The effects of porcine intestinal mucosa protein sources on nursery pig growth performance[1]

A. J. Myers,* R. D. Goodband,*[2] M. D. Tokach,* S. S. Dritz,† J. M. DeRouchey,* and J. L. Nelssen*

*Department of Animal Sciences and Industry, College of Agriculture; and †Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine; Kansas State University, Manhattan 66506-0201

ABSTRACT: Three studies were conducted to compare the effects of 4 different porcine intestinal mucosa products (PEP2, PEP2+, Peptone 50, and PEP-NS; TechMix Inc., Stewart, MN) with select menhaden fish meal (SMFM) on nursery pig performance. These intestine-derived mucosal ingredients are byproducts of heparin production, with a similar amount of mucosal protein, but differ based on the carriers with which they are co-dried. Enzymatically processed vegetable protein is the carrier for PEP2 whereas PEP2+ is co-dried with enzymatically processed vegetable proteins and biomass from crystalline AA production. Peptone 50 uses vegetable protein as its carrier while PEP-NS is co-dried with byproducts of corn wet milling and biomass from crystalline AA production. In Exp. 1, 300 weanling pigs (PIC 327 × 1050; initially 5.4 kg and 19 d of age) were allotted to 1 of 5 dietary treatments with 12 replications and 5 pigs per pen. Diets consisted of a negative control (NC) containing no specialty protein sources, NC with 4, 8, or 12% PEP2 in phases 1 (d 0 to 11) and 2 (d 11 to 25), and a positive control containing 4% spray-dried animal plasma (SDAP) in phase 1 and 4% SMFM in phase 2. From d 0 to 11, pigs fed SDAP had greater ($P < 0.05$) ADG and G:F than pigs fed PEP2. From d 11 to 25, increasing PEP2 increased (quadratic; $P < 0.01$) ADG and G:F, with the greatest response observed at 4%. In Exp. 2, 960 weanling pigs (Newsham GPK35 × PIC 380; initially 5.6 kg, and 20 d of age) were allotted to 1 of 5 dietary treatments with 32 pigs per pen and 6 replications per treatment. Diets included a control with 4.5% SDAP in phase 1 (d 0 to 7) and no specialty protein sources in phase 2 (d 7 to 21) or the control diet with 6% of the following: SMFM, PEP2+, Peptone 50, or PEP-NS. From d 0 to 21, pigs fed diets containing SMFM, PEP2+, or PEP-NS had greater ($P < 0.05$) ADG than pigs fed the control or 6% Peptone 50. In Exp. 3, 180 nursery pigs (PIC 327 × 1050; initially 6.4 kg and 28 d of age) were allotted to 1 of 5 dietary treatments with 5 pigs per pen and 6 replications per treatment. Treatment diets were fed from d 7 to 21 postweaning. Treatments consisted of a NC, NC with 3, 6, 9, or 12% PEP-NS, or NC with 6% SMFM. Overall, pigs fed increasing PEP-NS had improved (quadratic; $P < 0.01$) ADG and G:F, with the greatest improvement observed in pigs fed 6% PEP-NS, similar to those fed 6% SMFM. These results suggest PEP2, PEP2+, and PEP-NS can effectively replace SMFM in nursery pig diets.

Key words: fish meal, heparin, peptide, pig

J. Anim. Sci. 2014.92:783–792
doi:10.2527/jas2013-6551

INTRODUCTION

Numerous protein sources have been investigated for their efficacy to stimulate both feed intake and growth performance in the weanling pig. Research has indicated that porcine intestinal mucosa, a byproduct of heparin production, may be a suitable replacement for fish meal in nursery pig diets (Jones et al., 2010). Intestinal peptides are derived from the mucosa linings of pig intestines, which are collected at packing plants and are removed and hydrolyzed, resulting in a material composed of small-chain peptides. It has been observed that pigs may have an increased absorptive capacity for AA in peptide form rather than intact proteins (Gilbert

[1]Contribution no. 12-398-J of the Kansas State University Exp. Sta., Manhattan, KS 66506. The authors thank Denny McKilligan and Brent Ratliff for technical assistance and TechMix Inc., Stewart, MN, for partial financial support.

[2]Corresponding author: goodband@ksu.edu

Received April 4, 2013.
Accepted December 7, 2013.

et al., 2008). Peptone products (PEP2, PEP2+, PEP-NS, and Peptone 50; TechMix Inc., Stewart, MN) all originate from intestinal mucosa lining but differ in that they are co-dried with different carriers to create the final product. PEP2 is co-dried with enzymatically processed vegetable protein while PEP2+ is co-dried with enzymatically processed vegetable protein and byproducts of crystalline AA production. Peptone 50 uses an unprocessed vegetable protein as its carrier while PEP-NS is co-dried with byproducts of corn wet milling and byproducts of crystalline AA production. It was hypothesized that the different carriers used in developing these peptone products might have an effect on growth performance.

Fish meal is a commonly used protein source in nursery pig diets due to its digestibility and desirable AA profile (Stoner et al., 1990; Kim and Easter, 2001). This leads to our objectives: 1) to evaluate the effects of Peptone products (PEP2, PEP2+, PEP-NS, and Peptone 50) and select menhaden fish meal on the growth performance of nursery pigs and 2) to evaluate the effects of increasing PEP-NS inclusion on nursery pig growth performance.

