Effects of Replacing Dried Skim Milk With Wheat Gluten and Spray Dried Porcine Protein on Growth Performance and Digestibility of Nutrients in Nursery Pigs

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ABSTRACT : Three experiments were conducted to determine the nutritional value of wheat gluten (WG) and spray-dried porcine plasma (SDPP) in diets for nursery pigs. In Exp. 1, 120 weanling pigs (5.7 kg avg initial BW) were used in a 35-d growth assay. Treatments for d 0 to 14 were: 1) dried skim milk (DSM)-dried whey-SBM based control; 2) WG to replace the protein from DSM; 3) SDPP; and 4) WG-SDPP (50:50 blend on a protein basis) to replace the protein from DSM. From d 14 to 35, all pigs were fed a common corn-SBM-whey-based diet. For d 0 to 14, there were no differences in ADG, ADFI, and gain/feed ($p>0.11$). However, for d 14 to 35, pigs fed diets with WG had greater gain/feed than those fed SDPP ($p<0.05$), and pigs fed diets with the WG-SDPP blend had greater ADG than pigs fed diets with WG or SDPP alone ($p<0.07$). In a second experiment, 60 weanling pigs (5.1 kg avg initial BW) were used in a 28-d growth assay. All pigs were fed the WG-SDPP diet fed in Exp. 1 for d 0 to 14, and changed to experimental diets for d 14 to 28. Treatments were: 1) the whey-SBM-based diet used for d 14 to 28 in Exp. 1; or 2) a whey-SBM based diet with 3% added SDPP. There were no differences in ADG, ADFI, gain/feed, or apparent digestibilities of DM and N among treatments for d 14 to 28 or overall ($p>0.14$). In a third experiment, 150 weanling pigs (5.6 kg avg initial BW) were used in a 32-d growth assay to determine the optimal blend of WG and SDPP for use after weaning. The SDPP was added as 8% of the control diet, and WG was substituted on a protein basis to yield the desired SDPP:WG blends. Treatments were (d 0 to 14): 1) SDPP; 2) 75% SDPP and 25% WG; 3) 50% SDPP and 50% WG; 4) 25% SDPP and 75% WG; and 5) WG. As in Exp. 1, all pigs were switched to a common corn-SBM-whey-based diet for d 14 to 32. For d 0 to 14, ADG and ADFI increased as replacement of the SDPP was increased up to 50% and decreased when more of the SDPP was removed from the diet (quadratic effects, $p<0.004$ and 0.02, respectively). Apparent digestibilities of DM and N (at d 13) were not affected by treatments ($p>0.18$). For d 14 to 32, treatments did not affect ADG ($p>0.2$), although there were quadratic responses in ADFI ($p<0.04$), with pigs fed the 50:50 blend suggested the greatest intake of feed. For the overall experimental period (d 0 to 32), ADG, ADFI, and gain/feed increased as WG was used to replace as much as 50% of the SDPP (quadratic effects $p<0.04$, 0.02, and 0.06, respectively). In conclusion, WG can successfully replace up to 50% of the SDPP in a complex nursery diet, when SDPP is included at the 8% level. There is no advantage to keeping SDPP in the diet after Phase I (d 0 to 14). *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 11 : 1576-1583)*

Key Words : Pigs, Wheat Gluten, Porcine Protein, Skim Milk, Growth, Digestibility

