi								
DM, g/d	57	151	40.8	0.129				
N, g/d	0.97	−0.66	1.17	0.345				
GE, Mcal/d	0.18	0.23	0.13	0.787				
16 to 19 dpi								
DM, g/d	44	98	41.0	0.374				
N, g/d	1.96	1.46	1.57	0.824				
GE, Mcal/d	0.12	0.27	0.17	0.523				

HSBM−, LSBM− = high soybean meal (HSBM), low soybean meal (LSBM) without PRRS; HSBM+, LSBM+ = high soybean meal (HSBM), low soybean meal (LSBM) with PRRS; dpi = days post inoculation; PRRSV = porcine reproductive and respiratory syndrome virus.

[1]Main effect of diet, PRRS, and interaction of PRRS × diet.

no significance was detected. A potential increase in DM disappearance coupled with increased total tract endogenous N loss could be a result of increased microbial activity and/or abundance. In pigs fed protein-free diets, fecal and microbial protein composition is similar (Taverner et al., 1981), probably indicating an increase in microbial abundance in the hindgut of PRRSV pigs, which can have a beneficial outcome (Niederwerder et al., 2016).

Conclusion

Diet is known to impact AID and SID of AA. Crystalline AA are assumed to be 100% digestible, so when a diet is supplemented with crystalline AA, digestibility increases as demonstrated in the current study. Similarly, as dietary AA content decreases, AID and SID increase (Otto et al., 2003). Diet also can alter the microbial profile in the gut leading to changes in hindgut disappearance of nutrients. Health challenges are known to impact AID, but studies to determine SID values are scarce. Digestibility of AA during stress appears to be dependent on the stage of disease. After 24 h of *Salmonella* Typhimurium, AID of AA were minimally impacted while after 72 h, AID of Lys, Phe, Thr, and Ser were reduced (Lee, 2012). Interestingly, SID of His and Gly were increased at 24 h and SID of Lys was reduced at 72 h. In the current study, only SID of Arg, Gly, and Pro at 7 to 8 dpi and SID of Pro at 18 to 19 dpi were reduced. Similarly, environmental stress and pathogens impact BEL of AA where it has been shown that heat stressing pigs for 2 d resulted in increased BEL of Arg and His. After 8 d of adaptation to heat stress, BEL of total nonessential AA and Pro increased by 16% and 54%, respectively. In contrast, nursery or grower pigs challenged with *Salmonella* Typhimurium demonstrated increased BEL of all AA within 24 h but were not different after 56 h (Lee, 2012). In the current study, PRRSV reduced BEL of Arg, Ala, and Pro at 7 to 8 dpi only. Although oppositely affected, BEL differences were detected around peak disease in these studies and were not different during the recovery phase.

Altogether, these data suggest that potential benefits of feeding increased SBM during a PRRSV challenge are likely not related to digestibility of nutrients or AA. Also, PRRSV has little impact on digestibility. In contrast to other challenge models, BEL of some AA were reduced at peak viremia and were not different during seroconversion, although there is high variability associated with the determination of these values. In conclusion, SBM inclusion impacts SID of AA and hindgut disappearance of nutrients, regardless of PRRSV. Furthermore, there was minimal impact of PRRSV on BEL, and therefore, SID of most AA were not different.

LITERATURE CITED

Adedokun, S. A., K. M. Ajuwon, L. F. Romero, and O. Adeola. 2012. Ileal endogenous amino acid losses: Response of broiler chickens to fiber and mild coccidial vaccine challenge. Poult. Sci. 91:899–907. doi:10.3382/ps.2011-01777

AOAC. 2007. Official methods of analysis of AOAC International. 18th ed. AOAC Int., Gaithersburg, MD.

Boyd, R. D., M. E. Johnston, and C. E. Zier-Rush. 2010. Soybean meal level modulates the adverse effect of high immune stress on growth and feed efficiency in growing pigs. In: Proc 71st Minnesota Nutrition Conf, Owatonna, MN. University of Minnesota, St. Paul, MN.