MATERIALS AND METHODS

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee. Pigs used in all 3 studies were of good health and removals were negligible and not treatment related.

Ingredient Composition

Before Exp. 1, a sample of PEP2 was collected and submitted to the University of Missouri Chemical Laboratories for analysis of AA content using HPLC (method 994.12; AOAC, 2000) and CP (method 990.03; AOAC, 2000; Table 1). The values obtained from analysis were then used in diet formulation. The standardized ileal digestible (**SID**) AA coefficients for spray-dried animal plasma (**SDAP**) were obtained from the manufacturer (APC Inc., Ankeny, IA) and these values were also used as the SID AA digestibility coefficients for PEP2. The phosphorus in PEP2+ was assumed to be 61% available for diet formulation. Other nutrient values for SDAP and select menhaden fish meal (**SMFM**) used in diet formulation were obtained from the manufacturer or NRC (1998). All diets were formulated to meet or exceed NRC (1998) requirement estimates.

In Exp. 2, nutrient profiles, including SID values of AA for PEP2+, Peptone 50, and PEP-NS, were provided by the manufacturer (Table 2; TechMix Inc.) and used in diet formulation. Spray-dried animal plasma digestibility coefficients were obtained from the manufacturer (APC Inc.). Nutrients and SID AA digestibility values for corn, soybean meal, dried whey, and SMFM meal used in diet formulation were obtained from NRC (1998).

Table 1. Nutrient composition of specialty protein sources (Exp. 1; as-fed basis)

Item	Spray-dried animal plasma[1]	Select menhaden fish meal[2]	PEP2[3]
CP, %	75.17	56.10	55.2
Fat, %	2.00	6.50	16.60
Ash, %	9.01	19.44	8.76
AA,[4] %			
Arg	4.55	3.66	3.46
Cys	2.63 (91)	0.57 (88)	0.73 (91)
His	2.55	1.78	1.28
Ile	2.71 (91)	2.57 (94)	2.43 (91)
Leu	7.61 (90)	4.54 (94)	4.22 (90)
Lys	6.84 (87)	4.81 (95)	3.70 (87)
Met	0.75 (91)	1.77 (94)	0.88 (91)
Phe	4.42	2.51	2.47
Thr	4.72 (83)	2.64 (88)	2.18 (83)
Trp	1.36 (84)	0.66 (90)	0.65 (84)
Val	4.94 (85)	3.03 (93)	2.76 (85)

[1]Values provided by APC Inc., Ankeny, IA.

[2]Values provided by Omega Protein Corp., Houston, TX.

[3]TechMix Inc., Stewart, MN. Amino acids were analyzed by the University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia. Values represent the mean of 1 sample analyzed in duplicate.

[4]Values in parentheses indicate standardized ileal digestibility values used in diet formulation, provided by the manufacturer (spray-dried animal plasma) or NRC (1998; select menhaden fish meal).

In Exp. 3, SID AA values for PEP-NS were provided by the manufacturer (TechMix Inc.) and analyzed AA concentrations were similar to values used in diet formulation. Nutrients and SID AA digestibility values for SMFM used in diet formulation were obtained from NRC (1998). Samples of SMFM and PEP-NS were collected and analyzed for CP and AA content (AOAC, 2000; Table 3).

Experiment 1

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

A total of 300 weanling pigs (337 × 1050; PIC, Hendersonville TN; initially 5.4 ± 0.84 kg and 19 ± 2 d of age) were used in a 25-d trial. Pigs were allotted to 1 of 5 dietary treatments in a completely randomized design with 12 replicate pens per treatment.

Table 2. Formulated and analyzed nutrient composition of ingredients (Exp. 2; as-fed basis)

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

[1]Omega Protein Corp., Houston, TX. Diets were prepared using the formulated values provided by the manufacturer with standardized ileal digestible AA coefficients (%) from NRC (1998).

[2]TechMix Inc., Stewart, MN. Diets were prepared using the formulated values and their standardized ileal digestible AA coefficients (%) provided by the manufacturer.

[3]Values represent the mean of 1 sample analyzed in duplicate.

[4]Values in parentheses indicate standardized ileal digestibility values used in diet formulation, provided by the manufacturer (peptone products) or NRC (1998; select menhaden fish meal).

The 5 dietary treatments were a negative control (**NC**) containing no specialty protein sources, the NC diet with 4, 8, or 12% PEP2 (TechMix LLC, Stewart, MN) in phases 1 (d 0 to 11) and 2 (d 11 to 25), and a positive control containing 4% SDAP (APC Inc.) in phase 1 and 4% SMFM (Omega Proteins, Houston, TX) in phase 2. Increasing amounts of PEP2 replaced soybean meal in the diets. All diets were fed in 2 phases, and treatments containing PEP2+ had the same inclusion rate in both phases.

Phase 1 diets were fed in pellet (3.9 mm diameter) form from d 0 to 11 after weaning (Table 4) and were manufactured at the Kansas State University Grain Science Feed Mill. Phase 2 diets were fed in meal form from d 11 to 25 (Table 5). Average daily gain, ADFI, and G:F were determined by weighing individual pigs and feeders on d 0, 5, 11, 18, and 25.