INTRODUCTION

Milk or milk products were considered essential for growth and health of early-weaned pigs (Mahan, 1992). Although milk products are highly palatable and easily digested by young pigs and calves, competition from the human sector has increased costs and led to evaluate alternative protein sources. Blood products, such as blood meal and plasma protein have been used successfully in nursery diets, and have been used to induce feed consumption in early-weaned pigs (Hansen et al., 1993; Kats et al., 1994a). Blood products, like milk products, are expensive and more likely to carry pathogens than refined protein products of plant origin. Alternatively, soybean is a vegetable protein source that is readily available and relatively inexpensive. Soybean protein can be fed in various forms (soybean meal, roasted, or extruded soybeans; modified soy flour; soy concentrates; and soy isolates) with a general increase in nutritional value as complexity of processing increases. However, soybeans contain many antinutritional factors that must be destroyed or inactivated by processing (Kim et al., 1999; Kim et al., 2000) and as the degree of processing increases from raw soybean to soy isolate, so does the cost of the product. Finally, Kats et al. (1994a, b) reported that pigs fed diets containing spray-dried porcine plasma (SDPP) or blood meal had greater ADG and ADFI than pigs fed diets containing soy concentrate. They have suggested that the initial difference in ADFI for pigs fed SDPP are lost unless a similar blood product (SDPP or spray-dried blood meal) is fed into the next diet phase to gradually reduce the content of this product in the diet.

Wheat gluten (WG), the major protein in the wheat kernel, is 7 to 15% of total kernel weight. When fed in conjunction with other plant proteins or supplemented with synthetic amino acids (Batterham et al.,

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1979; Jansen and Hunsaker, 1986; Leibholz, 1986), WG can support growth performance similar to dried skim milk. Also, Richert et al. (1994) reported that weanling pigs fed spray-dried WG had greater ADG and ADFI than pigs fed other WG products (flash-dried WG, and solubilized-modified WG), DSM and soy protein isolate. Furthermore, the authors fed combinations of DSM, SBM, and WG in diets fed immediately after weaning, and found that a WG-SBM-based diet supported the greatest overall ADG and ADFI compared to diets that were DSM-SBM- and DSM-WG-based.

Thus, there are benefits when nursery pigs are fed diets with SDPP or WG. The objective of the following experiments was to determine the effects of combining SDPP and WG in diets for nursery pigs and to determine if SDPP in the diets for the second phase of the nursery period was necessary when a WG-SDPP blend was fed after weaning

MATERIALS AND METHODS

Experiment 1

One hundred and twenty crossbred weanling pigs (Duroc × Yorkshire × Hampshire × Chester White) with an average initial age and BW of 21 d and 5.7 kg, respectively, were used in a 35-d growth assay to evaluate WG and SDPP as replacements for dried skim milk (DSM) in diets for weanling pigs. The pigs were allotted six/pen and five pens/treatment. The pigs were housed in an environmentally-controlled nursery pens (1.2 m × 1.5 m) with wire mesh flooring. Each pen had a self-feeder and nipple water to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 0, 14, and 35 to allow calculation of ADG, ADFI, and gain/feed. Chromic oxide was included in diets and used as an indigestible marker. On d 10 and 20, fecal samples were collected from four pigs per pen and pooled.

Table 1. Diet composition, % (Exp. 1)[a]

	Protein sources for d 0-14[bc]				
Item	DSM	WG	SDPP	WG-SDPP	Common diet for d 14-35[d]
Corn	34.22	33.59	33.86	33.83	45.11
Dried-whey	20.00	20.00	20.00	20.00	20.00
DSM	20.00	-	-	-	-
Spray-dried wheat gluten	-	8.88	-	4.48	-
Spray-dried porcine plasma	-	-	9.25	4.63	-
Lactose	-	10.00	10.00	10.00	-
Soybean meal	19.64	19.64	19.64	19.64	28.81
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.19	2.12	2.21	2.16	1.27
Limestone	0.28	0.40	0.34	0.37	0.51
Vitamins[e]	0.25	0.25	0.25	0.25	0.25
Minerals[f]	0.15	0.15	0.15	0.15	0.15
Salt	-	0.20	-	-	0.20
Copper sulfate	0.10	0.10	0.10	0.10	0.10
Chromic oxide[g]	0.10	0.10	0.10	0.10	0.10
Lysine-HCl	0.07	0.57	-	0.29	-
dl-methionine	-	-	0.10	-	-
Antibiotic[h]	1.00	1.00	1.00	1.00	0.50
Total	100.00	100.00	100.00	100.00	100.00

[a] As-fed basis.

