The Effect of Spray Dried Plasma, Lactose and Soybean Protein Sources on the Performance of Weaned Pigs **

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ABSTRACT : A total of 371 weaned pigs were used in three experiments to evaluate the effects of spray dried plasma (SDP), soybean protein sources, and lactose on growth performance. In Exp. 1, 128 pigs (5.99 kg, 18±2 d) were used to evaluate the effect of SDP (0 vs 7%), lactose (0 vs 30%), and two soybean protein sources [soybean meal (SBM) and extruded soybean protein concentrate (ESPC)] in phase I (d 0 to 14) diets on pig performance in a 2 × 2 × 2 factorial arrangement. Spray-dried plasma increased phase I ADG ($p<0.01$) and ADFI ($p<0.05$) in the SBM diets, but not in the ESPC diets. Lactose improved ADG and gain/feed ratio (G/F) in phase I ($p<0.01$). In Exp. 2, 144 pigs (5.50 kg, 17±3 d) were used to evaluate the effect of SDP (0 vs. 3.5%) and three soybean protein sources [SBM, ESPC, and soybean protein concentrate (SPC)] in phase I diets, and the effects of two different phase II (d 14 to 28) diets (simple vs complex) in a 2 × 3 × 2 factorial arrangement of treatments. In phase I, SDP increased ADG ($p<0.01$) and improved G/F ($p<0.05$). Pigs fed SBM had the highest ADG and ADFI, with a G/F similar to the pigs fed ESPC. In phase II, pigs fed the complex diet had improved ADG ($p<0.01$), ADFI ($p<0.05$), and G/F ($p<0.05$) compared to the simple diet. In Exp. 3, 99 weaned pigs (5.77 kg, 17±3d) were used to evaluate the effect of SBM, ESPC, and ESPC with SDP in the phase I diets. Pigs fed SBM with no blood product in the diet had the lowest ADG ($p<0.01$), ADFI ($p<0.01$), and G/F ($p<0.05$) in the first week of phase I. There were no differences in soybean protein sources fed in phase I diets on overall pig performance. These experiments are indicated that SDP and lactose improve the phase I performance. Soybean meal can be used as the major protein source in phase I diets with SDP. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 9 : 1290-1298)***

Key Words : Spray Dried Plasma, Lactose, Soybean Protein, Weaned Pigs

INTRODUCTION

For weaned pigs, diets containing milk products improve growth performance compared to the plant carbohydrate based diets (Graham et al., 1981; Wilson and Leibholz, 1981; Himmelberg et al., 1985). Tokach et al. (1989) and Mahan (1992) indicated the importance of the lactose fraction in dried whey for improving the performance of weaned pigs. Lactose has been shown to improve weaned pig performance (Mahan, 1991; Owen et al., 1993; Touchette et al., 1995a, 1995b, 1996; Richert et al., 1996; Nessmith et al., 1997a, 1997b).

There are several soybean protein sources that may be used in the weaned pig diet. Sohn et al. (1994) demonstrated that ADG and gain to feed ratio (G/F) were greater for 21-d-old weaned pigs fed diets containing soybean protein concentrate (SPC) during the first 2-wk post-weaning period than for pigs fed soybean meal (SBM). Li et al. (1991b) reported that pigs fed diets containing moist extruded soybean protein concentrate (ESPC) during the first 14 d post-weaning had a higher ADG than pigs fed a diet with either SBM or SPC. In both of these experiments, there were no blood products in the experimental diets.

Feeding a diet containing spray-dried plasma (SDP) in phase I (d 0 to 14 postweaning), increases ADFI and ADG for early-weaned pigs (Gatnau and Zimmerman, 1990; Hansen et al., 1993; Kats et al., 1994a, 1994b). Kats et al. (1994a) observed increases of 46% in ADFI and 55% in ADG from d 0 to 14 for pigs fed diets with 8% compared to no SDP.

There have been numerous research studies conducted evaluating the use of SDP, lactose, and different soybean protein sources and their effects on postweaning performance; however, little research has been conducted on the potential interactions among these ingredients. Thus, the objectives of the following experiments were to evaluate the interactive effects of SDP, lactose, and various soybean protein sources (SBM, SPC, and ESPC) in weaned pigs diets on growth performance.

