Effects of Replacing Spray Dried Porcine Plasma with Solpro500 on Performance, Nutrient Digestibility and Intestinal Morphology of Starter Pigs

C. H. Lai, S. Y. Qiao*, Defa Li, X. S. Piao, L. Bai and X. F. Mao
National Feed Technology Engineering Research Center, China Agricultural University No.2.
Yuanmingyuan West Road, Beijing 100094, P. R. China

ABSTRACT : The objective of this study was to evaluate Solpro500 (a wheat hydrolysate containing a high level of glutamine) as a replacement for spray dried porcine plasma (SDPP) in diets fed to nursery pigs. One hundred and eight pigs (Dalland, 5.39±0.80 kg BW) weaned at 21 days were assigned to one of three treatment groups for a 28 day feeding trial. The experimental diets were based on corn and soybean meal and were supplemented with either 8% SDPP, 4% SDPP plus 4% Solpro500 or 8% Solpro500. Each treatment was fed to six pens with six pigs per pen (4 barrows and 2 gilts). The experimental results indicated no significant difference (p>0.05) in daily gain, feed intake or feed efficiency for pigs fed the three experimental diets. However, the diarrhea index for pigs fed either 4% SDPP and 4% Solpro500 or 8% Solpro500 was lower (p<0.05) than that for pigs fed 8% SDPP. No differences (p>0.05) were found in the apparent fecal digestibility of dry matter, organic matter or crude protein between pigs fed the three diets. The intestinal morphology (villous height, villous width and crypt depth) was not affected by diet treatments (p>0.05). In conclusion, Solpro500 SDPP can replace SDPP without any negative effects on nursery pig performance. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 2 : 237-243)***

Key Words : SDPP, Solpro500, Performance, Digestibility, Intestinal Morphology, Weanling Pigs

INTRODUCTION

The performance of early-weaned pigs is often decreased when they are fed corn-soybean meal diets because these diets contain many antigens and anti-nutritional factors such as trypsin inhibitors, globin or polyglobin which lead to hypersensitive pigs (Li et al., 1990; Kats et al., 1992). Finding alternative protein sources to replace or reduce the content of soybean meal is necessary for successful nursery pig nutrition (Thacker, 1999).

Spray-dried porcine plasma (SDPP) is usually considered to be an essential ingredient in the diet of early-weaned pigs (Thacker, 1999). Weaver et al. (1995) summarized 25 experiments in which the effects of adding SDPP to starter pig diets were examined and concluded that average daily gain was improved by 39%, feed intake increased by 32% and feed efficiency improved by 5.4% when SDPP was included in the diet. Unfortunately, SDPP tends to be more expensive than other protein sources and many attempts have been made to find alternative feeds that can be successfully used in starter pig diets to effectively replace SDPP (Thacker, 1999).

Solpro500 (Amylum Group, Aalst, Belgium) is a protein source produced in a process involving hydrolysis of wheat gluten. After wheat gluten is hydrolyzed by food grade protease and pH of hydrolysate is adjusted then Solpro500 is produced. It contains a similar level of protein (80%) as SDPP (78%) but has a much higher content of the amino acid glutamine (Table 1). Glutamine is the primary respiratory fuel for gut enterocytes and also provides amide nitrogen that may support nucleotide biosynthesis (Windmueller, 1984). Glutamine can also protect intestinal structure and barrier function by limiting cytokine production and inflammation (Burke et al., 1989; Salloum et al., 1989). A deficiency of glutamine has been suggested to cause atrophy of the villous in the small intestine (Thacker, 1999).

The objective of this experiment was to compare the performance of nursery pigs fed SDPP and Solpro500 and to determine the effects of these protein sources on nutrient digestibility and intestinal morphology.