Experiment 2

This study was conducted at a commercial research wean-to-finish facility in Anchor, IL. The facility was an environmentally controlled, fully slatted, wean-to-finish barn. A total of 960 nursery pigs (Newsham GPK35 × PIC380; initial BW of 5.6 ± 0.59 kg and 20 ± 2 d of age) were used in a 39-d study. Pigs were provided ad libitum access to feed and water via a 4-hole dry self-feeder (152.4 cm long) and 2 cup waterers. Each pen was 20.51 m^2 and provided each pig with 0.64 m^2 floor space. At weaning, pigs were moved to the nursery facility and randomly distributed to pens maintaining an equal number of barrows and gilts per pen. Pens of pigs were then weighed and were randomly allotted to 1 of 5 dietary treatments in a completely randomized design. There were 32 pigs per pen and 6 replicate pens per treatment.

The 5 dietary treatments were a NC diet containing 4.5% SDAP in phase 1 (d 0 to 7) followed by no specialty protein sources in phase 2 (d 7 to 21) or the NC containing either 6% SMFM, PEP2+, Peptone 50, or PEP-NS (Tables 6 and 7). The specialty protein source and crystalline AA replaced soybean meal in the NC diet. Phase 1 diets were fed in pellet (3.9 mm diameter) form from d 0 to 7 postweaning. Phase 2 diets were fed in meal form from d 7 to 21 (Table 5). A common phase 3 diet was fed in meal form from

Table 3. Formulated and analyzed nutrient composition of specialty protein sources (Exp. 3; as-fed basis)

	Select menhaden fish meal[1]		PEP-NS[2]	
Item	Formulated	Analyzed[3]	Formulated	Analyzed
CP, %	62.90	62.99	47.50	49.20
AA,[4] %				
Cys	0.50 (88)	0.49	0.62 (68)	0.49
Ile	2.42 (94)	2.42	2.06 (83)	2.16
Leu	4.27 (94)	4.28	3.44 (72)	3.78
Lys	4.57 (95)	4.67	3.50 (83)	3.44
Met	1.66 (94)	1.55	0.97 (86)	0.95
Thr	2.32 (88)	2.56	2.06 (77)	2.05
Trp	0.59 (88)	0.56	0.59 (83)	0.67

[1]Omega Protein Corp., Houston, TX. Diets were prepared using the formulated values provided by the manufacturer with standardized ileal digestible AA coefficients (%) from NRC (1998).

[2]TechMix Inc., Stewart, MN. Diets were prepared using the formulated values and their standardized ileal digestible AA coefficients (%) provided by the manufacturer.

[3]Values represent the mean of 1 sample analyzed in duplicate.

[4] Values in parentheses indicate standardized ileal digestibility values used in diet formulation, provided by the manufacturer (PEP NS) or NRC (1998; select menhaden fish meal).

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

Item	Negative control	Positive control	Proteins enzymatically processed (PEP2)[2] 4%	8%	12%
Ingredient, %					
Corn	37.80	43.80	43.30	44.55	45.75
Soybean meal (46.5% CP)	40.40	30.50	30.50	25.30	20.10
Spray-dried animal plasma	–	4.00	–	–	–
PEP2	–	–	4.00	8.00	12.00
Spray-dried whey	15.00	15.00	15.00	15.00	15.00
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium P (21% P)	1.40	1.18	1.40	1.30	1.25
Limestone	0.88	1.05	0.93	1.00	1.03
Salt	0.30	0.30	0.30	0.30	0.30
Zinc oxide (72% Zn)	0.38	0.38	0.38	0.38	0.38
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[3]	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.20	0.20	0.35	0.35	0.35
DL-Met	0.16	0.14	0.21	0.21	0.21
L-Thr	0.08	0.05	0.14	0.13	0.14
L-Val	–	–	0.08	0.08	0.08
Calculated analysis[4]					
Standardized ileal digestible AA,[5] %					
Lysine	1.45	1.45	1.45	1.45	1.45
Ile:Lys	65	60	59	58	57
Met:Lys	33	30	36	36	36
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	62	62	62	62	62
Trp:Lys	19	19	17	17	17
Val:Lys	69	69	69	69	69
Total Lys, %	1.61	1.60	1.59	1.59	1.58
CP, %	24.2	23.2	22.5	22.3	22.2
ME, kcal/kg	3,408	3,433	3,399	3,391	3,384
Ca, %	0.85	0.85	0.85	0.85	0.85
P, %	0.79	0.76	0.77	0.75	0.74
Available P, %	0.48	0.48	0.48	0.48	0.48

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

[2]TechMix Inc., Stewart, MN.