MATERIALS AND METHODS

Animal and housing

Crossbred pigs (Yorkshire × Landrace × Duroc) were used in all the three experiments. All experiments were conducted in an environmentally regulated on-site nursery building. Pigs had *ad libitum* access to a nipple waterer and

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Table 1. Phase I diets composition (%), as-fed basis (Exp. 1)[a]

Items	0% SDP				7% SDP			
	0% Lactose		30% Lactose		0% Lactose		30% Lactose	
	SBM	ESPC	SBM	ESPC	SBM	ESPC	SBM	ESPC
Corn	51.40	61.49	18.97	29.36	60.36	66.12	27.55	34.00
Soybean meal (48.5% CP)	37.21	-	39.37	-	21.26	-	23.79	-
ESPC [b]	-	27.00	-	28.83	-	15.43	-	17.26
Lard	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Spray-dried plasma protein	-	-	-	-	7.00	7.00	7.00	7.00
Spray-dried blood cells	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Lactose	-	-	30.00	30.00	-	-	30.00	30.00
Dicalcium phosphate	2.24	2.39	2.64	2.81	2.10	2.19	2.51	2.61
Limestone	0.68	0.65	0.45	0.43	0.83	0.81	0.61	0.59
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Carbadox premix [c]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix [d]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix [e]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Zinc Oxide	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Copper Sulfate	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
L-Lysine·HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.10	0.10	0.20	0.20	0.08	0.08	0.17	0.17

[a] Diets were formulated to contain 1.56% lysine, 0.86% sulfur amino acid, 0.85% Ca, and 0.8% tP.
[b] Extruded soybean protein concentrate.
[c] Provided 55 mg/kg of carbadox.
[d] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.
[e] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.

Table 2. Composition (%) of phase II diets, as-fed basis (Exp. 1 and 2)[a]

Items	Simple diet	Complex diet
Ground corn	57.91	54.66
Soybean meal (48.5% CP)	34.67	27.73
Spray-dried blood cells	-	2.50
Lactose	-	7.50
Lard	3.00	3.00
Dicalcium phosphate	2.22	2.50
Limestone	0.83	0.70
L-Lysine·HCl	0.10	0.10
DL-Methionine	0.04	0.08
Vitamin premix [b]	0.25	0.25
Mineral premix [c]	0.15	0.15
Salt	0.50	0.50
Carbadox premix [d]	0.25	0.25
Copper sulfate	0.08	0.08

[a] Diets were formulated to contain 1.3% lysine. Only complex diet was used in Exp.1.
[b] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.
[c] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.
[d] Provided 55 mg/kg of carbadox.

a four-space self-feeder. The pen size was 1.2 m × 1.2 m, with concrete slatted flooring. All experiments used a three phase feeding program, which were phase I (fed d 0 to 14 postweaning), phase II (d 15 to 28 or 29), and phase III (d 29 or 30 to 39 or 40). The diet form in phase I was pelleted and crumbled. In phases II and III the diets were pelleted. The University of Missouri - Columbia Animal Care and Use Committee approved all animal protocols used in this study.

Experiment 1

One hundred and twenty-eight weaned pigs (average BW 5.99 kg, 18±2 d old) were used to evaluate the effects of SDP, lactose, and different soybean protein sources (SBM and ESPC) in the phase 1 diet and their effects on subsequent performance. At weaning, pigs were blocked by weight into four groups and were randomly allotted to one of the eight dietary treatments in a 2 × 2 × 2 factorial arrangement of treatments with two levels of SDP (0 and 7%), two levels of lactose (0 and 30%), and two soybean protein sources (SBM and ESPC). All the phase I diets contained 1.75% spray-dried blood cells, and were formulated to contain 1.56% lysine, .86% sulfur-containing amino acid, .85% Ca and .8% total phosphorus (tP) (table 1). The phase II diet, fed to all pigs, contained 2.5% spray-dried blood cells and 7.5% lactose (table 2). The phase III

Table 3. Composition (%) of diets of Exp. 3, and phase III diet of Exp. 1, 2 and 3, as-fed basis [a]

