Optimal Dietary Ratio of Spray Dried Plasma Protein (SDPP) and Dried Porcine Solubles (DPS) in Improving Growth Performance and Immune Status in Pigs Weaned at 21 Days of Age**

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ABSTRACT : An experiment was conducted to determine the optimal inclusion ratio of spray dried plasma protein (SDPP) and dried porcine solubles (DPS) for maximizing growth and improving immunity in weaned pigs. One hundred-fifty male (barrow) pigs were allotted in a completely randomized block design. Treatments were as follows: 1) control (6% SDPP), 2) S6D6 (6% SDPP+6% DPS), 3) S6D3 (6% SDPP+3% DPS), 4) S3D6 (3% SDPP+6% DPS) and 5) S3D3 (3% SDPP+3% DPS). Each treatment has 6 replicates with 5 pigs per replicate. Average daily gain (ADG) and average daily feed intake (ADFI) were highest, but not significantly different when pigs were fed a diet contained 6% SDPP and DPS from d 0 to 7 after weaning. Pigs fed the S6D3 diet showed better weight gain and feed intake than other treatments, especially compared with pigs fed S3D6 diet ($p<0.05$) from d 8 to 21 after weaning. For the overall experimental period, pigs fed the S6D3 diet showed the best improvement in ADG and ADFI. The digestibilities of dry matter (DM) and crude protein (CP) were higher in pigs fed the S6D6 diet than other diets from d 0 to 7 after weaning. However, pigs fed S6D3 diet showed higher DM, CP and essential amino acids (except methionine and arginine) digestibilities than pigs fed other diets from d 8 to 21 after weaning, although there was no significant difference. From d 8 to 21 after weaning, threonine, valine, isoleucine and leucine digestibilites were higher in S6D6 group, and phenyalanine, histidine, lysine and arginine digestibility were higher in S6D3 group than other groups. The ratio of CD4 and CD8 positive lymphocytes during the overall experimental period was independent of the ratio of SDPP and DPS. However, CD4+:CD8+ ratio was numerically lowered in pigs fed diet the S6D3 diet. Therefore, the present study suggests that an optimal inclusion ratio for maximizing growth performance and maintaining low immune status is 6% of SDPP and 3% of DPS in weaned pigs. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 3 : 338-345)*

Key Words : SDPP, DPS, Growth Performance, Immune Status, Weaned Pigs

INTRODUCTION

Traditionally, blood was considered as a by-product of the meat industry regardless of functional components and nutritional value. In the past, blood products were processed into blood meal by subjecting the clotted blood to an extensive heat treatment (high temperature and long duration) to ensure dried products and eliminate biological contamination. This type of processing resulted in inconsistent quality of products, such as variable digestibility and solubility, and variable degree of contamination with other livestock by-products during processing. Successful processing methods of the blood were developed approximately 10 years ago and the methods have led to the production and utilization of high quality blood proteins in pig diets.

Careful handling of the raw material and utilization of the spray-dried process have dramatically improved the quality and subsequent use of blood protein products in the feed industries (Campbell, 1998). Zimmerman (1987), and Gatnau and Zimmerman (1990) initially evaluated plasma proteins for pigs. Using 10% plasma to replace soybean meal in starter pig diets plasma improved growth rate, feed intake and feed efficiency. Several studies were conducted to evaluate the effect of plasma protein on performance when it replaced various protein sources, such as dried skim milk (Hansen et al., 1993; Kats et al., 1994; de Rodas et al., 1995), soybean meal (Fakler et al., 1993; Coffey and Cromwell, 1994), fishmeal (Richert et al., 1994) and potato protein (Smith et al., 1994). In these studies, the dietary addition of plasma protein ranged from 3.75% to 10%.

The major protein fraction of plasma protein includes high molecular weight components (globulin) and many researchers have suggested that the superior performance observed in pigs fed plasma protein may be due to the presence of immunoglobulins that contribute to health of the pig. According to the study

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by Gatnau et al. (1989), immunoglobulins present in spray-dried porcine plasma have been implicated as contributing to overall immunocompetence of the newborn pigs.