Chung, T. K., and D. H. Baker. 1992. Apparent and true amino acid digestibility of a crystalline amino acid mixture and of casein: Comparison of values obtained with ileal-cannulated pigs and cecectomized cockerels. J. Anim. Sci. 70:3781–3790. doi:10.2527/1992.70123781x

Curry, S. M., K. A. Gibson, E. R. Burrough, K. J. Schwartz, K. J. Yoon, and N. K. Gabler. 2017. Nursery pig growth performance and tissue accretion modulation due to porcine epidemic diarrhea virus or porcine deltacoronavirus challenge. J. Anim. Sci. 95:173–181. doi:10.2527/jas.2016.1000

de Lange, C. F., W. C. Sauer, and W. Souffrant. 1989. The effect of protein status of the pig on the recovery and amino acid composition of endogenous protein in digesta collected from the distal ileum. J. Anim. Sci. 67:755–762. doi:10.2527/jas1989.673755x

Dierick, N. A., I. J. Vervaeke, J. A. Decuypere, and H. K. Henderickx. 1990. Bacterial protein synthesis in relation to organic matter digestion in the hindgut of growing pigs; contribution of hindgut fermentation to total energy supply and growth performances. J. Anim. Physiol. Anim. Nutr. (Berl) 63:220–235. doi:10.1111/j.1439-0396.1990.tb00139.x

Escobar, J., W. G. Van Alstine, D. H. Baker, and R. W. Johnson. 2004. Decreased protein accretion in pigs with viral and bacterial pneumonia is associated with increased myostatin expression in muscle. J. Nutr. 134:3047–3053.

Eyre, D. R., and H. Muir. 1975. The distribution of different molecular species of collagen in fibrous, elastic and hyaline cartilages of the pig. Biochem. J. 151:595–602. doi:10.1042/bj1510595

Fenton, T. W., and M. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and feces. Can. J. Anim. Sci. 59:631–634. doi:10.4141/cjas79-081

Girard, M., P. Cléroux, P. Tremblay, S. Dea, and Y. St-Pierre. 2001. Increased proteolytic activity and matrix metalloprotease expression in lungs during infection by porcine reproductive and respiratory syndrome virus. J. Gen. Virol. 82(Pt 6):1253–1261. doi:10.1099/0022-1317-82-6-1253

Greiner, L. L., T. S. Stahly, and T. J. Stabel. 2000. Quantitative relationship of systemic virus concentration on growth and immune response in pigs. J. Anim. Sci. 78:2690–2695. doi:10.2527/2000.78102690x

Greiner, L. L., T. S. Stahly, and T. J. Stabel. 2001a. The effect of dietary soy daidzein on pig growth and viral replication during a viral challenge. J. Anim. Sci. 79:3113–3119. doi:10.2527/2001.79123113x

Greiner, L. L., T. S. Stahly, and T. J. Stabel. 2001b. The effect of dietary soy genistein on pig growth and viral replication during a viral challenge. J. Anim. Sci. 79:1272–1279. doi:10.2527/2001.7951272x

Holtkamp, D. J., J. B. Kliebenstein, E. J. Neumann, J. J. Zimmerman, H. F. Rotto, T. K. Yoder, C. Wang, P. E. Yeske, C. L. Mowrer, and C. A. Haley. 2013. Assessment of the economic impact of porcine reproductive and respiratory syndrome virus on United States pork producers. J. Am. Vet. Med. Assoc. 21:72–84.

Jansman, A. J. M., W. Smink, P. van Leeuwen, and M. Rademacher. 2002. Evaluation through literature data of the amount and amino acid composition of basal endogenous crude protein at the terminal ileum of pigs. Anim. Feed Sci. Technol. 98:49–60. doi:10.1016/S0377-8401(02)00015-9

Jung, K., A. Gurnani, G. J. Renukaradhya, and L. J. Saif. 2010. Nitric oxide is elicited and inhibits viral replication in pigs infected with porcine respiratory coronavirus but not porcine reproductive and respiratory syndrome virus. Vet. Immunol. Immunopathol. 136:335–339. doi:10.1016/j.vetimm.2010.03.022

Kerr, B. J., and R. A. Easter. 1995. Effect of feeding reduced protein, amino acid-supplemented diets on nitrogen and energy balance in grower pigs. J. Anim. Sci. 73:3000–3008. doi:10.2527/1995.73103000x

Lee, H. 2012. Impact of exogenous factors on amino acid digestibility in non-ruminants. Virginia Polytechnic Institute and State University. http://scholar.lib.vt.edu/theses/available/etd-05112012-081827/