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

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

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

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

Item	Negative control	Positive control	PEP2[2] 4%	8%	12%
Ingredient, %					
Corn	55.10	62.90	62.05	63.25	64.50
Soybean meal (46.5% CP)	40.10	28.75	28.75	23.50	18.30
Select menhaden fish meal	–	4.00	–	–	–
PEP2	–	–	4.00	8.00	12.00
Spray-dried whey	–	–	–	–	–
Soybean oil	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	1.60	1.10	1.55	1.53	1.45
Limestone	0.92	0.72	1.02	1.05	1.10
Salt	0.35	0.35	0.35	0.35	0.35
Zinc oxide (72% Zn)	0.25	0.25	0.25	0.25	0.25
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[3]	0.15	0.15	0.15	0.15	0.15
Lys HCl	0.15	0.30	0.35	0.35	0.35
DL-Met	0.09	0.12	0.15	0.15	0.15
L-Thr	0.04	0.11	0.13	0.13	0.13
L-Val	–	–	–	0.01	0.01
Total	100	100	100	100	100
Calculated analysis[4]					
Standardized ileal digestible amino acids,[5] %					
Lys	1.32	1.32	1.32	1.32	1.32
Ile:Lys	69	61	60	59	58
Met:Lys	32	35	34	35	35
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	62	62	62	62	62
Trp:Lys	20	17	17	17	17
Val:Lys	75	68	68	68	68
Total Lys, %	1.47	1.45	1.45	1.45	1.44
CP, %	23.6	21.7	21.4	21.3	21.1
ME, kcal/kg	3,336	3,364	3,331	3,322	3,314
Ca, %	0.80	0.80	0.80	0.80	0.80
P, %	0.77	0.73	0.73	0.73	0.71
Available P, %	0.42	0.42	0.42	0.42	0.42

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

[2]TechMix Inc., Stewart, MN.

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

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

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

d 21 to 39. Average daily gain, ADFI, and G:F were determined by weighing pens of pigs and feeders on d 0, 7, 21, and 39.

Experiment 3

Similar to Exp. 1, this study was conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan. A total of 180 nursery pigs (C327 × 1050; PIC, Hendersonville, TN; initial BW of 6.4 ± 1.03 kg and 28 ± 2 d of age) were used in a 24-d study. Pigs

Table 6. Composition of diets, phase 1 (as-fed basis),[1] Exp. 2

Item	Negative control	SMFM[2]	PEP2+[3]	Peptone 50[4]	PEP-NS[5]
Ingredient, %					
Corn	43.60	44.78	43.54	43.36	43.48
Soybean meal (46.5% CP)	22.45	16.69	16.70	16.69	16.70
Spray-dried animal plasma	4.50	4.50	4.50	4.50	4.50
Select menhaden fish meal	–	6.00	–	–	–
PEP2+	–	–	6.00	–	–
Peptone 50	–	–	–	6.00	–
PEP-NS	–	–	–	–	6.00
Spray-dried whey	25.00	25.00	25.00	25.00	25.00
Soybean oil	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	0.85	0.10	0.75	0.80	0.65
Limestone	1.00	0.60	1.05	1.07	1.13
Salt	0.35	0.35	0.35	0.35	0.35
Zinc oxide (72% Zn)	0.25	0.25	0.25	0.25	0.25
Vitamin premix[6]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[6]	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.28	0.12	0.17	0.24	0.23
DL-Met	0.17	0.11	0.16	0.18	0.17
L-Thr	0.10	0.05	0.08	0.11	0.09
Phytase[7]	0.05	0.05	0.05	0.05	0.05
Calculated analysis[8]					
Standardized ileal digestible amino acids,[9] %					
Lys	1.40	1.40	1.40	1.40	1.40
Ile:Lys	55	54	57	55	56
Met:Lys	31	32	32	33	32
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	65	65	65	65	65
Trp:Lys	18	17	18	18	18
Val:Lys	65	65	68	66	67
Total Lys, %	1.54	1.56	1.56	1.56	1.54
CP, %	21.1	22.3	21.8	21.2	21.5
ME, kcal/kg	3,331	3,331	3,318	3,329	3,322
Ca, %	0.82	0.82	0.82	0.82	0.82
P, %	0.71	0.70	0.70	0.70	0.69
Available P, %	0.56	0.56	0.55	0.56	0.56

[1]Phase 1 diets were fed from d 0 to 7 in pellet form.

[2]Special select menhaden fish meal (SMFM): Omega Protein Corp., Houston, TX.

[3]TechMix Inc., Stewart, MN.

[4]TechMix Inc.

[5]TechMix Inc.

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

[7]Natuphos (BASF Animal Nutrition, Mount Olive, NJ) provided 509 phytase units/kg, with a release of 0.10 available P.