MATERIALS AND METHODS

Animals and diets

One hundred and eight pigs (Dalland, 5.39±0.80 kg BW with a 2 to 1 ratio of barrows to gilts) weaned at 21 days of age were selected for a 28 day growth trial to evaluate the effects of SDPP and Solpro500 in diets fed to nursery pigs. The experimental diets were based on corn and soybean meal and were supplemented with either 8% SDPP, 4% SDPP plus 4% Solpro500 or 8% Solpro500. The diets were formulated to contain 3,300 kcal DE/kg, 21% crude protein, 1.50% lysine, 0.92% threonine and 0.44% methionine and to meet or exceed NRC (1998) requirements for all other nutrients (Table 2). Chromic oxide (Cr_2O_3) was added (0.25%) to all diets as a digestibility indicator.

The pigs were used a completely randomized design and

* Corresponding Author: S. Y. Qiao. Tel: +86-10-62893588, Fax: +86-10-62893688, E-mail: qiaoshy@mafic.ac.cn
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Table 1. Composition of spray dried porcine plasma and Solpro500 (% as fed)

Item	Solpro500[1]	Spray dried porcine plasma [2]
Dry matter	94.0	92.0
Crude protein	80.0	78.0
Lysine	1.24	6.84
Methionine	1.37	0.75
Cystine	1.69	2.63
Threonine	2.08	4.72
Tryptophan	0.64	1.36
Histidine	1.50	2.55
Arginine	2.48	4.55
Leucine	5.31	7.61
Isoleucine	2.93	2.71
Phenylalanine	3.95	4.42
Valine	3.22	4.94
Glutamic acid+glutamine	29.51	10.5

[1] The data were the analyzed values (AOAC, 1990).
[2] The data were quoted from NRC (1998).

allotted to six pens per treatment with six pigs per pen (4 barrows and 2 gilts). The pigs were housed in an environmentally controlled nursery in 1.5×2.0 m^2 pens with mesh flooring. The room temperature was maintained at 27-30°C. Each pen had a self-feeder and nipple water to allow *ad libitum* consumption of both feed and water.

Experimental procedure and chemical analysis

Pigs and feed were weighed on days 0, 7, 14, 21 and 28 and these values were used to calculate daily gain, daily feed intake and feed conversion efficiency. The incidence of diarrhea was observed and recorded and these observations were used to calculate a diarrhea index (DI) using the following equation: DI (%)=(the number of pigs with diarrhea×the number of days pigs had diarrhea)/(108 experimental pigs×28 experimental days).

On day 14, one pig per pen was randomly selected and bled from the anterior vena cava using vacutainer tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ). Blood samples were centrifuged (Heraeus Biofuge 22R Centrifuge, Osterode**,** Germany) at 3,000 rpm for 15 minutes in order to obtain plasma. Plasma samples were stored at -20°C and then thawed prior to analysis for blood urea nitrogen and glucose using a fully automatic Biochemical Analyzer (Technicon RA-1000, Bayer Diagnostics Limited, Beijing, China) using reagents supplied by the Beijing Zhong Sheng High-Tech Bioengineering Company (Beijing, China).

On days 15, 16 and 17, fecal samples were collected from each pen with the accumulation of the three-day fecal collection subsequently being pooled. The fecal samples were oven dried at 60°C for 72 h, allowed to equilibrate for 24 h at room temperature and then ground through a 40 mesh screen with a high speed grinder (Taisite, Company, Tianjin, China).

The dry matter and crude protein in Solpro500, feed and feces and organic matter in feed and feces were analyzed according to AOAC (1990) procedures and the concentration of chromic oxide was measured using an atomic absorption spectrophotometer (Z-5000, Polarized Zeeman, Hitachi Company, Tokyo, Japan). Tryptophan in

Table 2. The formulation and composition of diets

Ingredient (%)	8% SDPP[3]	4% SDPP +4% Solpro500	8% Solpro500
Corn	64.40	64.00	64.00
Soybean meal	14.30	13.40	12.60
Dried whey	2.50	2.70	2.25
Fish meal	5.00	5.00	5.00
Soybean oil	2.5	3.10	3.80
Limestone	0.80	0.70	0.60
Dicalcium phosphate	0.90	1.00	1.15
Salt	0.25	0.25	0.25
Chromic oxide	0.25	0.25	0.25
Vitamin-mineral premix[1]	1.00	1.00	1.00
L-lysine	0.10	0.45	0.80
Methionine	-	0.05	0.11
Threonine	-	0.10	0.20
Spray dried porcine plasma	8.00	4.00	-
Solpro500	-	4.00	8.00
Nutrient level[2]			
Crude protein, %	20.9	20.91	20.89
Calcium, %	0.86	0.83	0.85
Total phosphorus, %	0.72	0.69	0.70