Lee, S. M., and S. B. Kleiboeker. 2007. Porcine reproductive and respiratory syndrome virus induces apoptosis through a mitochondria-mediated pathway. Virology 365:419–434. doi:10.1016/j.virol.2007.04.001

Maciolek, J. A., J. A. Pasternak, and H. L. Wilson. 2014. Metabolism of activated T lymphocytes. Curr. Opin. Immunol. 27:60–74. doi:10.1016/j.coi.2014.01.006

Moughan, P. J., G. Schuttetr, and M. Leenaars. 1992. Endogenous amino acid flow in the stomach and small intestine of the young growing pig. J. Sci. Food Agric. 60:437–442. doi:10.1002/jsfa.2740600406

Niederwerder, M. C., C. J. Jaing, J. B. Thissen, A. G. Cino-Ozuna, K. S. McLoughlin, and R. R. Rowland. 2016. Microbiome associations in pigs with the best and worst clinical outcomes following co-infection with porcine reproductive and respiratory syndrome virus (PRRSV) and porcine circovirus type 2 (PCV2). Vet. Microbiol. 188:1–11. doi:10.1016/j.vetmic.2016.03.008

NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl Acad. Press, Washington, DC.

Oresanya, T. F., A. D. Beaulieu, and J. F. Patience. 2008. Investigations of energy metabolism in weanling barrows: The interaction of dietary energy concentration and daily feed (energy) intake. J. Anim. Sci. 86:348–363. doi:10.2527/jas.2007-0009

Otto, E. R., M. Yokoyama, P. K. Ku, N. K. Ames, and N. L. Trottier. 2003. Nitrogen balance and ileal amino acid digestibility in growing pigs fed diets reduced in protein concentration. J. Anim. Sci. 81:1743–1753. doi:10.2527/2003.8171743x

Pampusch, M. S., A. M. Bennaars, S. Harsch, and M. P. Murtaugh. 1998. Inducible nitric oxide synthase expression in porcine immune cells. Vet. Immunol. Immunopathol. 61:279–289. doi:10.1016/S0165-2427(97)00139-6

Pilcher, C. M., R. Arentson, and J. F. Patience. 2013. Impact of tylosin phosphate and distillers dried grains with solubles on energy and nutrient digestibility and flow through the gastrointestinal tract in growing pigs. J. Anim. Sci. 91:5687–5695. doi:10.2527/jas.2013-6746

Quintana-Hayashi, M. P., M. Mahu, N. De Pauw, F. Boyen, F. Pasmans, A. Martel, P. Premaratne, H. R. Fernandez, O. Teymournejad, L. Vande Maele, et al. 2015. The levels

of brachyspira hyodysenteriae binding to porcine colonic mucins differ between individuals, and binding is increased to mucins from infected pigs with de novo MUC5AC synthesis. Infect. Immun. 83:1610–1619. doi:10.1128/IAI.03073-14

Rakhshandeh, A., J. K. Htoo, and C. F. M. de Lange. 2010. Immune system stimulation of growing pigs does not alter apparent ileal amino acid digestibility but reduces the ratio between whole body nitrogen and sulfur retention. Livest. Sci. 134:21–23. doi:10.1016/j.livsci.2010.06.085

Rakhshandeh, A., J. K. Htoo, N. Karrow, S. P. Miller, and C. F. de Lange. 2014. Impact of immune system stimulation on the ileal nutrient digestibility and utilisation of methionine plus cysteine intake for whole-body protein deposition in growing pigs. Br. J. Nutr. 111:101–110. doi:10.1017/S0007114513001955

Rauw, W. M. 2012. Immune response from a resource allocation perspective. Front. Genet. 3:267. doi:10.3389/fgene.2012.00267

Rérat, A. 1978. Digestion and absorption of carbohydrates and nitrogenous matters in the hindgut of the omnivorous nonruminant animal. J. Anim. Sci. 46:1808–1837. doi:10.2527/jas1978.4661808x

Rochell, S. J., L. S. Alexander, G. C. Rocha, W. G. Van Alstine, R. D. Boyd, J. E. Pettigrew, and R. N. Dilger. 2015. Effects of dietary soybean meal concentration on growth and immune response of pigs infected with porcine reproductive and respiratory syndrome virus. J. Anim. Sci. 93:2987–2997. doi:10.2527/jas.2014-8462