[b] Diets for d 0 to 14 were formulated to contain 1.4% lysine, 25% lactose, 0.9% Ca, and 0.8% P.

[c] DSM=dried skim milk, WG=spray-dried wheat gluten, and SDPP=spray-dried porcine plasma.

[d] Common diet for d 14 to 35 was formulated to contain 1.2% lysine, 0.8% Ca, and 0.7% P.

[e] Supplied per kilogram of complete diet: 5,513 IU of vitamin A; 551 IU of vitamin D_3, 22 IU of vitamin E; 2.2 mg of menadione; 5.5 mg of riboflavin; 13.8 mg of d-calcium pantothenate; 30.3 mg of niacin; 551 mg of choline; and 0.03 mg of vitamin B_{12}.

[f] Supplied per kilogram of complete diet: 150 mg of Mn; 150 mg of Fe; 150 mg of Zn; 60 mg of Ca; 269 mg of Cu; 4.5 mg of I; 1.5 mg of Co; and 0.3 mg of Se.

[g] Used as an indigestible marker.

[h] Antibiotic for d 0 to 14 supplied per kilogram of diet: 220 mg of furazolidone; 110 mg of oxytetracycline; and 99 mg of arsinilic acid. Antibiotic for d 14 to 35 supplied per kilogram diet: 110 mg of chlortetracycline; 110 mg of sulfathiazole; and 55 mg of penicillin.

The fecal samples were lyophilized, ground, and analyzed, with the diet samples for DM, and N (AOAC, 1990) and Cr concentration (Williams et al., 1962). Digestibilities of DM and N were then calculated using the indirect ratio method.

Treatments were: 1) DSM-SBM-based control; 2) WG to replace the protein from DSM; 3) SDPP to replace the protein from DSM; and 4) a WG-SDPP blend (50:50 on a protein basis) to replace the protein from DSM. The diets were fed from d 0 to 14 post-weaning. For d 14 to 35, all pigs were fed the same corn-SBM-whey based diet. All diets (table 1) were formulated to meet or exceed the nutrient concentrations suggested by NRC (1998). Diets fed from d 0 to 14, and d 14 to 35 were formulated to contain 1.4 and 1.2% lysine, 0.9 and 0.8% Ca, and 0.8 and 0.7% P, respectively. The WG and SDPP were added to supply the same amount of protein as supplied by DSM in the control diet, with 20% dried whey added to all diets.

The experiment was a randomized complete block with initial average BW as the blocking criterion, and pen as the experimental unit. Response criteria were ADG, ADFI, gain/feed, and apparent digestibilities of N and DM. Data were analyzed using the General Linear Model Procedure of SAS (1985). Treatment means were separated using the orthogonal contrasts (Peterson, 1985): 1) DSM vs other protein sources; 2) WG and SDPP vs the WG-SDPP blend; and 3) WG vs SDPP.

Experiment 2.

Sixty crossbred (Duroc × Yorkshire × Hampshire × Chester White) weanling pigs (avg initial BW of 5.1 kg) were allotted by BW, sex, and ancestry to two dietary treatments to determine if the early nursery phase benefits of plasma protein and the late nursery phase benefits of wheat gluten are additive and raised in condition described in Exp 1. Pigs and feeders were weighed on d 0, 14, and 24 for calculation of ADG, ADFI, and gain/feed. Feces were collected from four pigs in each pen on d 10, pooled, dried and analyzed for DM, N, and Cr concentrations as in Exp. 1. For d 0 to 14 of the 28 d growth assay, all pigs received the same SBM-whey based diet supplemented with a 50:50 WG:SDPP blend (9% of total diet, WG and SDPP supplied on an equal lysine basis). At d 14, one-half of the pigs received a SBM-whey based diet (Treatment 1), and the other one-half a SBM-whey-SDPP based diet (Treatment 2). Data were analyzed as a randomized complete block design using the General Linear Model Procedure of SAS (1985).