Blood products, like milk products, are expensive compared with other protein sources. Dried porcine solubles (DPS) has recently emerged as another protein source. It is a by-product of heparin extraction from the pig intestine. The product is also a high quality protein source and has improved growth performance of weanling pigs. Bregendahl et al. (1998) reported that pigs fed a diet containing 5% of DPS added with lactose increased growth performance compared with pigs fed a diet containing dried whey. Zimmerman (1997) also reported that there was no feed waste when DPS was incorporated into the diet at 5% of the mixture. Therefore, DPS is a potential protein source for weaned pigs, if its optimal inclusion ratio is experimentally determined. The present study was also conducted to determine the optimal inclusion level of SDPP and DPS for maximizing growth rate, nutrient digestibilities and immunocompetence of weanling pigs.

MATERIALS AND METHODS

This experiment was conducted with one hundred-fifty crossbred pigs (Barrow, Landrace × Large White × Duroc) at the Seoul National University Swine Research Farm. Pigs weaned at 21 days of age average body weight of 6.01 ± 0.12 kg were allotted in a completely randomized block design.

Treatments were as follows : 1) control (6% SDPP), 2) S6D6 (6% SDPP+6% DPS), 3) S6D3 (6% SDPP+3% DPS), 4) S3D6 (3% SDPP+6% DPS) and 5) S3D3 (3% SDPP+3% DPS). Each treatment had 6 replicates of 5 pigs (5 pigs per pen).

Experimental diets and chemical composition are presented in tables 1 and 2. Phase I (d 0 to 7) basal diets were formulated to contain 3.49 Mcal ME/kg

Table 1. Formulas and chemical compositions of the experimental diets fed between d 0 to 7

	Control	S6D6	S6D3	S3D6	S3D3
Ingredients					
Corn	19.00	19.00	19.00	16.78	16.82
Whey, dried	25.00	25.00	25.00	25.00	25.00
Soybean meal	23.77	17.77	20.77	22.90	25.86
Lactose	15.00	15.00	15.00	15.00	15.00
Soy oil	4.00	4.00	4.00	4.00	4.00
Fish meal	4.50	4.50	4.50	4.50	4.50
Spray dried plasma protein	6.00	6.00	6.00	3.00	3.00
Dried porcine soluble	-	6.00	3.00	6.00	3.00
Spray dried blood meal	1.30	1.30	1.30	1.30	1.30
Monocalcium phosphate	0.30	0.30	0.30	0.30	0.30
Limestone	0.50	0.50	0.50	0.50	0.50
Vitamin mixture[1]	0.25	0.25	0.25	0.25	0.25
Mineral mixture[2]	0.15	0.15	0.15	0.15	0.15
Antibiotics	0.03	0.03	0.03	0.03	0.03
Cr_2O_3	0.20	0.20	0.20	0.20	0.20
Lysine	-	-	-	0.05	0.05
Threonine	-	-	-	0.04	0.04
Chemical composition[3]					
ME (Mcal/kg)	3.49	3.44	3.46	3.45	3.48
Crude protein (%)	23.73	23.70	23.71	23.71	23.71
Lysine (%)	1.66	1.65	1.65	1.65	1.66
Methionine (%)	0.37	0.35	0.35	0.35	0.36
Threonine (%)	1.08	1.09	1.08	1.09	1.08
Calcium (%)	0.83	0.81	0.82	0.82	0.83
Total phosphorus (%)	0.70	0.69	0.70	0.67	0.67
Avail. phosphorus (%)	0.56	0.58	0.57	0.54	0.53

[1] Contains per kg : vitamin A, 4,000,000 IU; vitamin D_3, 800,000 IU; vitamin E, 16,000 IU; vitamin K_3, 1,200 mg; vitamin B_2, 1,600 mg; calcium pantothenate, 4,000 mg; niacin, 8,000 mg; vitamin B_{12}, 6 mg; biotin, 32 mg; ethoxyquin, 6,000 mg.

[2] Contains per kg : Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe 4,000 mg; BHT, 5,000 mg.

[3] Chemically defined value.

diet and 1.66% lysine, while the phase II (d 8 to 21) basal diet contained 3.48 Mcal ME/kg diet and 1.49% lysine. During the entire experimental period, feed and water were provided *ad libitum*, and the environmental temperature was maintained in the range of 26 to 30℃. Body weight and feed intake were recorded weekly to calculate ADG, ADFI and feed/gain.

Experimental diets contained 0.2% Cr_2O_3 to determine the digestibilities of experimental diets, and feces were collected three times a day for two days after four days of adjustment period. All pigs (20 pigs, 4 pigs per treatments) used for a metabolic trial were adjusted to the experimental diet during one week, before they were moved into metabolic crates. Fecal samples were dried in an air-forced drying oven at 60℃ for 72 hours and ground with a 1 mm mesh Wiley Mill.