Items	Phase I			Phase II	Phase III
	SBM	ESPC	ESPC + SDP		
Ground corn	31.79	43.66	47.99	57.91	61.97
Soybean meal (48.5% CP)	43.76	-	-	34.67	31.15
ESPC [b]	-	31.76	22.12	-	-
Spray-dried plasma protein	-	-	3.50	-	-
Spray-dried blood cells	-	-	1.75	-	-
Lactose	15.00	15.00	15.00	-	-
Lard	5.00	5.00	5.00	3.00	3.00
Dicalcium phosphate	2.30	2.50	2.50	2.22	1.75
Limestone	0.61	0.60	0.62	0.83	0.80
Salt	0.50	0.50	0.50	0.50	0.50
Vitamin premix [c]	0.25	0.25	0.25	0.25	0.25
Mineral premix [d]	0.15	0.15	0.15	0.15	0.15
L-Lysine HCl	0.15	0.15	0.15	0.10	0.10
DL-Methionine	0.10	0.09	0.13	0.04	-
L-Threonine	0.05	-	-	-	-
Carbadox premix [e]	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.09	0.09	0.09	0.08	0.08

[a] Diets were formulated to contain 1.56% lysine, .86% sulfur amino acid, 1.00% threonine, .85% Ca, and 0.8 % tP in phase I (d 0 to 14), 1.3% lysine in phase II (d 0 to 28), 1.2% lysine in phase III (d 28 to 39 in Exp. 1 and 2, d 28 to 40 in Exp. 3).

[b] Extruded soybean protein concentrate.

[c] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.

[d] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.

[e] Provided 55 mg/kg of cabadox.

diet, fed to all pigs was corn-SBM based diet (table 3). There were four pigs per pen. Individual pig weight and feed consumption of each pen were recorded on d 7, 14, 28, and 39 to evaluate ADG, ADFI, and G/F.

Experiment 2

One hundred and forty-four weaned pigs (average BW 5.50 kg, 17±3 d old) were used to evaluate the effect of SDP and different soybean protein sources (SBM, ESPC, and SPC) in the phase I diet and the effect of a complex versus a simple phase II diet. At weaning, pigs were blocked by weight into three groups and were randomly allotted to one of the 12 dietary treatments in a 2 × 3 × 2 factorial arrangement with two SDP levels (0 and 3.5%), three soybean protein sources (SBM, SPC, and ESPC), and two phase II dietary treatments (complex and simple diets; table 2). Phase I diets were formulated to the same nutrient content as Exp. 1; however, all phase I diets contained 15% lactose and 1.75% spray-dried blood cells (table 4). The complex diet of phase II contained 2.5% spray-dried blood cell and 7.5% lactose, and the simple diet was a corn-SBM based diet with no spray-dried blood cells or lactose (table 2). In phase III, pigs were fed the same diet as Exp. 1. The number of pigs per pen and the measurement criteria were same as Exp.1.

Experiment 3

Ninety-nine weaned pigs (average BW 5.77 kg, 17±3 d old) were used in this experiment to evaluate the effects of SBM, ESPC, and ESPC with SDP in phase I diets and on subsequent performance. At weaning, pigs were blocked by weight into three groups and randomly allotted to one of the three dietary treatments. In phase I, diet 1 was a corn-SBM diet without any blood products; diet 2 was a corn-ESPC diet without any blood products; diet 3 was a corn-ESPC diet with added SDP (3.5%) and spray-dried blood cells (1.75%). All phase I diets were formulated with 15% lactose and the same nutrient content of Exp. 1. The phase II diet was the same as the simple diet of Exp. 2 and the phase III diet was same as Exp. 1. There were three pigs per pen and same measurement criteria of Exp. 1.

Statistical analysis

Data were analyzed as a randomized complete block with pen as the experimental unit. Analysis of variance was performed using the GLM procedures of SAS (1996). For Exp. 1, the statistical model included the main effects of SDP, lactose, soybean protein sources, and all possible interactions. For Exp. 2, the statistical model included the main effect of SDP, soybean protein sources, phase II treatments, and all possible interactions. For Exp. 3, the statistical model included the effect of three dietary treatments.

Table 4. Composition (%) of phase I diets, as-fed basis (Exp. 2)[a]