[1] Provided per kilogram diet: vitamin A, 12,000 IU; vitamin D_3 2,500 IU; vitamin E 30; vitamin B_1, 1.5 mg; Vitamin B_2, 4.0 mg; vitamin B_6, 3.0 mg; vitamin B_{12}, 0.12 mg; Pantothenic acid, 15 mg; Nicotinic acid 40 mg; Folic acid 0.7 mg; Biotin, 0.10 mg; Choline, 0.4 g; Fe, 105 mg; Cu, 30 mg; Zn, 80 mg; Mn, 23 mg; I, 0.48 mg; Se, 0.36 mg; Ca, 2.2 g; P, 0.60 g; Salt, 0.60 g.
[2] The data of crude protein, calcium and total phosphorus were the analyzed values.

Table 3. Effects of SDPP[1] and Solpro500 on performance and diarrhea in weaned pigs

Item	8% SDPP	4% SDPP+4% Solpro500	8% Solpro500	SEM	P-value
Days 0 to 14					
Daily gain (g)	194	190	182	7.0	0.58
Daily intake (g)	245	233	218	10.0	0.15
Feed conversion	1.26	1.23	1.19	0.03	0.43
Diarrhea index (%)	27.38	0	9.5	ND[2]	ND
Days 15 to 28					
Daily gain (g)	543	549	559	13.0	0.75
Daily intake (g)	914	941	880	23.0	0.17
Feed conversion	1.68	1.71	1.57	0.06	0.26
Days 0 to 28					
Daily gain (g)	369	371	370	8.0	0.92
Daily intake (g)	579	587	549	15.0	0.19
Feed conversion	1.56	1.58	1.48	0.08	0.27

[1] SDPP=Spray dried porcine plasma. [2] ND=not detected.

Solpro500 was measured by HPLC (Shimadzu LC-10A, Japan) after 4 N NaOH hydrolysis for 24 h; Sulfur-containing amino acids were determined by an amino acid automatic analyzer (Hitachi 8800, Japan) after being protected first by performic acid and then hydrolyzed in 6 N HCl for 24 h; Other amino acids were determined by an amino acid automatic analyzer (Hitachi 8800, Japan) after hydrolysis in 6 N HCl for 24 h. Digestibility of dry matter, organic matter and crude protein were then calculated using the indicator method with the following equation:

$$AD_F=100\%-[(Cr_2O_{3D}\times N_F)/(Cr_2O_{3F}\times N_D)]\times 100\%$$

(Sauer et al., 2000)

Where AD_F is the apparent fecal digestibility of dry matter, crude protein and organic matter in feces (%), Cr_2O_{3D} is the chromic oxide concentration in the assay diet (g kg^{-1}), N_F is the concentration of a nutrient in the feces (g kg^{-1}), Cr_2O_{3F} is the concentration of chromic oxide in the feces (g kg^{-1}) and N_D is the concentration of a nutrient in the assay diet (g kg^{-1}).

On day 25, six pigs from each treatment were selected for sacrifice by bleeding. The middle of the duodenum, jejunum, and ileum (about 2-3 cm) were removed and flushed with 0.9% salt solution. Samples were fixed with 10% formaldehyde-phosphate buffer and kept at 4°C until further analysis. The fixed intestinal samples were prepared using conventional paraffin embedding techniques. Samples were sectioned at 8 μm thickness and stained with hematoxylin and eosin. Villous height and width as well as crypt depth were measured under 10×40 magnification using an Olympus CK 40 microscope (Olympus Optical Company, Shenzhen, China). Fifteen intact villous were measured in triplicate for each pig.