Schachtschneider, K. M., C. J. Yeoman, R. E. Isaacson, B. A. White, L. B. Schook, and M. Pieters. 2013. Modulation of systemic immune responses through commensal gastrointestinal microbiota. PLoS ONE 8:e53969. doi:10.1371/journal.pone.0053969

Schweer, W. P., S. C. Pearce, E. R. Burrough, K. Schwartz, K. J. Yoon, J. C. Sparks, and N. K. Gabler. 2016a. The effect of porcine reproductive and respiratory syndrome virus and porcine epidemic diarrhea virus challenge on growing pigs II: Intestinal integrity and function. J. Anim. Sci. 94:523–532. doi:10.2527/jas.2015-9836

Schweer, W. P., K. Schwartz, E. R. Burrough, K. J. Yoon, J. C. Sparks, and N. K. Gabler. 2016b. The effect of porcine reproductive and respiratory syndrome virus and porcine epidemic diarrhea virus challenge on growing pigs I: Growth performance and digestibility. J. Anim. Sci. 94:514–522. doi:10.2527/jas.2015-9834

Schweer, W., K. Schwartz, J. F. Patience, L. Karriker, C. Sparks, M. Weaver, M. Fitzsimmons, T. E. Burkey, and N. K. Gabler. 2017. Porcine reproductive and respiratory syndrome virus reduces feed efficiency, digestibility, and lean tissue accretion in grow-finish pigs. Transl. Anim. Sci. 1:480–488. doi:10.2527/tas2017.0054

Stein, H. H., B. Seve, M. F. Fuller, P. J. Moughan, and C. F. de Lange. 2007. Invited review: Amino acid bioavailability and digestibility in pig feed ingredients: Terminology and application. J. Anim. Sci. 85:172–180. doi:10.2527/jas.2005-742

Stein, H. H., C. F. Shipley, and R. A. Easter. 1998. Technical note: A technique for inserting a T-cannula into the distal ileum of pregnant sows. J. Anim. Sci. 76:1433–1436. doi:10.2527/1998.7651433x

Taverner, M. R., I. D. Hume, and D. J. Farrell. 1981. Availability to pigs of amino acids in cereal grains: 1. Endogenous levels of amino acids in ileal digesta and faeces of pigs given cereal diets. Br. J. Nutr. 46:149–158. doi:10.1079/BJN19810017

Wilberts, B. L., P. H. Arruda, J. M. Kinyon, D. M. Madson, T. S. Frana, and E. R. Burrough. 2014. Comparison of sesion severity, distribution, and colonic mucin expression in pigs with acute swine dysentery following oral inoculation with "brachyspira hampsonii" or brachyspira hyodysenteriae. Vet. Pathol. 51:1096–1108. doi:10.1177/0300985813516646

Yan, M., M. Hou, J. Liu, S. Zhang, B. Liu, X. Wu, and G. Liu. 2017. Regulation of inos-derived ROS generation by HSP90 and cav-1 in porcine reproductive and respiratory syndrome virus-infected swine lung injury. Inflammation 40:1236–1244. doi:10.1007/s10753-017-0566-9

Yu, M., C. Zhang, Y. Yang, C. Mu, Y. Su, K. Yu, and W. Zhu. 2017. Long-term effects of early antibiotic intervention on blood parameters, apparent nutrient digestibility, and fecal microbial fermentation profile in pigs with different dietary protein levels. J. Anim. Sci. Biotechnol. 8:60. doi:10.1186/s40104-017-0192-2

Zhai, H., and O. Adeola. 2011. Apparent and standardized ileal digestibilities of amino acids for pigs fed corn- and soybean meal-based diets at varying crude protein levels. J. Anim. Sci. 89:3626–3633. doi:10.2527/jas.2010-3732

Zimmerman, J. J., D. A. Benfield, S. A. Dee, M. P. Murtaugh, T. Stadejek, G. W. Stevenson, and M. Torremorell. 2012. Chapter 31—Porcine reproductive and respiratory syndrome virus (porcine arterivirus). In: J. J. Zimmerman, L. A. Karriker, A. Ramirez, K. J. Schwartz, and G. W. Stevenson, editors. Diseases of swine. 10th ed. John Wiley and Sons, Hoboken, NJ. p. 461–486.