Items	0% SDP			3.5% SDP		
	SBM	SPC	ESPC	SBM	SPC	ESPC
Ground corn	35.00	45.42	45.42	39.47	47.73	47.73
Soybean meal (48.5% CP)	38.47	-	-	30.50	-	-
SPC[b]	-	27.92	-	-	22.13	-
ESPC[c]	-	-	27.92	-	-	22.13
Spray-dried plasma protein	-	-	-	3.50	3.50	3.50
Spray-dried blood cells	1.75	1.75	1.75	1.75	1.75	1.75
Lactose	15.00	15.00	15.00	15.00	15.00	15.00
Lard	5.00	5.00	5.00	5.00	5.00	5.00
Dicalcium phosphate	2.44	2.60	2.60	2.37	2.50	2.50
Limestone	0.57	0.54	0.54	0.64	0.62	0.62
L-Lysine·HCl	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin Premix[d]	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix[e]	0.15	0.15	0.15	0.15	0.15	0.15
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Carbadox premix[f]	0.25	0.25	0.25	0.25	0.25	0.25
Zinc oxide	0.23	0.23	0.23	0.23	0.23	0.23
Copper sulfate	0.09	0.09	0.09	0.09	0.09	0.09

[a] Diets were formulated to contain 1.56% lysine, 0.86% sulfur amino acid, 0.85% Ca, and 0.8% tP.
[b] Soybean protein concentrate.
[c] Extruded soybean protein concentrate.
[d] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.
[e] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.
[f] Provided 55 mg/kg of cabadox.

RESULTS

Experiment 1

In phase I (d 0 to 14 postweaning), there was a SDP by soybean protein source interaction for ADG ($p<0.05$) (table 5). For pigs fed the diet with SBM, SDP improved ADG, while SDP had no effect on ADG for pigs fed the diet with ESPC. Providing SDP improved ADFI ($p<0.05$) during the phase I period. In phase II (d 14-28), pigs fed SDP in phase I had a lower ADG ($p<0.05$), compared with the pigs fed no SDP in phase I. There was a SDP by soybean protein source interaction ($p<0.05$) for ADFI and G/F. When ESPC was the soybean protein source, SDP fed in phase I resulted in a decrease in ADFI ($p<0.05$), with no effect on G/F in phase II. When SBM was the soybean protein source, SDP fed in phase I resulted in a decrease in G/F ($p<0.05$), with no effect on ADFI in phase II. In phase III (d 29-39), SDP fed in phase I had no effect on pig performance.

There was a SDP by soybean protein source interaction for overall ADFI ($p<0.05$). When there was SDP in the diet, pigs fed SBM in phase I had higher overall ADFI than ESPC (.680 kg vs. .624 kg, $p<0.05$). When there was no SDP in the diet, there was no difference in ADFI between the two treatments (.631 vs. .662, $p=0.27$). Neither SDP nor soybean protein source had an effect on pig weight at d 39.

There was no interaction between lactose and SDP or soybean protein sources ($p>0.05$). In phase I, lactose increased ADG and G/F ($p<0.01$), with no effect on ADFI (table 6). Lactose fed in phase I had no effect on pig performance in phase II and III. However, there was a trend of increased pig weight at d 39 fed lactose in phase I ($p<0.1$).

Experiment 2

In phase I, SDP increased ADG ($p<0.01$) and improved G/F ($p<0.05$), and SBM increased ADG ($p<0.01$). There was a SDP by soybean protein source interaction in ADFI ($p<0.05$). When SBM or SPC was the protein source in the diet, SDP increased ADFI significantly ($p<0.01$). But, when ESPC was the soybean source in the diet, SDP had no effect on ADFI ($p>0.05$) (table 7).

In phase II, there was a trend of lowering G/F on pigs fed SDP in phase I ($p<0.1$). Feeding SDP in phase I had no effect on pig performance in phase III and for the overall experimental period (d 0 to 39). Different soybean protein sources fed in phase I had no effect on performance in phase II and III. At d 39, pigs fed SBM in phase I had a

Table 5. Performance of pigs fed soybean meal or extruded soybean protein concentrate, with 0 or 7% SDP (Exp. 1)

	0% SDP		7% SDP		
	SBM	ESPC	SBM	ESPC	SEM
BW, kg					
d 0	5.97	5.97	6.00	6.02	0.05
d 14 [ab]	8.57	8.98	9.61	9.00	0.23
d 28	14.88	15.57	15.67	14.80	0.40
d 39	22.40	23.49	23.70	22.75	0.51
Days 0-14					
ADG, kg [ab]	0.186	0.215	0.258	0.213	0.016
ADFI, kg [b]	0.238	0.243	0.299	0.248	0.015
G/F	0.762	0.870	0.867	0.866	0.037
Days 14-28					
ADG, kg [b]	0.451	0.471	0.433	0.414	0.016
ADFI, kg [a]	0.633	0.661	0.654	0.577	0.024
G/F [a]	0.714	0.710	0.661	0.718	0.013
Days 28-39					
ADG, kg	0.684	0.720	0.729	0.723	0.014
ADFI, kg	1.129	1.195	1.199	1.163	0.026
G/F	0.606	0.605	0.610	0.622	0.007
Days 0-39					
ADG, kg	0.421	0.449	0.454	0.429	0.013
ADFI, kg [a]	0.631	0.662	0.680	0.624	0.019
G/F	0.668	0.679	0.668	0.689	0.007

[a] SDP × Soybean protein source interaction ($p<0.05$).
[b] SDP effect ($p<0.05$).