Experiment 3

A total of 150 crossbred (Duroc × Yorkshire × Hampshire × Chester White) weanling pigs (avg initial BW of 5.6 kg) were used in a 32-d growth assay to determine the optimal blend of spray-dried WG and SDPP in diets for nursery pigs. The SDPP was added at 8% of the diet, and the WG was substituted on a lysine basis to yield the desired SDPP:WG blend. Pigs were housed as in Exp. 1, with five pigs allotted by BW, sex, and ancestry to each pen, and six pens per treatment. Pigs and feeders were weighed on d 0, 14,

Table 2. Diet composition, % (Exp. 2)[a]

Item	Common diet for d 0 to 14[b]	diets for d 14 to 28[cd]	
		SBM-whey	SBM-whey-SDPP
Corn	33.39	44.22	47.39
Dried-whey	20.00	28.90	20.00
Spray-dried wheat gluten	4.48	-	-
Spray-dried porcine Plasma	4.63	-	3.00
Lactose	10.00	-	-
Soybean meal, 48% CP	19.80	28.90	22.70
Soybean oil	3.00	3.00	3.00
Monocalcium Phosphate	1.95	1.62	1.75
Limestone	0.78	0.90	0.86
Vitamins[e]	0.25	0.25	0.25
Minerals[f]	0.15	0.15	0.15
Salt	0.10	0.20	0.10
Copper sulfate	0.08	0.08	0.08
Chromic oxide[g]	-	0.10	0.10
Lysine-HCl	0.35	0.06	0.07
dl-methionine	0.05	0.03	0.05
Antibiotic[h]	1.00	0.50	0.50
Total	100.00	100.00	100.00

[a] As-fed basis.

[b] Common diet for d 0 to 14 was formulated to contain 1.5% lysine, 0.9% Ca, and 0.8% P.

[c] SBM=soybean meal and SDPP=spray-dried porcine plasma.

[d] Diets for d 14 to 28 were formulated to contain 1.25% lysine, 0.9% ca, and 0.8% P.

[e] Supplied per kilogram of complete diet: 5,513 IU of vitamin A; 551 IU of vitamin D_3, 22 IU of vitamin E; 2.2 mg of menadione; 5.5 mg of riboflavin; 13.8 mg of d-calcium pantothenate; 30.3 mg of niacin; 551 mg of choline; and 0.03 mg of vitamin B_{12}.

[f] Supplied per kilogram of complete diet: 150 mg of Mn; 150 mg of Fe; 150 mg of Zn; 60 mg of Ca; 269 mg of Cu; 4.5 mg of I; 1.5 mg of Co; and 0.3 mg of Se.

[g] Used as an indigestible marker.

[h] Antibiotic for d 0 to 14 supplied per kilogram of diet: 55 mg of carbadox. Antibiotic for d 14 to 28 supplied per kilogram of diet: 110 mg of chlortetracycline; 110 mg of sulfathiazole; and 55 mg of penicillin.

and 32 to allow for calculation of ADG, ADFI, and gain/feed. Feces were collected on d 13 from four pigs per pen, pooled, dried and analyzed as in Exp. 1. Treatments were: 1) SDPP; 2) 75% SDPP and 25% WG; 3) 50% SDPP and 50% WG; 4) 25% SDPP and 75% WG; and 5) WG. All diets for d 0 to 14 were formulated to contain 1.5% lysine, 0.42% methionine, 0.9% Ca, and 0.8% P, with all other nutrients in excess of NRC (1988) suggestions. For d 14 to 32, all pigs were fed the same corn-SBM-whey-based diet with 1.5% blood meal, that was formulated to 1.2% lysine, 0.8% Ca, and 0.7% P.

The experiment was analyzed as a randomized complete block design with initial BW as the blocking criterion, and pen as the experimental unit. Response criteria and statistical analyses were the same as in Exp. 1, except polynomial regression was used to describe the trends in responses when WG was added in increasingly greater concentrations (i.e., linear, quadratic, cubic and quartic effects).