Feed and fecal samples were analyzed to determine proximate nutrient digestibilities according to AOAC (1995) methods. Amino acid contents were determined by acid hydrolysis with 6 N HCl at 110℃ for 16 hours (Mason, 1984), using an amino acid analyzer (Biochrom 20, Pharmacia Biotech., England). Chromium contents in diets and feces were measured using an Atomic Absorption Spectrophotometer (Shimadzu, AA6145F, Japan).

Blood samples were collected by venipuncture from the anterior vein cava using heparinized vacuum tubes for analysis of immune parameters at the beginning of the experiment and at the end of each feeding phase. After collection, blood samples were centrifuged and leukocytes were isolated using Hypaque-Ficoll (density 1.119, Sigma, USA). Three monoclonal antibodies specifically reactive with porcine leukocyte subpopulations were used for this experiment (table 3). Proportions of cells were counted using Flow Cytometry (FACSCalibur, Becton Dickinson, USA) with cell Quest program (Cell Quest, USA).

Table 2. Formulas and chemical compositions of the experimental diets fed between d 8 to 21

	Control	S6D6	S6D3	S3D6	S3D3
Ingredients					
Corn	37.00	36.95	37.00	34.78	34.82
Whey, dried	17.00	17.00	17.00	17.00	17.00
Soybean meal	18.77	12.80	15.77	17.90	20.86
Lactose	10.00	10.00	10.00	10.00	10.00
Soy oil	4.00	4.00	4.00	4.00	4.00
Fish meal	4.50	4.50	4.50	4.50	4.50
Spray dried plasma protein	6.00	6.00	6.00	3.00	3.00
Dried porcine soluble	-	6.00	3.00	6.00	3.00
Spray dried blood meal	1.30	1.30	1.30	1.30	1.30
Monocalcium phosphate	0.30	0.30	0.30	0.30	0.30
Limestone	0.50	0.50	0.50	0.50	0.50
Vitamin mixture[1]	0.25	0.25	0.25	0.25	0.25
Mineral mixture[2]	0.15	0.15	0.15	0.15	0.15
Antibiotics	0.03	0.03	0.03	0.03	0.03
Cr_2O_3	0.20	0.20	0.20	0.20	0.20
Lysine	-	0.02	-	0.05	0.05
Threonine	-	-	-	0.04	0.04
Chemical composition[3]					
ME (Mcal/kg)	3.48	3.43	3.46	3.45	3.47
Crude protein (%)	21.93	21.92	21.91	21.91	21.91
Lysine (%)	1.49	1.49	1.48	1.48	1.48
Methionine (%)	0.35	0.33	0.34	0.34	0.35
Threonine (%)	0.98	0.99	0.99	0.99	0.98
Calcium (%)	0.75	0.74	0.74	0.75	0.76
Total phosphate (%)	0.65	0.65	0.65	0.62	0.63
Avail. phosphate (%)	0.50	0.52	0.51	0.48	0.47

[1] Contains per kg diet : vitamin A, 4,000,000 IU; vitamin D_3, 800,000 IU; vitamin E, 16,000 IU; vitamin K_3, 1,200 mg; vitamin B_2, 1,600 mg; calcium pantothenate, 4,000 mg; niacin, 8,000 mg; vitamin B_{12}, 6 mg; biotin, 32 mg; ethoxyquin, 6,000 mg.

[2] Contains per kg diet : Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe 4,000 mg; BHT, 5,000 mg.

[3] Chemically defined value.

Table 3. A panel of monoclonal antibodies specifically reactive with swine leukocyte differentiation antigens

Specificity of MoAbs	Monoclonal antibodies	Cell types	References
PoCD4	PT90A	T h/i cells	Hammerberg & Schuring, 1989
PoCD8	PT81B	T c/s cells	Hammerberg & Schuring, 1989
G&M[1]	DH59B	Granulocyte & Monocyte	Davis et al., 1990

[1] Granulocyte and monocyte.

Data in this experiment were analyzed as a randomized complete block design using the GLM procedure of SAS (1989), and treatment means were compared using Duncan's multiple range test (Duncan, 1955).