Table 6. Performance of weaned pigs fed 0% or 30% lactose (Exp. 1)

	0% Lactose	30% Lactose	SEM
BW, kg			
d 0	6.00	5.98	0.03
d 14 [a]	8.63	9.44	0.17
d 28 [b]	14.79	15.67	0.28
d 39	22.61	23.56	0.36
Days 0-14			
ADG, kg [a]	0.188	0.248	0.012
ADFI, kg	0.244	0.270	0.011
G/F [a]	0.764	0.918	0.026
Days 14-28			
ADG, kg	0.439	0.445	0.011
ADFI, kg	0.623	0.640	0.017
G/F	0.707	0.695	0.009
Days 28-39			
ADG, kg	0.711	0.717	0.010
ADFI, kg	1.160	1.182	0.018
G/F	0.614	0.608	0.005
Days 0-39			
ADG, kg	0.426	0.451	0.009
ADFI, kg	0.638	0.660	0.013
G/F [b]	0.668	0.684	0.005

[a] Lactose effect ($p<0.01$).
[b] Lactose effect ($p<0.05$).

higher body weight than ESPC ($p<0.05$). Also pigs fed SBM in phase I had higher overall ADFI than ESPC ($p<0.05$).

The complex diet fed in phase II increased ADG ($p<0.01$), ADFI ($p<0.05$), and G/F ($p<0.05$), but had no effect on phase III performance (table 8). There was no interaction between phase I and phase II treatments. Pigs fed the complex diet in phase II had a higher final BW ($p<0.05$) than a simple phase II diet.

Experiment 3

During the first week (d 0-7) of phase I period (table 9), pigs fed SBM had a lower ($p<0.05$) ADG and ADFI than ESPC diet. Pigs fed SBM had lower ADG ($p<0.01$), ADFI ($p<0.01$) and G/F ($p<0.05$) than fed the ESPC + SDP. There were no differences in ADG, ADFI, and G/F between the pigs fed ESPC + SDP and fed ESPC only. During the second week (d 8-14) in phase I, there were no differences in ADG, ADFI, and G/F among the three dietary treatments. In the overall phase I, there were no differences in ADG, ADFI, and G/F among the three dietary treatments.

In phase II, pigs fed ESPC + SDP in phase I had lower ADG ($p<0.05$) than SBM. Pigs fed SBM in phase I had higher ADFI ($p<0.05$) than the pigs fed ESPC or ESPC plus SDP. In phase III (d 28 to 40), there were no differences in ADG, ADFI, and G/F among the pigs fed different diets in phase I. From d 0 to 40, there were no differences in ADG, ADFI, and G/F among the pigs fed different diets in phase I.

Table 7. Effect of SDP and different soybean protein sources on growth performance of weaned pigs (Exp. 2)

	0% SDP			3.5% SDP			SEM
	ESPC	SBM	SPC	ESPC	SBM	SPC	
BW, kg							
d 0	5.50	5.50	5.57	5.51	5.51	5.52	0.03
d 14 [ab]	7.87	8.03	7.57	8.15	8.79	8.12	0.14
d 29	15.03	15.15	14.83	14.77	15.76	15.42	0.24
d 39 [c]	22.15	22.33	21.82	21.50	23.09	22.23	0.32
Days 0-14							
ADG, kg [ab]	0.169	0.181	0.143	0.189	0.234	0.185	0.011
ADFI, kg [abd]	0.214	0.224	0.197	0.220	0.277	0.234	0.008
G/F [e]	0.793	0.807	0.726	0.857	0.845	0.791	0.031
Days 14-29							
ADG, kg	0.477	0.474	0.484	0.441	0.465	0.487	0.013
ADFI, kg	0.666	0.697	0.690	0.666	0.697	0.718	0.021
G/F	0.720	0.682	0.703	0.664	0.668	0.680	0.019
Days 29-39							
ADG, kg	0.712	0.719	0.699	0.672	0.733	0.680	0.017
ADFI, kg	1.098	1.140	1.122	1.078	1.192	1.157	0.032
G/F	0.653	0.634	0.622	0.625	0.616	0.591	0.017
Days 0-39							
ADG, kg	0.427	0.432	0.417	0.410	0.451	0.428	0.009
ADFI, kg [c]	0.614	0.641	0.624	0.612	0.673	0.657	0.016
G/F	0.698	0.676	0.669	0.671	0.671	0.654	0.014