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

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

Table 7. Composition of diets, phase 2 (as-fed basis),[1] Exp. 2

	Negative	6%			
Item	control	SMFM[2]	PEP2+[3]	Peptone 50[4]	PEP-NS[5]
Ingredient, %					
Corn	54.46	54.81	53.55	53.41	53.53
Soybean meal (46.5% CP)	30.76	25.89	25.91	25.89	25.88
Select menhaden fish meal	–	6.00	–	–	–
PEP2+	–	–	6.00	–	–
Peptone 50	–	–	–	6.00	–
PEP-NS	–	–	–	–	6.00
Spray-dried whey	10.00	10.00	10.00	10.00	10.00
Soybean oil	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	1.20	0.43	1.10	1.15	1.00
Limestone	0.88	0.48	0.93	0.93	1.07
Salt	0.35	0.35	0.35	0.35	0.35
Zinc oxide (72% Zn)	0.25	0.25	0.25	0.25	0.25
Vitamin premix[6]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[6]	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.35	0.17	0.22	0.28	0.28
DL-Met	0.16	0.10	0.15	0.16	0.15
L-Thr	0.14	0.08	0.10	0.13	0.11
Phytase[7]	0.05	0.05	0.05	0.05	0.05
Calculated analysis[8]					
Standardized ileal digestible amino acids,[9] %					
Lys	1.30	1.30	1.30	1.30	1.30
Ile:Lys	60	60	63	60	62
Met:Lys	34	35	35	35	34
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	63	63	63	63	63
Trp:Lys	17	17	18	17	18
Val:Lys	65	66	69	67	68
Total Lys, %	1.44	1.46	1.45	1.46	1.44
CP, %	20.7	22.2	21.7	21.1	21.4
ME, kcal/kg	3,333	3,336	3,049	3,331	3,051
Ca, %	0.75	0.75	0.75	0.75	0.75
P, %	0.69	0.67	0.68	0.68	0.67
Available P, %	0.47	0.47	0.47	0.47	0.47

[1]Phase 2 diets were fed from d 7 to 21 and were in meal form.

[2]Special select menhaden fish meal (SMFM): Omega Protein Corp., Houston, TX.

[3]TechMix Inc., Stewart, MN.

[4]TechMix Inc.

[5]TechMix Inc.

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

[7]Natuphos (BASF Animal Nutrition, Mount Olive, NJ) provided 509 phytase units/kg, with a release of 0.10 available P.

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

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

Table 8. Composition of diets (as-fed basis),[1] Exp. 3

Item	Pretest[2]	PEP-NS[3,5] 0%	3%	6%	9%	12%	6% SMFM[6]	Phase 3[4]
Ingredient, %								
Corn	38.50	53.70	53.90	53.45	38.36	38.35	38.31	62.80
Soybean meal (46.5% CP)	25.00	31.55	28.30	25.85	22.20	22.19	22.21	32.25
Spray-dried animal plasma	5.00	–	–	–	–	–	–	–
Select menhaden fish meal	–	–	–	–	–	–	6.00	–
PEP-NS	–	–	3.00	6.00	9.00	12.00	–	–
Spray-dried whey	25.00	10.00	10.00	10.00	10.00	10.00	10.00	–
Soybean oil	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	1.18	1.20	1.18	1.15	1.10	1.08	0.43	1.25
Limestone	1.03	0.88	0.93	0.93	0.98	1.00	0.48	1.05
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Zinc oxide (72% Zn)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.16	0.33	0.33	0.30	0.28	0.25	0.17	0.33
DL-Met	0.13	0.16	0.16	0.15	0.15	0.14	0.09	0.14
L-Thr	0.03	0.13	0.14	0.13	0.12	0.11	0.08	0.13
Phytase[8]	–	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calculated analysis[9]								
Standardized ileal digestible amino acids,[10] %								
Lys	1.40	1.30	1.30	1.30	1.30	1.30	1.30	1.26
Ile:Lys	59	61	60	60	60	61	64	61
Met:Lys	29	34	35	35	35	35	35	34
Met and Cys:Lys	58	58	58	58	58	58	58	59
Thr:Lys	63	63	63	63	63	63	63	63
Trp:Lys	18.9	17.4	17.1	17.1	17.1	17.1	17.6	17.5
Val:Lys	69	66	66	67	68	69	71	68
Total Lys, %	1.55	1.44	1.45	1.46	1.46	1.47	1.44	1.39
CP, %	22.1	20.9	20.9	21.1	21.3	21.5	21.9	20.8
ME, kcal/kg	3,140	3,333	3,333	3,331	3,331	3,329	3,371	3,349
Ca, %	0.90	0.75	0.76	0.75	0.75	0.75	0.75	0.76
P, %	0.79	0.69	0.69	0.68	0.68	0.67	0.68	0.66
Available P, %	0.55	0.47	0.47	0.47	0.47	0.47	0.47	0.34

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

[2]The pretest diet was a common diet fed the first 7 d postweaning and was in pellet form.

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

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

[5]TechMix Inc., Stewart, MN.

[6]Special select menhaden fish meal (SMFM): Omega Protein Corp., Houston.

[7]Provided (per kilogram of complete diet) 11,025 IU of vitamin A, 1,654 IU of vitamin D, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate), 55.1 mg of niacin, 33.1 mg of pantothenic acid (as D-calcium pantothenate), 9.9 mg of riboflavin, 0.044 mg of vitamin B_{12}, 16.5 mg of Cu as $CuSO_4 5H_2O$, 165.4 mg of Fe as $FeSO_4 H_2O$, 39.7 mg of Mn as $MnSO_4 H_2O$, 0.30 mg of Se Na_2SeO_3, 165.4 mg of Zn as ZnO, and 0.30 mg of I as $C_2H_2(NH_2)_2 2HI$.

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

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

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

used in this study were subjected to the same allotment and management protocol as outlined in Exp. 1 with the exception that after arrival at the nursery facility, pigs were fed a common pretest diet (Table 8) for the first 7 d after weaning. On d 7 after weaning, pigs were allotted to 1 of 6 dietary treatments. Therefore, d 7 after weaning was d 0 of the experiment. There were 5 barrows per pen and 6 replicate pens per treatment.

