Soy protein concentrate as a protein source in weaned pig diets

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Introduction

The combination of soybean meal and animal protein such as spray-dried plasma and fish meal are common protein feedstuffs used in nursery pig diets. Soybean meal with a relative well-balanced amino acid profile is the main plant-based protein source used in animal diets, but it contains anti-nutritional factors such as oligosaccharides (raffinose, stachyose, verbascose), trypsin inhibitors, and allergenic proteins (glycinins, β-conglycinin) that can negatively affect the growth performance of young animals (Li et al., 1990). Because piglets are much more sensitive to anti-nutritional factors than other livestock animals (Huisman, 1990), a large dietary soybean meal inclusion is limited in young pigs. Animal proteins are usually used in weaned pig diets to avoid the anti-nutritional factors in soybean meal, but they commonly are highly variable in nutrient composition and more expensive than plant protein sources (Casas et al., 2016). Therefore, a higher soy proteins inclusion in nursery pig diets might bring positive economic results in the pig industry, when growth performance is not affected, considering the high price of animal proteins. Processing of soybean meal results in a reduction in concentrations of anti-nutritional factors, and consequently in increased tolerance by weanling pigs. Soy protein concentration (SPC) is produced by removing the soluble carbohydrates and some of the non-protein constituents from the soybean meal using an alcohol extraction procedure, which removes the anti-nutritional factors from soybean meal. Dietary SPC inclusion is an opportunity to add value to weaned pigs, which are very sensitive to anti-nutritional factors exacerbated by their immature biological functions and the transitional period from a milk-based diet to a solid cereal-based diet. Because SPC is a protein source highly digestible, fewer protein amounts are fermented into potentially harmful microbial metabolites improving the intestinal health of nursery pigs.

Early weaning of pigs

The constant demand for better economic results and more piglets per sow per year have resulted in progressively earlier weaning of piglets from 10 - 12 wk to the current 3 wk (Edwards et al., 2020). The post-weaning period remains a critical phase in most swine production systems, which is characterized by nutritional, physiological, environmental, and social stress when both the digestive and immune systems of piglets are still immature (Rhouma et al., 2017). The gastrointestinal functions of piglets have some limitations in the early weaning associated with insufficient secretion of enzymes, hydrochloric acid, bicarbonate, and mucus (Molly, 2001), along with a higher gastric pH and this may contribute, in part, to the susceptibility of piglets to enteric infections (Heo et al., 2013). Adverse changes in intestinal morphology are commonly seen in weaned pigs, including reduced villus height and hyperplasia of crypt cells, resulting in reduced absorptive capacity and brush-border enzyme activity (Pluske et al., 1997). These factors compromise digestion and absorption of nutrients. With the lower dietary digestibility, depending on ingredients used, a greater amount of nutrients are used as a substrate for the proliferation of pathogenic bacteria and resulting in intestinal health problems such as post-weaning diarrhea. Along with the oligosaccharides content and ingredient composition, protein digestibility is one of the most important dietary factors influencing post-weaning diarrhea in piglets (Guzman et al., 2016). Thus, feeding weaned pigs a balanced diet with high digestibility feedstuffs is essential for maximizing nutrient utilization due to the positive correlation between nutrient digestibility and feed intake of piglets (Dong and Pluske, 2007). The SPC has shown to be an excellent ingredient for weaned pigs with high nutrient digestibility and low antigenicity (Sohn et al., 1994; Casas et al., 2016, Guzmán et al., 2016).

Nutrient digestibility in pigs fed SPC

Several studies indicated that the SPC is a potential protein source for starter pig diets improving the digestibility of CP and indispensable AAs (Sohn et al., 1994; Yang et al., 2007; Casas et al., 2016, Guzmán et al., 2016). Standardized ileal digestibility (SID) values of CP and AAs in SPC with three particle sizes (70, 180, or 700 µm) compared with soybean meal and fish meal by weanling pigs were evaluated by Casas et al. (2016). The SID values of CP were higher (P < 0.05) in SPC ground to 180 µm than the soybean meal and fish meal (Table 1). The removal of soluble carbohydrates from soybean meal resulted in higher protein digestibility.

The SID values of Leu were lower (P < 0.05) in soybean meal than in the other ingredients and the SID values of Arg, Ile, Trp, and Tyr were greater (P < 0.05) in SPC ground to 70 and 180 µm than in soybean. Fish meal resulted in lower SID values of Arg, Phe, and Tyr than in SPC ground to 70 and 180 µm. The lower anti-nutritional factor and low-molecular weight carbohydrates in SPC with the alcohol extraction makes the protein more digestible and further improvements in AAs digestibility might be obtained if the particle size of SPC is reduced from 700 to 180 µm.

The substitution of soybean meal by SPC has shown to reduce post-weaning diarrhea (Berrocoso et al., 2014; Guzmán et al., 2016) possibly due to the higher protein and AAs digestibility and the lower trypsin inhibitors of SPC compared with soybean meal. A higher amount of trypsin inhibitors have been associated with increased ileal endogenous nitrogen losses and dietary nitrogen losses (Schulze et al., 1995; Grala et al., 1998). A high intake of protein inhibitors limits proteolysis of dietary protein and may result in a compensatory secretion of trypsin and chymotrypsin by the pancreas, which causes an increase in endogenous losses of AAs (Nitsan and Liener, 1976).