[a] SDP effect ($p<0.01$).
[b] Soybean protein source effect ($p<0.01$).
[c] Soybean protein source effect ($p<0.05$).
[d] SDP × Soybean protein source interaction ($p<0.05$).
[e] SDP effect ($p<0.05$).

Table 8. Performance of weaned pigs fed complex or simple diet from day 14 to 29 (Exp. 2)

	Complex diet	Simple diet	SEM
BW, kg			
d 14	8.12	8.06	0.08
d 29 [a]	15.58	14.74	0.14
d 39 [b]	22.52	21.86	0.18
Days 14-29			
ADG, kg [a]	0.497	0.446	0.008
ADFI, kg [b]	0.709	0.669	0.012
G/F [b]	0.704	0.669	0.011
Days 29-39			
ADG, kg	0.693	0.711	0.010
ADFI, kg	1.131	1.131	0.019
G/F	0.616	0.632	0.010
Days 0-39			
ADG, kg [b]	0.437	0.418	0.005
ADFI, kg	0.644	0.629	0.009
G/F	0.680	0.666	0.008

[a] Diet effect ($p<0.01$).
[b] Diet effect ($p<0.05$).

DISCUSSION

These results indicate that in the absence of blood products (SDP and blood cells) ESPC is a superior protein source to SBM. However, when blood products are included in the diet, SBM may be used as a major protein source. Similar to our results in Exp. 1 and 2, Nessmith et al. (1996) found that weaning pigs fed SBM had similar ADG to pigs fed fish meal or ESPC when there was 2.5 or 5% SDP in the experimental diets. Touchette et al. (1996) reported that SBM had no detrimental effects in the phase I diets for weaning pigs when these diets contained blood meal and SDP. In Exp. 3, when there was no blood product in the SBM diet, the pigs fed ESPC had better performance than the pigs fed SBM in the first week postweaning. However, this difference was observed only in the first week postweaning.

Sohn et al. (1994) demonstrated that early-weaned pigs fed isolated soybean protein (ISP) or SPC had better performance than pigs fed SBM. Li et al. (1991a) found that early-weaned pigs fed ESPC had a higher ADG than pigs fed SBM. Contrary to these findings, the results of Exp. 1 and 2 indicated that when there was SDP in the diet, SBM was at least equivalent to ESPC for early-weaned pigs. Additionally, Touchette et al. (1996) reported that weaned pigs fed a SBM diet with SDP had a higher ADFI and ADG than pigs fed a diet with ESPC. Thus, SDP appears to be necessary for early-weaned pigs fed SBM to have

Table 9. Effect of different soybean protein sources on growth performance of weaned pigs (Exp. 3)

	SBM	ESPC	ESPC + SDP	SEM
BW, kg				
d 0	5.77	5.82	5.73	0.03
d 7 [ab]	6.55	6.88	6.95	0.08
d 14	8.40	8.78	8.71	0.15
d 28	14.21	14.18	13.93	0.24
d 40	23.01	22.88	22.72	0.39
Days 0-7				
ADG, kg [ac]	0.111	0.152	0.175	0.010
ADFI, kg [ac]	0.137	0.160	0.172	0.006
G/F [d]	0.816	0.956	1.017	0.052
Days 7-14				
ADG, kg	0.265	0.271	0.251	0.014
ADFI, kg	0.323	0.319	0.307	0.008
G/F	0.816	0.844	0.824	0.035
Days 0-14				
ADG, kg	0.188	0.212	0.213	0.010
ADFI, kg	0.230	0.240	0.239	0.006
G/F	0.817	0.881	0.891	0.032
Days 14-28				
ADG, kg [c]	0.415	0.386	0.373	0.013
ADFI, kg [ac]	0.645	0.584	0.588	0.017
G/F	0.644	0.664	0.634	0.012
Days 28-40				
ADG, kg	0.733	0.725	0.733	0.016
ADFI, kg	1.328	1.272	1.280	0.024
G/F	0.553	0.571	0.574	0.007
Days 0-40				
ADG, kg	0.431	0.427	0.425	0.010
ADFI, kg	0.705	0.670	0.674	0.012
G/F	0.612	0.638	0.631	0.007

[a] ESPC + SDP vs SBM ($p<0.01$).
[b] ESPC vs SBM ($p<0.01$).
[c] ESPC vs SBM ($p<0.05$).
[d] ESPC + SDP vs SBM ($p<0.05$).

acceptable performance.