The 6 dietary treatments included a NC containing no specialty protein products, the NC diet with 3, 6, 9, or

Table 9. Effects of PEP2 and spray-dried animal plasma on nursery pig performance (Exp. 1)[1]

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

[1]A total of 300 nursery pigs (initially 5.4 ± 0.84 kg and 19 ± 2 d of age) were used in a 25-d trial to determine the effects of PEP2 on nursery pig growth performance. There were 12 pens per treatment with 5 pigs per pen.

[2]Contained no specialty protein products.

[3]Contained 4% spray-dried animal plasma in phase 1 (d 0 to 11) and 4% select menhaden fish meal in phase 2 (d 11 to 25).

[4]TechMix Inc., Stewart, MN.

12% PEP-NS, or the NC with 6% SMFM (Table 8). The increasing amounts of PEP-NS replaced soybean meal in the NC diet. Treatment diets were fed in meal form from d 0 to 14 and were manufactured at the Kansas State University Animal Science Feed Mill. From d 14 to 24, all pigs were fed a common diet. Average daily gain, ADFI, and G:F were determined by weighing individual pigs and feeders on d 0, 7, 14, and 24.

Statistical Analysis

In Exp. 1 pigs were housed in 2 different barns during the study. Pen was the experimental unit with treatments randomly assigned to pen in a completely randomized design within each barn. Analysis of variance for Exp. 1 was performed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC) with barn as random effect and treatments as fixed effects. There were 6 replicates within barn. In Exp. 1, the following preplanned contrast statements used were 1) linear and quadratic effects of increasing PEP2 (NC and 4, 8, and 12% PEP2) and 2) mean of PEP2-fed pigs vs. pigs fed the positive control diet. Experiments 2 and 3 were analyzed as a completely randomized design with pen as the experimental unit. Analysis of variance was performed using the MIXED procedure in SAS. In Exp. 2, because of slight differences in initial BW, it was used as a covariate for response criteria. Means were separated using LSD. In Exp 3, preplanned contrast statements used were 1) linear and quadratic effects of increasing PEP-NS and 2) 6% PEP-NS vs. 6% SMFM. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

RESULTS

Nutrient and SID AA analysis of SDAP and SMFM used in diet formulation in Exp.1 were derived from NRC (1998; Table 1). The PEP2 product contained 16.6% fat, and although it had a CP content similar to SMFM, in general, essential AA values were lower than that compared to fish meal. Comparing PEP2 and PEP2+, the only difference is the added AA biomass in the drying process for PEP2+. This resulted in greater concentrations of essential AA and a profile similar to fish meal (Table 2). In Exp. 3, analyzed AA values were consistent with values supplied by the manufacturer that were used in diet formulation (Table 3). All specialty protein sources were obtained over time from different batches.

Experiment 1

In phase 1 (d 0 to 11), pigs fed the positive control diet had a tendency ($P < 0.09$) toward greater ADG and had improved ($P < 0.03$) G:F compared with pigs fed the NC diet (Table 9). Pigs fed the positive control diet also had greater ($P < 0.04$) ADG and G:F compared with pigs fed diets containing PEP2. No effects of increasing PEP2 were observed for any of the growth criteria.

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

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

Item	Negative control[3]	6% SMFM[4]	6% PEP2+[5]	6% PEP-NS[6]	6% Peptone 50[7]	SEM
Initial wt, kg	5.66	5.61	5.65	5.64	5.66	–
Day 0 to 21						
ADG, g	198[b]	241[a]	245[a]	255[a]	196[b]	7
ADFI, g	286[b]	341[a]	343[a]	347[a]	294[b]	9
G:F	0.693[ab]	0.707[ab]	0.715[a]	0.735[a]	0.665[b]	0.015
Day 21 to 39[8]						
ADG, g	501[b]	528[ab]	541[a]	542[a]	518[ab]	13
ADFI, g	797[b]	876[a]	885[a]	907[a]	808[b]	16
G:F	0.630[ab]	0.603[c]	0.612[bc]	0.598[c]	0.641[a]	0.009
Day 0 to 39						
ADG, g	333[b]	373[a]	380[a]	386[a]	343[b]	9
ADFI, g	544[b]	597[a]	603[a]	614[a]	557[b]	11
G:F	0.611	0.625	0.630	0.629	0.614	0.009

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

[1]A total of 960 nursery pigs were used in a 39-d trial. Pigs were randomly allotted to 1 of 5 dietary treatments with 32 pigs per pen and 6 pens per treatment.

[2]Initial weights were used as a covariate in the analysis.

[3]The negative control included a diet containing 4.5% spray-dried animal plasma (APC Inc., Ankeny, IA) from d 0 to 7 and no specialty protein sources from d 7 to 21.

[4]SMFM = select menhaden fish meal: Omega Proteins Corp, Houston, TX.

[5]TechMix Inc., Stewart, MN.

[6]TechMix Inc.

[7]TechMix Inc.

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

PEP2 were greater ($P < 0.04$) than those of positive control pigs fed SMFM during this phase.