Statistical analysis

Data were statistically analyzed as a one-way ANOVA using SPSS (1997). The significance of differences among treatment means was compared using Duncan's multiple range test (Duncan, 1955). Pens were used as the statistical unit for performance and digestibility data while pig was the experimental unit for blood parameters and intestinal morphology.

RESULTS

Performance and diarrhea index

The performance of pigs fed SDPP, Solpro500 or the combination of the two protein sources was presented in Table 3. There were no significant differences ($p>0.05$) in body weight gain, feed intake or feed conversion ratio between pigs fed the three treatments. Numerically, the performance of pigs fed 8% SDPP was slightly better than that of pigs fed 8% Solpro500 during the first 2 weeks of the experiment while the reverse situation occurred during the last 2 weeks resulting in no difference when the overall experimental period was considered.

Piglet diarrhea occurred mainly during the second week of the trial (day 8 to 14). The diarrhea index for pigs fed the 8% SDPP and 8% Solpro500 diets were 27.38% and 9.5%, respectively while piglets fed the 4% SDPP plus 4% Solpro500 diet had no diarrhea. The occurrence of diarrhea lasted five days, and after that time, no pigs were observed with diarrhea.

Fecal digestibility and blood parameters

Apparent fecal digestibility was presented in Table 4. The digestibility of dry matter, organic matter and crude protein were similar among pigs fed the three treatments ($p>0.05$). The concentration of blood glucose and blood urea nitrogen in pigs fed 8% Solpro500 were significantly higher ($p<0.05$) than in pigs fed 4% SDPP plus 4% Solpro500 while the values for pigs fed 8% SDPP were intermediate.

Table 4. Effects of SDPP and Solpro500 on digestibility of nutrients and blood glucose and urea nitrogen levels in weaned pigs[1]

Item	8% SDPP	4% SDPP+4% Solpro500	8% Solpro500	SEM	P-value
Dry matter digestibility (%)	85.84	84.73	84.41	0.7	0.41
Organic matter digestibility (%)	85.80	84.70	85.03	0.6	0.59
Crude protein digestibility (%)	85.32	83.66	81.87	0.9	0.14
Blood glucose (mg/dl)	96.07[ab]	92.48[a]	113.2[b]	8.5	0.04
Blood urea nitrogen (mg/dl)	12.40[ab]	10.33[a]	15.67[b]	1.8	0.04

[a, b] Values with different superscript in the same row are significantly different ($p<0.05$).

Table 5. Effects of SDPP[1] and Solpro500 on intestinal morphology

	8% SDPP	4% SDPP+4% Solpro500	8% Solpro500	SEM	P-value
Villous height (μm)					
Duodenum	298.4	304.6	276.1	11.2	0.48
Jejunum	331.2	368.2	395.6	22.4	0.25
Ileum	222.3	221.8	251.5	10.1	0.32
Villous width (μm)					
Duodenum	118.6	100.5	107.2	7.0	0.38
Jejunum	105.6	98.6	103.3	6.2	0.26
Ileum	96.4	90.1	93.7	5.1	0.64
Crypt depth (μm)					
Duodenum	205.3	190.2	196.2	9.0	0.42
Jejunum	191.8	179.0	183.8	8.0	0.39
Ileum	168.4	159.1	153.8	6.0	0.65
Villous height/crypt depth ratio					
Duodenum	1.45	1.60	1.41	0.14	0.22
Jejunum	1.92	1.85	2.15	0.17	0.18
Ileum	1.32	1.39	1.64	0.13	0.11

[1] SDPP=Spray dried porcine plasma.

Intestinal morphology

The effects of SDPP and Solpro500 on intestinal morphology were presented in Table 5. There were no significant differences between pigs fed the various treatments in regards to villous height and width or in crypt depth within the duodenum, jejunum or ileum.