RESULTS

When pigs were fed a diet containing 6% SDPP and DPS (S6D6), from d 0 to 7 after weaning, average daily gain (ADG) and average daily feed intake (ADFI) were highest, but not significantly different among treatments (table 4). Pigs fed the diet with 3% SDPP and DPS showed worse feed/gain ratio than other treatments ($p<0.05$). From d 8 to 21 after weaning, pigs fed with 6% SDPP and 3% DPS (S6D3) showed better weight gain and feed consumption than other treatments, especially compared to pigs fed with 3% SDPP and 6% DPS (S3D6) diet ($p<0.05$). For the overall experimental period, pigs fed 6% SDPP and 3% DPS showed the best ADG and ADFI, while pigs fed with 3% SDPP and 6% DPS (S3D6) diets showed the worst growth rate. During the entire experimental period, pigs fed 6% SDPP diets, including the control, S6D6 and S6D3 diets, showed numerically higher weight gain and feed intake than pigs fed 3% SDPP, diets including S3D6 and S3D3 diets, regardless of inclusion level of DPS.

Proximate nutrient digestibilities for experimental diets are presented in table 5. From d 0 to 7 after weaning, the digestibilities of dry matter (DM) and crude protein (CP) were higher in pigs fed 6% SDPP and DPS (S6D6) diet than other pigs. Regardless of DPS inclusion, pigs fed 6% of SDPP diets (control, S6D6 and S6D3) showed better DM digestibility than pigs fed diets with 3% SDPP (S3D6 and S3D3). During the late experimental period (d 8 to 21 after weaning), pigs fed 6% SDPP and 3% DPS (S6D3) diet showed slightly higher DM and CP digestibilities than pigs fed other diets, although there was no significant difference between treatments.

The effects on apparent amino acid digestibilities are presented in table 6. Although there was no significant difference, all apparent digestibilities of essential amino acids except methionine and arginine were higher in pigs fed the diet containing 6% SDPP and 3% DPS (S6D3) compared with others during d 0 to 7 after weaning. However, the digestibilities of valine, leucine, lysine and arginine showed significant differences between treatments ($p<0.05$). From d 8 to 21 after weaning, threonine, valine, isoleucine and leucine digestibilities were higher in the S6D6 group, and phenyalanine, histidine, lysine and arginine digestibility were higher in the S6D3 group. The apparent digestibility of lysine was significantly higher in pigs fed diets with 6% SDPP (control, S6D6 and S6D3) than pigs fed diets with 3% SDPP regardless of DPS inclusion. The apparent digestibilities of non-essential amino acids showed significant differences by dietary treatments.

Table 4. Effects of SDPP and DPS on growth performance in weaned pigs

Items	Control	S6D6	S6D3	S3D6	S3D3	SE[1]
		-------------- Phase I (d 0-7) -----------				
ADG (kg)	0.169	0.180	0.176	0.142	0.123	0.0085
ADFI (kg)	0.217	0.251	0.241	0.211	0.241	0.0091
F/G	1.32[b]	1.41[b]	1.39[b]	1.53[b]	1.98[a]	0.061
		-------------- Phase II (d 8-21) ---------				
ADG (kg)	0.411[ab]	0.412[ab]	0.433[a]	0.353[b]	0.391[ab]	0.0113
ADFI (kg)	0.547[a]	0.545[a]	0.580[a]	0.476[b]	0.516[ab]	0.0122
F/G	1.34	1.34	1.35	1.36	1.34	0.022
		------------- Overall (d 0-21) ------------				
ADG (kg)	0.330[ab]	0.335[a]	0.347[a]	0.283[b]	0.303[ab]	0.0094
ADFI (kg)	0.437[ab]	0.447[a]	0.467[a]	0.387[b]	0.425[ab]	0.0103
F/G	1.33	1.35	1.35	1.38	1.41	0.021

[1] Pooled standard error.

[a,b] Means with different superscripts are different at $p<0.05$.

During the overall experimental period, the different inclusion levels of SDPP and DPS did not alter the ratio of CD4 and CD8 positive lymphocytes, but the CD4+:CD8+ ratio was slightly lowered in pigs fed diets with 6% SDPP and 3% DPS (S6D3) (table 7).

DISCUSSION

Kats et al. (1994) reported that nursery pig performance was improved with up to 10% spray-dried animal plasma in the diet when dietary methionine was supplemented and maintained above requirement.