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

Experiment 2

From d 0 to 21, pigs fed diets containing 6% SMFM, PEP2+, or PEP-NS had improved ($P < 0.05$) ADG compared to those fed the NC diet or diets containing 6% Peptone 50 (Table 10). Furthermore, pigs fed 6% SMFM, PEP2+, or PEP-NS had increased ($P < 0.05$) ADFI compared to those fed the NC diet or 6% Peptone 50. Pigs fed diets containing 6% PEP2+ or PEP-NS had increased ($P < 0.05$) G:F compared to pigs fed 6% Peptone 50.

During phase 3 (d 21 to 39), pigs previously fed diets containing 6% PEP2+ or PEP-NS had increased ($P < 0.05$) ADG compared to those previously fed the NC diet, with those fed 6% SMFM or Peptone 50 intermediate. Pigs previously fed 6% SMFM, PEP2+, or PEP-NS had increased ($P < 0.05$) ADFI compared to pigs previously fed the NC diet or diets containing 6% Peptone 50. Pigs previously fed the diet containing 6% Peptone 50 had increased ($P < 0.05$) G:F compared to those fed SMFM, PEP2+, and PEP-NS, with those fed the NC intermediate.

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

Experiment 3

From d 0 to 14, pigs fed increasing PEP-NS had increased (quadratic; $P < 0.01$) ADG, ADFI, and G:F, with an increase observed in pigs fed up to 9% PEP-NS and no improvement thereafter (Table 11). There were no differences observed between pigs fed the diet with 6% SMFM and 6% PEP-NS. From d 14 to 24, when all pigs were fed a common diet, there were no differences in ADG, ADFI, or G:F observed in pigs previously fed increasing PEP-NS.

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

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

Item	PEP-NS[2] 0%	3%	6%	9%	12%	6% SMFM[3]	SEM	P < Linear	Quadratic	6% PEP-NS vs. 6% SMFM
Day 0 to 14										
ADG, g	197	289	353	373	327	351	12	0.01	0.01	0.91
ADFI, g	359	401	437	455	419	459	13	0.01	0.01	0.52
G:F	0.550	0.721	0.808	0.819	0.797	0.781	0.018	0.01	0.01	0.29
Day 14 to 24[4]										
ADG, g	537	506	542	508	509	546	22	0.44	0.95	0.89
ADFI, g	759	721	762	741	732	784	24	0.64	0.95	0.51
G:F	0.701	0.698	0.710	0.687	0.695	0.699	0.020	0.58	0.99	0.67
Day 0 to 24										
ADG, g	367	397	447	440	417	449	13	0.01	0.01	0.95
ADFI, g	559	561	600	598	569	617	16	0.27	0.10	0.46
G:F	0.658	0.707	0.746	0.737	0.733	0.729	0.015	0.01	0.01	0.42

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

[2]TechMix Inc., Stewart, MN.

[3]Special select menhaden fish meal (SMFM): Omega Protein Corp., Houston, TX.

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

differences observed between pigs fed 6% PEP-NS and those fed 6% SMFM.

DISCUSSION

Specialty protein sources are used in nursery pig diets to help maintain gut integrity while stimulating feed intake (Bergstrom et al., 1997). Spray-dried animal plasma is a widely used animal protein source for nursery pig diets because it has shown consistent improvement in feed intake and growth performance in weaned pigs (Hansen et al., 1993). Similar to previous findings, pigs fed diets containing SDAP in Exp. 1 had increased ADG, ADFI, and G:F compared with pigs fed the NC (which did not contain any specialty protein sources) or diets containing PEP2; however, in phase 2, pigs fed PEP2 had improved ADG and feed intake compared with pigs fed SMFM. This result partially coincides with the findings of Jones et al. (2010), in which pigs fed a porcine intestinal mucosa byproduct of heparin production (DPS 50; Nutra-Flo, Sioux City, IA) from d 7 to 21 postweaning had improved ADG compared with pigs fed SMFM during this period.

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

Unlike fish meal, which provides the pigs with intact proteins (long chains of AA), peptide products, such as porcine intestinal mucosa byproducts, are hydrolyzed protein sources (short chains of AA). Silk et al. (1985) observed that peptides with 5 or fewer AA were absorbed with greater efficiency compared to larger peptides whereas Furst and Stehle (1993) stated that certain AA may be more difficult to absorb in their free form and may be more available when provided as a dipeptide. Furthermore, a larger amount of AA were absorbed in the small intestine when provided in peptide form vs. intact protein, suggesting that amino acids provided as peptides may be more readily available for absorption (Gilbert et al., 2008). Therefore, providing newly weaned pigs with protein sources in the peptide form rather than as intact proteins may help to explain the increase in growth performance and feed intake in pigs fed diets containing PEP2 compared with those fed fish meal. Cho et al. (2010) found that weanling pigs fed diets containing dried porcine solubles (DPS 50) had similar and, in some instances, even improved growth performance compared with pigs fed diets containing SDAP. The researchers hypothesized that this improvement in growth performance could be due to this product containing more short-chain peptides and consequently having AA that are more readily absorbed (Gilbert et al., 2008; Cho et al., 2010).