RESULTS AND DISCUSSION

Experiment 1.

For d 0 to 14, pigs fed SDPP had greater ADG ($p<0.03$) and ADFI ($p<0.04$) than pigs fed WG (table 5). However, for d 14 to 21, pigs fed WG in the initial diets had greater ADG ($p<0.09$) and ADFI ($p<0.02$) compared to pigs fed SDPP in the initial diets. Hansen et al. (1993) and Richert et al. (1992) reported an increased rate and efficiency of gain when pigs were fed diets with SDPP immediately after weaning, compared to pigs fed DSM. In contrast, Richert et al. (1992) reported similar growth rate among pigs fed DSM and WG in diets fed immediately after weaning, but a carryover effect of

Table 3. Diet composition, % (Exp. 3)[a]

Item	Protein sources for d 0 to 14[bc]					Common diet for d 14 to 32[d]
	100 % SDPP	75% SDPP+ 25% WG	50% SDPP+ 50% WG	25% SDPP+ 75% WG	100% WG	
Corn	34.45	34.55	34.55	34.65	34.67	49.50
Whey	20.00	20.00	20.00	20.00	20.00	20.00
Spray-dried wheat gluten	-	1.82	3.64	5.45	7.25	-
Spray-dried porcine plasma	8.00	6.00	4.00	2.00	-	-
Lactose	10.00	10.00	10.00	10.00	10.00	-
Soybean meal, 48% CP	18.54	18.54	18.54	18.54	18.54	22.22
Spray-dried blood meal	1.50	1.50	1.50	1.50	1.50	1.50
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.98	1.96	1.95	1.93	1.91	1.24
Limestone	0.65	0.66	0.67	0.69	0.69	0.70
Vitamins[e]	0.25	0.25	0.25	0.25	0.25	0.25
Minerals[f]	0.15	0.15	0.15	0.15	0.15	0.15
Salt	-	-	0.10	0.10	0.20	0.20
Copper sulfate	0.08	0.08	0.08	0.08	0.08	0.08
Chromic oxide[g]	0.20	0.20	0.20	0.20	0.20	-
Lysine-HCl	0.05	0.18	0.30	0.43	0.55	0.10
DL-methionine	0.15	0.12	0.08	0.05	0.01	0.05
Antibiotic[h]	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.0	100.00	100.00	100.00	100.00	100.00

[a] As-fed basis.

[b] Diets for d 0 to 14 were formulated to contain 1.5% lysine, 0.9% Ca, and 0.8% P.

[c] WG=spray-dried wheat gluten, and SDPP=spray-dried porcine plasma.

[d] Common diet for d 14 to 32 was formulated to contain 1.2% lysine, 0.8% Ca, and 0.7% P.

[e] Supplied per kilogram of complete diet: 5,513 IU of vitamin A; 551 IU of vitamin D_3, 22 IU of vitamin E; 2.2 mg of menadione; 5.5 mg of riboflavin; 13.8 mg of d-calcium pantothenate; 30.3 mg of niacin; 551 mg of choline; and 0.03 mg of vitamin B_{12}.

[f] Supplied per kilogram of complete diet: 150 mg of Mn; 150 mg of Fe; 150 mg of Zn; 60 mg of Ca; 269 mg of Cu; 4.5 mg of I; 1.5 mg of Co; and 0.30 of mg Se.

[g] Used as an indigestible marker.

[h] Antibiotic for d 0 to 14 supplied per kilogram of diet: 55 mg of apramycin; and antibiotic for d 14 to 32 supplied per kilogram of diet: 55 mg of carbadox.

WG that resulted in greater weight gain during the last half of the nursery phase.