Table 5. Effects of SDPP and DPS on nutrient digestibilities in weaned pigs (%)

Items	Control	S6D6	S6D3	S3D6	S3D3	SE[1]
			Phase I (d 0-7)			
Dry matter	85.5^{a}	86.9^{a}	85.5^{a}	78.4^{b}	77.3^{b}	1.01
Crude protein	78.4^{a}	79.8^{a}	78.9^{a}	73.1^{ab}	68.7^{b}	1.32
Ether extract	70.5	72.7	71.6	71.1	67.6	1.15
Crude ash	67.4	68.6	68.0	68.9	69.9	0.82
Calcium	74.6	76.9	76.8	76.0	76.3	1.34
Phosphorus	55.6	56.1	53.8	52.9	52.9	0.98
			Phase II (d 8-21)			
Dry matter	75.4	77.6	78.1	76.6	75.5	0.79
Crude protein	73.0	76.5	78.9	73.5	70.0	1.34
Ether extract	68.4	70.4	70.2	70.8	68.7	1.00
Crude ash	67.9	64.8	66.7	65.5	65.0	0.68
Calcium	71.4	68.9	70.3	69.7	68.1	0.62
Phosphorus	52.7	58.5	56.6	54.0	56.7	1.40

[1] Pooled standard error, n=20.

[a,b] Means with different superscripts are different at $p<0.05$.

Table 6. Effects of SDPP and DPS on apparent amino acid digestibilities in weaned pigs (%)

Items	Control	S6D6	S6D3	S3D6	S3D3	SE[1]
			Phase I (d 0-7)			
THR	78.5	77.6	83.3	78.8	81.1	1.09
VAL	81.1^{ab}	79.9^{ab}	86.8^{a}	78.6^{b}	79.9^{ab}	1.17
MET	79.8	79.9	77.5	76.0	76.1	0.95
ILE	84.0	80.4	84.2	80.2	74.7	1.43
LEU	75.0^{b}	82.8^{a}	84.5^{a}	78.6^{ab}	78.6^{ab}	1.06
PHE	77.5	83.8	84.5	78.7	81.7	1.07
HIS	83.4	83.0	84.2	83.1	80.9	0.82
LYS	80.3^{bc}	84.2^{ab}	85.0^{a}	77.9^{c}	80.8^{abc}	0.83
ARG	82.2^{ab}	85.0^{a}	79.7^{b}	77.7^{b}	80.7^{ab}	0.80
Submean	80.2^{bc}	81.8^{ab}	83.3^{a}	78.8^{c}	79.4^{bc}	0.51
			Phase II (d 8-21)			
THR	80.2	82.7	81.6	79.5	78.4	0.68
VAL	81.7	82.7	82.6	78.2	81.6	0.92
MET	78.9	78.6	79.2	80.9	78.4	0.90
ILE	78.1^{ab}	81.7^{a}	76.0^{ab}	74.8^{b}	75.6^{ab}	1.00
LEU	82.7	83.5	82.9	76.4	74.7	1.40
PHE	79.1	79.9	82.5	77.5	77.9	0.89
HIS	79.5	81.8	83.7	78.4	78.6	1.09
LYS	81.0^{ab}	77.8^{ab}	82.9^{a}	77.6^{b}	76.1^{b}	1.00
ARG	79.6	79.5	84.0	80.0	77.4	0.96
Submean	80.1^{ab}	80.9^{ab}	81.7^{a}	77.9^{b}	77.6^{b}	0.57

[1] Pooled standard error.

[a,b,c] Means with different superscripts are different at $p<0.05$.

* Abbreviations: THR, Threonine; VAL, Valine; MET, Methionine; ILE, Isoleucine; LEU, Leucine; PHE, Phenylalanine; HIS, Histidine; LYS, Lysine; ARG, Arginine.

Table 7. Effects of SDPP and DPS on proportion of leukocyte sub-populations in weaned pigs

Item	Treatment					SE[1]
	Control	S6D6	S6D3	S3D6	S3D3	
Day 7						
CD4+ (%)	14.6	14.6	13.1	14.2	14.5	0.64
CD8+ (%)	17.4	16.6	16.3	15.3	16.4	0.66
CD4+:CD8+	0.87	0.93	0.83	0.98	0.95	0.071
G&M (%)	23.4	23.9	22.7	22.2	22.3	1.08
Day 21						
CD4+ (%)	15.7	17.8	16.6	18.1	19.4	0.65
CD8+ (%)	16.6	19.9	21.4	20.2	20.4	0.72
CD4+:CD8+	0.96	0.90	0.77	0.92	0.97	0.034
G&M (%)	22.3	20.5	22.9	22.5	22.0	0.69

[1] Pooled standard error.