Fish meal has historically been a widely used protein source in nursery pig diets due to its desirable amino acid profile (Stoner et al., 1990). Recent price volatility has made fish meal a less attractive option in weanling pig diets.

Our findings coincide with previous studies (Lindemann et al., 1998; DeRouchey et al., 2003, Jones et al., 2010) evaluating porcine intestinal mucosa products, where pigs fed diets containing PEP2+ or PEP-NS had similar and in some cases improved growth performance compared to pigs fed diets containing fish meal.

Sulabo et al. (2013) conducted a study evaluating SID of AA in PEP2+ and Peptone 50. The calculated digestibility coefficients for Lys used for PEP2+ and Peptone 50 were higher (88 and 91%, respectively) in the present studies than the SID values (84.1 and 87.5%, respectively) observed by Sulabo et al. (2013). It was also observed that Peptone 50 and fish meal had similar SID values for all indispensable AA, which coincides with the Peptone 50 SID values used in our present studies. In addition, Sulabo et al. (2013) observed that PEP2+ had lower SID values for indispensable AA when compared to Peptone 50 and fish meal, which also corroborates with the SID AA values used in the present studies.

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

In conclusion, the intestinal mucosa products, PEP2, PEP2+, and PEP-NS, are suitable replacements for fish meal in nursery diets from d 7 to 21 postweaning. PEP-NS can be included at 6 to 9% of the diet for optimal growth performance. Pigs fed Peptone 50 generally had decreased ADG and G:F than those fed SMFM or the other peptone products, possibly as a result of different carrier proteins on to which it is dried.

LITERATURE CITED

AOAC International (AOAC). 2000. Official methods of analysis of AOAC International. 17th ed. AOAC Int., Gaithersburg, MD.

Bergstrom, J. R., J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz, K. Q. Owen, and W. B. Nessmith Jr. 1997. Evaluation of spray dried animal plasma and select menhaden fish meal in transition diets of pigs weaned at 12 to 14 days of age and reared in different production systems. J. Anim. Sci. 75:3004–3009.

Cho, J. H., M. D. Lindemann, J. Monegue, and G. L. Cromwell. 2010. Feeding value of dried porcine solubles for weanling pigs. Prof. Anim. Sci. 26:424–434.

DeRouchey, J. M., M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz, J. C. Woodworth, B. W. James, and D. E. Real. 2003. Effects of irradiation of individual feed ingredients and the complete diet on nursery pig performance. J. Anim. Sci. 81:1799–1805.

Furst, P., and P. Stehle. 1993. The potential use of parenteral dipeptides in clinical nutrition. Nutr. Clin. Pract. 8(3):106–114.

Gilbert, E. R., E. A. Wong, and K. E. Webb Jr. 2008. Peptide absorption and utilization: Implications for animal nutrition and health. J. Anim. Sci. 86:2135–2155.

Hansen, J. A., J. L. Nelssen, R. D. Goodband, and T. L. Weeden. 1993. Evaluation of animal protein supplements in diets of early-weaned pigs. J. Anim. Sci. 71:1853–1862.

Ji, C. 1999. Feeding trial performance report. Tech Bull. No. 32. Nutra-Flo Protein Products, Sioux City, IA.

Jones, C. K., J. M. DeRouchey, J. L. Nelssen, M. D. Tokach, S. S. Dritz, and R. D. Goodband. 2010. Effects of fermented soybean meal and specialty animal protein sources on nursery pig performance. J. Anim. Sci. 88:1725–1732.

Kim, S. W., and R. A. Easter. 2001. Nutritional value of fish meals in the diet for young pigs. J. Anim. Sci. 79:1829–1839.

Lindemann, M. D., J. L. G. van de Ligt, H. J. Monegue, G. Keller, and G. L. Cromwell. 1998. Evaluation of dried porcine solubles (DPS) as a feed ingredient for weanling pigs. J. Anim. Sci. 76(Suppl. 1):181 (Abstr.).

McCalla, J., T. Waugh, and E. Lohry. 2010. Protein hydrolysates/peptides in animal nutrition. In: V. K. Pasupuleti and A. L. Demain, editors, Protein hydrolysates in biotechnology. Springer, New York, NY. p. 179–190.

NRC. 1998. Nutrient requirements of swine. 10th rev. ed. Natl. Acad. Press, Washington, DC.

Silk, D. B. A., G. K. Grimble, and R. G. Rees. 1985. Protein digestion and amino acid and peptide absorption. Proc. Nutr. Soc. 44:63–72.

Stein, H. 2002. Feeding trial performance report. Tech Bull. No. 43. Nutra-Flo Protein Products, Sioux City, IA.

Stoner, G. R., G. L. Allee, J. L. Nelssen, M. E. Johnston, and R. D. Goodband. 1990. Effects of select menhaden fish meal in starter diets for pigs. J. Anim. Sci. 68:2729–2735.

Sulabo, R. C., J. Mathai, J. L. Usry, B. W. Ratliff, D. M. McKilligan, J. D. Moline, G. Xu, and H. H. Stein. 2013. Nutritional value of dried fermentation biomass, hydrolyzed porcine intestinal mucosa products, and fish meal fed to weanling pigs. J. Anim. Sci. 91:2802–2811.