DISCUSSION

Performance

Chae et al. (1999) and Burnham et al. (2000) reported that SDPP was the best protein source for early-weaned pigs. Feed intake was increased when SDPP was included in starter diets (Hansen et al., 1993). Growth rate was faster when 6% SDPP was added in the phase 1 diet (Faltys et al., 1998). As those reports showed, optimum performance could be obtained, the additive level of SDPP should be no less than 3%, usually was at 6-8%, and sometimes exceeded 10% (Kats et al., 1994), even up to 15% (Van Dijk et al., 2001). In this present study, pigs fed 8% SDPP numerically showed better in the first two weeks after weaning, which was agreement with stated results and previous results (Richert et al., 1992; Hansen et al., 1993; Burnham et al., 2000; Van Dijk et al., 2001;). But in the last two weeks the results were reversed and overall the performance of pigs fed SDPP and Solpro500 was similar. Burnham et al. (2000) reported that for d 0 to 14, pigs fed SDPP had greater weight gain and feed intake than pigs fed wheat gluten, but from d 14 to 21, pigs fed wheat gluten had greater gain and intake compared with pigs fed SDPP. Batterham et al. (1979) reported that 20 kg pigs fed a wheat and wheat gluten-based diet supplemented with methionine, threonine, and lysine had 7% greater average daily gain and gain/feed than pigs fed a basal diet with dried skim milk as the major protein source. Bassat and Mokady (1985) conducted a 21 d growth assay with rats and found that a diet with 10% wheat gluten (supplemented with lysine and threonine) supported 17% greater body weight gain and 10% greater food intake than a diet with casein. Richert et al. (1994) reported that pigs fed wheat gluten had greater gain/feed than pigs fed diets with soybean protein isolate. Leibholz (1986) used 21 d-old pigs in an experiment demonstrating that pigs fed diets with wheat gluten and crystalline amino acids supported similar body weight gain and gain/feed compared with pigs fed a diet with dried slim milk and soybean meal. Kim and Kim (1998) reported that from day 0 to 14, there were no differences in performance between the pigs (21 d -weaned) fed diets with SDPP and pigs fed diets with wheat gluten, but the gain/feed ratio in pigs fed the blend of SDPP and wheat gluten (50:50) had the lowest gain/feed ratio from day 14 to 35 and from day 0 to 35 ($p<0.05$). Terui (1996) reported that the gain of calves (7 weeks of age) fed calf starters with soybean meal or spray-dried wheat gluten had no significant differences. These results indicate that wheat gluten can improve starter animal performance. Solpro500 is a similar vegetable protein source as wheat gluten and made from wheat gluten. It contains a much higher content of the glutamine than SDPP (Table 1). Glutamine is very important for damaged gut enterocytes to renew and can protect intestinal structure and can be helpful to improve the absorption ability of intestine. Consequently, Solpro500 can indirectly influence the performance of pigs. In this present study, an increased growth and improved feed conversion (d 14 to 28) for pigs fed Solpro500 suggested that Solpro500 had potential effects on the rate and efficiency of growth in the late nursery phase after weaning. The intake of pigs fed Solpro500 was lower than that of pigs fed SDPP, which maybe related to the palatability of the protein source especially in the early nursery phase. Ermer et al. (1994) demonstrated that starter pigs were more like to consume diets including SDPP, compared with dried skim milk. The improved palatability and increased feed intake with SDPP maybe can explain the increased daily gain in the first two weeks, but this advantage was lost or diminished two weeks later after weaning.

Fecal digestibility and blood parameters

The digestibility of dry matter, organic matter and crude protein of pigs fed SDPP and Solpro500 did not differ. The digestibility of dry matter in this study was in agreement with Burnham et al. (2000), who reported that on d 10, the digestibility of dry matter of diets containing SDPP, wheat gluten, dried skim milk, and wheat gluten-SDPP (50:50) were 87.2, 81.9, 83.1 and 83.4%, respectively. Richert (1994) reported the apparent dry matter digestibility of flash-dried wheat gluten and spray-dried wheat gluten were 87.8 and 87.5%, respectively. Kim and Kim (1998) reported the dry matter digestibility in pigs fed SDDP and wheat gluten did not differ on day 13 after weaning but there was a linear response in N digestibility when wheat gluten was increased ($p<0.10$). The similar performance of pigs fed the three diets in the current study was possibly related to the lack of difference in digestibility of nutrients between SDPP and Solpro500. The apparent ileal digestibility of protein sources commonly used in young pigs diets is between 70 and 80% (Chae et al., 1999). Generally, the apparent fecal digestibility of nutrients is higher than the apparent ileal digestibility. In the present study, the results of crude protein digestibility are nearly consistent with those results from Kim et al. (2000) and Chae et al. (1999), who respectively, reported that the ileal digestibility of crude protein of SDPP was 76.67 and 71.2% in piglets.