Overall (d 0 to 35), pigs fed diets with WG or SDPP had greater ADG ($p<0.05$) and gain/feed ($p<0.01$). Pigs fed SDPP had the greater DM ($p<0.001$) and N ($p<0.02$) digestibility at d 10, compared to pigs fed WG, although by d 20, there were no differences among treatments in DM or N digestibility. Richert et al. (1994) reported no difference in DM or N digestibilities when pigs were fed DSM-SBM-, WG-SBM-, or DSM-WG-based diets. However, in another experiment, the authors found that digestibilities of DM and N, taken at d 21 of the experiment, were improved for pigs fed WG after weaning, compared to pigs fed DSM after weaning.

Thus, the results from Exp. 1 were consistent with the early growth response for weanling pigs fed SDPP as reported by Hansen et al. (1993), Kats et al. (1994a), and Richert et al. (1994) and the late growth response for pigs fed WG as reported by Richert et al. (1994). Furthermore, the overall performance of pigs fed the blend of SDPP and WG suggests a possible means of reducing diet costs for early-weaned pigs by replacing a portion of the SDPP with WG.

Table 4. Chemical composition of protein sources (Exp. 1, 2, and 3)

Item	Dried skim milk[a]	Spray-dried wheat gluten[b]	Spray-dried porcine plasma[c]
CP, %	33.3	74.3	72.0
Amino acids, % of sample			
Arginine	1.2	2.6	4.3
Histidine	0.9	1.4	2.4
Isoleucine	2.2	2.2	2.8
Leucine	3.3	4.7	7.3
Lysine	2.5	1.3	6.5
Methionine	0.9	2.5	0.7
Phenylalanine	1.6	3.4	4.1
Threonine	1.6	2.4	5.2
Tryptophan	0.4	0.6	1.5
Valine	2.3	2.2	4.7
Amino acids, % of CP			
Arginine	3.6	3.5	5.6
Histidine	2.7	1.9	3.1
Isoleucine	6.6	3.0	3.6
Leucine	9.9	6.3	9.4
Lysine	7.5	1.8	8.5
Methionine	2.7	3.4	1.0
Phenylalanine	4.8	4.6	5.3
Threonine	4.8	3.2	6.8
Tryptophan	1.2	0.8	1.9
Valine	6.9	3.0	6.1

[a] Amino acids from NRC (1988).
[b] Amino acids analyzed using AOAC (1990) procedures.
[c] Amino acid profile courtesy of Merricks, Inc.

Experiment 2

There were no differences in ADG, ADFI, or gain/feed for d 14 to 28, or overall for pigs fed SDPP into the last half of the nursery phase ($p>0.17$). This is in contrast to research reported by Kats et al. (1994a), that feeding SDPP in the initial and subsequent diets after weaning had an additive effect on final BW. The authors did acknowledge, however, that the overall ADG, ADFI, and gain/feed ratio were not improved by feeding SDPP for the entire nursery period.

Nursery pigs generally undergo a lag in growth

Table 5. Effects of replacing milk products with wheat gluten and spray-dried porcine plasma (Exp. 1)[a]

	Protein sources for d 0 to 14[b]					Contrasts[cd]		
Item	DSM	WG	SDPP	WG -SDPP	SE	1	2	3
d 0 to 14								
ADG, g	359	349	395	373	13	-	-	0.03
ADFI, g	373	339	390	357	16	-	-	0.04
Gain/feed	962	1,029	1,013	1,045	57	-	-	-
d 14 to 21								
ADG, g	288	429	307	325	47	-	-	0.09
ADFI, g	501	592	492	469	25	-	0.04	0.02
Gain/feed	575	725	624	693	93	-	-	-
d 14 to 35								
ADG, g	404	465	425	494	13	0.07	0.14	-
ADFI, g	722	742	689	739	9	-	-	0.07
Gain/feed	560	627	617	668	29	0.05	-	-
d 0 to 35								
ADG, g	386	419	413	446	16	0.05	0.15	-
ADFI, g	582	581	570	586	12	-	-	-
Gain/feed	663	721	725	761	21	0.01	-	-
Apparent fecal digestibility, %								
d 10								
DM	83.1	81.9	87.2	83.4	0.7	-	-	0.001
N	81.0	77.7	84.3	79.8	1.4	-	-	0.02
d 20								
DM	79.8	83.1	77.3	80.9	3.1	-	-	-
N	74.6	76.6	73.4	74.1	4.8	-	-	-