Early weaned pigs fed SBM have a decreased villous height (Li et al., 1990, 1991a, 1991b). Decreased villous height and increased serum IgG titers to soybean proteins coincided with inferior performance of early weaned pigs fed diets containing SBM (Li et al., 1990). Early weaned pigs fed SDP have an increased villous height compared with the pigs fed a diet without spray dried plasma protein (Touchette et al., 1997; Spencer et al., 1997). Pierce et al. (1996) reported that weaned pigs fed the globulin-rich fraction of bovine plasma performed as well as the pigs fed SDP. Godfredson-Kisic and Johnson (1997) also reported that the globulin fraction of plasma may responsible for improved growth. Immunoglobulins present in blood products may function to decrease or eliminate the hypersensitivity caused by the antigens in SBM. This may explain why pigs fed SBM performed as well as the pigs fed ESPC when there was SDP in the diets.

In Exp. 1 and 2, SDP increased phase I ADFI and ADG when SBM was the major protein source in the diets. However, feeding SDP in phase I decreased phase II performance. As a result, there was no difference in final pig BW at the end of the experiment. Similar to our results, Kats et al. (1994a) reported that during phase I (d 0 to 10 postweaning), ADG was increased with increasing SDP. From d 14 to 28 post-weaning, when all pigs were fed the same diet, a reduction in ADG occurred with increasing level of SDP fed during phase I. Touchette et al. (1998) reported that when SDP is removed from the diet at d 10 postweaning, feed intake and growth rate are reduced for at least 3 d. However, when SDP was only partially removed from 7 to 3.5%, the magnitude of this reduction was not as great. In the present study, SDP was completely removed from the diet at the end of the phase I period. We may have been able to maintain the difference in body weight if we had utilized a feeding program where SDP was gradually reduced over a two or three phase program.

Separation from the sow changes the main energy source for the pig because the milk fat and lactose of sow' milk are replaced by plant carbohydrates (mainly starch) in the postweaning diet. Such a change in diet composition requires a major adaptation in the secretion of digestive enzymes (Hongtrakul et al., 1998). Shields et al. (1980) and Efrid et al. (1982) reported that amylase production of the pancreas increases progressively until 10 wk of age. Previous studies by Mahan (1991), Owen et al. (1993), Touchette et al. (1995a, 1995b, 1996), and Richert et al. (1996) also demonstrated that increasing lactose levels in phase I diets increased weaned pig performance. Digestible carbohydrate is the limiting nutrient in a corn-SBM diet for weanling pigs (Mahan, 1991). Increasing dietary simple sugars increased weaned pig performance (Richert et al., 1996).

In Exp. 1, lactose improved phase I ADG and G/F significantly, and increased the final pig BW. In Exp. 2, the phase II complex diet, which contained 2.5% blood cells and 7.5% lactose, improved pig performance significantly. Similarly, Richert et al. (1996) reported that increasing lactose levels increased ADG from d 14 to 21 and d 21 to 28. Dritz et al. (1993) reported that phase II ADG, ADFI, and G/F increased as dietary dried whey levels increased. Crow et al. (1995) reported that pigs responded to lactose levels of at least 15% in the diet during the second and third week postweaning. Also Touchette et al. (1995b) indicated that pigs fed SDP needed between 0 and 15% lactose to maximize performance, whereas pigs fed no SDP needed between 30 and 45% lactose to maximize performance.

IMPLICATIONS

These results demonstrate that SBM can be the major protein source in phase I diets that contain blood products. Providing SDP in the SBM diet stimulates feed intake and gain of early-weaned pigs in phase I. Lactose fed in phase I improves weaned pig performance. With no blood products in the diet, ESPC is superior to SBM in the first week after weaning. However, after that, there were no differences in performance between pigs fed SBM and ESPC.

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