Tagari et al. (1964) reported that the concentration of blood urea nitrogen was interrelated to nitrogen deposition, the coefficient was -0.9. Heitzman et al. (1977) also reported that decreasing level of blood urea nitrogen indicated increased nitrogen deposition and improved availability of protein in diet. In this study, the level of blood urea nitrogen in pigs fed 8% Solpro500 was significant higher ($p<0.04$) than that of pigs fed 4% Solpro500 plus 4% SDPP diet, which was probably attributed to higher levels of glutamine in Solpro500 because the metabolism of glutamine can spur the synthesis of blood urea nitrogen. As a result, the content of blood urea nitrogen was increased. When exogenous glutamine in diet increased, the level of blood urea nitrogen was increased as well (Ziegler et al., 1990).

Intestinal morphology and diarrhea index

Weanling stress or transient hypersensitivity to antigens in the diet can cause morphological changes such as villous atrophy and crypt hypertrophy in early-weaned piglets (Kenworthy, 1976; Li et al., 1991), which may last up to 12 d. Villous atrophy and crypt hypertrophy after weaning reduce the number of mature enterocytes and lead to a reduction in the activity of brush-border enzymes, which is related to the limited digestive and absorptive area or specific digestive and absorptive capacity of the small intestine, respectively. Therefore, undigested nutrients may accumulate in the distal gut and cause abnormal fermentation and diarrhea (Hampson, 1986), which is a major limiting factor to health and growth after weanling. Van Dijk et al.（2001）reported that villous height did not differ significantly on the day 2, 4 and 7 when 15% SDPP and 15% casein was added to diet. But the baseline values of villous height were reduced 2 days after weaning when pigs were fed a diet containing 8% SDPP and 8% casein (Van Dijk et al., 2002). So they concluded that SDPP had no effects on the villous height and crypt depth in the first week after weaning. In present study, the villous height of the jejunum and ileum in the pigs fed the diet including 8% Solpro500 is higher （$p>0.05$）than that in pigs fed the diet with SDPP, however, the crypt depth in pigs fed 8% SDPP was deeper （$p>0.05$）than that in pigs fed the diet with Solpro500. These results were consistent with the result of Van Dijk et al. (2002). In addition, we found an interesting result that the diarrhea index of pigs fed 8% Solpro500 was lower than that of pigs fed 8% SDPP (9.5 vs. 27.38%) and there were no diarrhea in pigs fed 4% Solpro500 and 4% SDPP. Reduced diarrhea index and better villous morphology in pigs fed Solpro500 was partially attributed to the effect of glutamine. The content of glutamine in Solpro500 is far higher than that of SDPP. Glutamine serves as the primary metabolic fuel for rapid cell differentiation including intestinal epithelial cells (Windmueller, 1982). It plays an important role in promoting gut rescue, maintaining the gut barrier, and normalizing local immune function (Souba et al., 1990; Yoo et al., 1997). So glutamine was defined a conditional essential amino acid (NRC, 1998). Grant et al. (1987) reported that total parenteral nutrition containing lots of glutamine increased the villous height. Illig et al. (1992) also reported total parenteral nutrition without glutamine decreased the intestine volume, villous and mucous height.

IMPLICATION

SDPP is an excellent protein source, but it is too expensive. It appears that SDPP can be partially replaced by Solpro500 without any negative effect on performance, fecal digestibility of nutrients and intestinal morphology in early-weaned pigs. Moreover, Solpro500 has a positive effect on preventing diarrhea in weaned pigs.

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