[a] A total of 120 weanling pigs (avg initial BW of 6.4 kg) were allotted six pigs per pen and five pens per treatment.
[b] DSM=dried skim milk, WG=spray-dried wheat gluten, and SDPP=spray-dried porcine plasma. Note that all pigs were fed the same diet (corn-SBM-whey-based) for d 14 to 35.
[c] Contrasts were: 1) DSM vs other protein sources; 2) WG and SDPP vs the WG-SDPP blend; and 3) WG vs SDPP.
[d] Dash indicates $p>0.15$.

when they are switched to a solid diet post-weaning. Hansen et al. (1993) did not observe this lag in pigs fed porcine plasma immediately post-weaning, until they were switched to a common diet in the second half of the nursery phase. Although ADFI in the current experiment was numerically different for pigs fed the diets with and without SDPP in the second half of the nursery phase, they did not differ significantly, suggesting neither group experienced a lag phase. Ermer et al. (1994) demonstrated that weanling pigs had a clear preference for diets with SDPP compared to DSM, which the authors attribute to improved palatability. Richert et al. (1992) reported a significant increase in ADFI for pigs fed SDPP compared to pigs fed DSM immediately after weaning, although this difference disappeared by the second half of the nursery phase. Improved palatability and increased feed intake with the addition of SDPP may explain increased ADG in the early half of the nursery phase, but this advantage is lost, or diminished after pigs reach approximately 21 d of age (Ermer et al., 1994).

There were no differences in digestibilities of DM and N ($p>0.14$). This is in agreement with Richert et al. (1992) who reported no difference in digestibilities of DM or N when pigs were fed diets with DSM or SDPP, although in that study, fecal samples were collected on d 13 for DM and N digestibility determinations.

Experiment 3

Results of the previous experiments suggested that there was an advantage to feeding a SDPP:WG blend. The objective of the third experiment was to estimate the optimum blend of SDPP and WG. For d 0 to 14, ADG and ADFI increased with up to 50% replacement of the SDPP and decreased when more of the SDPP was removed from the diet (quadratic effects, $p<0.004$ and 0.02, respectively). This is in contrast with the results from Exp. 1, where pigs fed SDPP had numerically greater ADG and ADFI than those fed the SDPP-WG blend immediately after weaning. For d 14 to 32, treatment did not affect ADG ($p>0.2$), although there were quadratic responses in ADFI with pigs fed the 50:50 blend having the greatest ADFI ($p<0.04$). A similar response in gain/feed was noted, with pigs fed the 25:75 blend of SDPP:WG having the greatest feed efficiency ($p<0.03$). Overall (d 0 to 32), ADG and ADFI increased as WG was used to replace 50% of the SDPP (quadratic effects, $p<0.04$ and 0.02, respectively). The overall response of pigs fed the SDPP:WG blend in Exp. 1 was similar to the response of pigs fed the 50:50 blend in Exp. 2, although improvements in ADG, ADFI and gain/feed in Exp. 1 were not statistically significant.

There were no differences in digestibilities of DM and N at d 13 ($p>0.18$). These results are in contrast to those in Exp. 1, in which digestibilities of DM and N at d 10 were greater for pigs fed SDPP compared to pigs fed WG. Thus, it seems unlikely that the effects of SDPP or WG on growth performance can be attributed to improved digestibility of nutrients. In the experiments reported herein, DSM, WG, and SDPP are all highly digestible protein sources.