* Abbreviations: CD4+, CD4 positive T-lymphocyte; CD8+, CD8 positive T-lymphocyte; G&M, Granulocyte and Monocyte.

However, in the present study, there was no need to consider methionine supplementation when spray-dried plasma was included up to 6%. According to previous studies (Gatnau and Zimmerman, 1990, 1992; Sohn et al., 1991; Hansen et al., 1993; Rojas et al., 1994; de Rodas et al., 1995) the improvements in ADG associated with spray-dried plasma resulted from increased ADFI. In addition, Ermer et al. (1994) reported that pigs preferred a diet containing spray-dried animal plasma to a diet containing dried skim milk. Results cited above coincide with the present study because pigs fed with diets containing 6% SDPP (control, S6D6 and S6D3) gained more weight and consumed more feed than pigs fed diets containing 3% SDPP (S3D6 and S3D3) disregarding DPS inclusion levels during the overall experimental period. Additionally, the digestibilities of dry matter and crude protein were also improved as the inclusion level of SDPP increased.

The inclusion of DPS improved pig growth and increased feed intake compared with pigs fed the control diet when SDPP was supplemented at the higher level (6%). This result is in accordance with a study of Bregendahl et al. (1998) on the beneficial effect of the addition of SDPP to a diet containing DPS for the improvement of growth performance. On the contrary, with a low inclusion level of SDPP, pigs fed with diets containing DPS (S3D6 and S3D3) had a lower growth rate compared with pigs fed with the basal diet (6% SDPP and no DPS).

Williams et al. (1997c) reported that low immune status requires higher dietary lysine intake because of a greater capacity for body protein accretion. In the present study, pigs exhibiting better growth rate and more feed consumption showed better digestibilities of amino acid, and maintained their low immune status. However, the intake of other amino acids which are related in establishing immune proteins may be also influenced by the immune system. Amino acids absorbed in the animal body are used for establishing muscle accretion and immune protein. We cannot exactly explain the metabolism of amino acids with only digestibility. Therefore, further research is needed to elucidate the amino acid metabolism during the immune response.

The major plasma protein fractions of plasma include fibrin, high molecular weight globulin, medium molecular weight albumin and low molecular weight components. Many researchers have indicated that the response to feeding plasma protein could be achieved by feeding the high molecular weight fraction (Owen et al., 1995; Pierce et al., 1995, 1996; Weaver et al., 1995). Hansen et al. (1993) suggested that one possible reason for the superior performance observed in pigs fed SDPP may be the presence of biologically active plasma proteins (e.g., immunoglobulins) that may contribute to the improved health of the starter pigs. Although the origin and processing method of DPS are different from those of SDPP, the major protein fraction of DPS also includes the high molecular weight globulin, which contributes to improvements in animal growth. In the present study, although there was no significant difference, pigs fed with the S6D3 diet showed higher CD4 positive lymphocytes and lower CD4+:CD8+ ratio at day 7, and higher CD8 positive lymphocytes and lower CD4+:CD8+ ratio at day 21 than pigs fed other diets. According to Williams et al. (1997a, b, c) and Stahly (1996), the pigs in the low immune system possessed fewer CD4 positive lymphocytes, more CD8 positive lymphocytes and lower CD4+:CD8+ ratios than high immune system pigs. Williams et al. (1997a, b, c) also reported that the pig with low immune status consumed more feed, grew faster and required less feed per unit of gain than those with high immune status. These results are in agreement with the current study that pigs fed with the diet containing 6% SDPP and 3% DPS (S6D3) maintained low immune status, showed better growth performance and consumed more feed than others during the overall experimental period.

In conclusion, the higher inclusion level of SDPP (6%) showed better growth rate and feed intake, and maintained low immune system compared to the lower inclusion level of SDPP (3%). On the contrary, the lower inclusion level of DPS (3%) mixed with higher inclusion level of SDPP (6%) showed better growth rate and maintained low immune status, although the high inclusion level of DPS (6%) did not improve growth and immunocompetence of weaned pigs. Therefore, the present study suggested that the 6% of SDPP and 3% DPS is an optimal inclusion level for maximizing growth performance and maintaining low immune status in weaned pigs.

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