Li et al. (1991) and Friesen et al. (1993) suggested that young pigs will experience a decrease in growth performance no matter when they are initially exposed to soy protein, but the sooner they are exposed, the sooner they will be able develop a digestive tolerance to soy proteins. All of the diets in the three experiments described herein had SBM, so it is likely that all the pigs in these experiments experienced (to some degree) the delayed-type hypersensitivity response that has been associated with the consumption of soy proteins. However, the addition of WG (a vegetable protein source like SBM that lacks the same degree of antigenicity) may allow the young pig to activate enzyme systems that are involved in the digestion of vegetable proteins without the antigenic effect

Table 6. Effects of wheat gluten and spray-dried porcine plasma on growth performance and fecal digestibility of nursery pigs (Exp. 2)[a]

Item	Protein sources[b] SBM-whey	SBM-whey-SDPP	SE	P value[c]
d 0 to 14				
ADG, g	320	322	11	-
ADFI, g	361	340	14	-
Gain/feed, g/kg	886	947	35	-
d 14 to 28				
ADG, g	478	437	20	-
ADFI, g	803	720	61	-
Gain/feed, g/kg	595	607	125	-
d 0 to 28				
ADG, g	399	379	15	-
ADFI, g	401	360	75	-
Gain/feed, g/kg	995	1,056	70	-
Apparent fecal digestibility (d 28), %				
DM	83.5	84.8	0.7	-
N	72.7	77.7	1.7	0.14

[a] A total of 60 weanling pigs (avg initial BW of 5.1 kg) were allotted five pigs per pen and six pens per treatment.

[b] SBM=soybean meal and SDPP=spray-dried porcine plasma. Note that all pigs were fed a common corn-SBM-whey-WG/SDPP diet in Phase I (d 0 to 14).

[c] Dash indicates $p>0.15$.

Table 7. Effects of optimum blend of spray-dried wheat gluten and porcine plasma protein on growth performance and fecal digestibility for nursery pigs (Exp. 3)[a]

Item	Protein sources[b]					SE	Contrasts[cd]			
	100 % SDPP	75% SDPP : 25% WG	50% SDPP : 50% WG	25% SDPP : 75% WG	100% WG		1	2	3	4
d 0 to 14										
ADG, g	412	427	426	393	357	11	0.0005	0.004	-	-
ADFI, g	433	457	458	435	393	15	0.05	0.02	-	-
Gain/feed, g/kg	952	934	930	903	908	16	0.05	-	-	-
d 14 to 32										
ADG, g	548	570	578	547	548	16	-	-	-	-
ADFI, g	805	845	880	842	805	26	-	0.04	-	-
Gain/feed, g/kg	681	675	657	650	681	10	-	0.03	0.09	-
d 0 to 32										
ADG, g	488	507	512	479	464	12	0.06	0.04	-	-
ADFI, g	642	675	695	664	625	20	-	0.02	-	-
Gain/feed, g/kg	760	751	737	721	742	9	0.06	0.06	0.11	-
Apparent fecal digestibility (d 13), %										
DM	88.4	90.5	89.5	89.6	89.5	1.0	-	-	-	-
N	84.0	87.6	86.8	86.8	87.6	1.4	-	-	-	-

[a] A total of 150 weanling pigs (avg initial BW of 5.6 kg) were allotted five pigs per pen and six pens per treatment.
[b] WG=spray-dried wheat gluten, and SDPP=spray-dried porcine plasma. Note that the same corn-SBM-whey-based diet was fed for d 14 to 32.
[c] Contrasts were: 1) linear; 2) quadratic; 3) cubic and 4) quartic.
[d] Dash indicates p>0.15.

stimulated by SBM.

In conclusion, the combination of the animal protein source (SDPP) to stimulate feed intake and increase initial ADG, with a vegetable protein source (WG) to improve adaptation to subsequent diets, can effectively improve overall nursery pig growth performance.

IMPLICATIONS

Spray-dried porcine plasma, have supported equal or greater growth performance compared to dried skim milk, but they are expensive too. By replacing 50% of the spray-dried porcine plasma with 4% spray-dried wheat gluten containing 8% SDPP, the producer can combine the early nursery feed intake increase from spray-dried porcine plasma, and the late nursery increase in rate of gain from wheat gluten, to improve overall nursery performance.

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