Dietary SCP might reduce the ileal nitrogen losses with no endogenous damage to the intestinal mucosa since it contains less antigenic and anti-nutritional factors. With the higher digestibility of SPC, fewer nutrients might remain available for bacteria proliferation improving the intestinal health of nursery pigs. Moreover, dietary SPC inclusion showed to increase the villus height in pigs (Berrocoso et al., 2014) and broilers (Vasconcelos et al., 2014).

Table 1. Standardized ileal digestibility (SID) of CP and AAs in soybean meal, fish meal, and soy protein concentrate (SPC) ground to 70, 180, or 700 µm (SPC-70, SPC-180, and SPC-700, respectively) by weaned pigs (Casas et al., 2016).

Item	Soybean meal	SPC-70	SPC-180	SPC-700	Fish meal	SEM	P-value
CP	83.9[c]	90.5[ab]	91.5[a]	87.4[abc]	85.9[bc]	1.83	0.029
Arg	94.4[b]	97.4[a]	97.8[a]	94.8[b]	92.7[b]	1.01	0.004
His	87.8	92.3	93.4	90.1	89.5	1.53	0.09
Ile	87.1[b]	91.4[a]	92.5[a]	89.5[ab]	90.0[ab]	1.25	0.049
Leu	86.8[b]	91.5[a]	92.6[a]	90.8[a]	91.3[a]	1.14	0.029
Lys	85.3	90.3	92.7	89.9	91.1	1.74	0.078
Met	89.4	92.1	91.0	88.8	90.3	1.38	0.254
Phe	86.4[c]	92.6[a]	93.4[a]	90.7[ab]	88.7[bc]	1.12	0.001
Thr	84.7	88.9	90.9	88.3	91.9	1.82	0.097
Trp	87.3[c]	93.6[ab]	94.5[a]	89.8[bc]	92.9[ab]	1.42	0.011
Val	86.1	90.5	91.5	88.5	89.6	1.49	0.118
Tyr	87.7[c]	93.4[ab]	94.3[a]	90.7[bc]	89.6[c]	1.28	0.006

[a-c] Means in columns followed by different superscript letters are statistically different (P < 0.05)

Growth performance and blood parameters of weaned pigs fed SPC

A second study was performed by Casas et al. (2016) to determine effects on growth performance and the inflammatory immune response in blood of weaned pigs fed diets including SPC ground to 180 µm (SPC-180) as a replacement for spray-dried protein plasma or fish meal or both. In phase 1, dietary treatments consisted of a control diet containing 5% fish meal, 5% spray-dried protein plasma, and no SPC (Table 2). The SPC-180 was included in diets 2, 3, and 4 to replace an equivalent amount of SID Lys as provided by the spray-dried protein plasma, the fish meal, or both used in the control diet. Pigs were assigned one of 4 dietary treatments during phase 1 (0 to 14 d). A common diet was fed during phase 2 (14 to 28 d). All diets were formulated to meet nutrient requirements for weanling pigs (NRC, 2012).

Table 2. Ingredient and analyzed composition (as-fed basis) of experimental diets containing soy protein concentrate (SPC) (Casas et al., 2016).

Item	Phase 1 diet				Phase 2 diet
	No SPC	No plasma	No fish meal	SPC-180[±]	
Ingredient, %					
Corn	46.55	46.35	48.22	48.65	52.13
Whey powder	15.00	15.00	15.00	15.00	10.00
Soybean meal	23.24	20.00	20.00	16.00	29.00
SPC-180	–	8.00	5.25	13.25	–
Fish meal	5.00	5.00	–	–	3.00
Spray-dried protein plasma	5.00	–	5.00	–	–
Choice white grease	3.00	3.22	3.38	3.65	3.00
Limestone	1.20	1.00	1.25	1.05	0.90
Dicalcium phosphate	0.15	0.36	0.86	1.10	0.70
Others	0.86	1.07	1.04	1.30	1.27
Analyzed composition					
GE, kcal/kg	4023	4069	4042	4062	3995
DM, %	88.93	89.08	88.81	89.75	87.83
Ash, %	6.35	6.23	5.60	5.92	5.63
CP, %	22.90	23.02	22.43	22.26	21.10
ADF, %	2.92	4.01	3.72	5.23	3.51
NDF, %	7.40	6.42	7.27	7.59	7.36

[±]SPC-180 = soy protein concentrate ground to 180 µm.

Growth performance results indicated that SPC ground to 180 µm can replace the inclusion of both fish meal and spray-dried protein plasma in diets fed to piglets without affecting growth performance during the initial 4 wk post-weaning (Table 3). Then, the higher dietary addition of soy protein is possible using SPC reducing the inclusion of animal proteins usually more expensive.

Table 3. Growth performance of weanling pigs fed soy protein concentrate (SPC), spray-dried plasma protein, and fish meal (Casas et al. 2016)[£]

	No SPC	No plasma	No fish meal	SPC-180[±]	SEM	*P-value*
Phase 1, d 0 to 14 d						
Initial BW, kg	7.05	7.06	7.09	7.06	0.401	0.999
Final BW, kg	9.11	9.11	9.00	9.03	0.403	0.996
ADG, kg/d	0.146	0.149	0.135	0.140	0.009	0.744
ADFI, kg/d	0.213	0.204	0.193	0.208	0.008	0.424
G:F	0.689	0.726	0.699	0.673	0.033	0.722
Phase 2, d 14 to 28 d						
Initial BW, kg	9.11	9.11	9.00	9.03	0.403	0.996
Final BW, kg	16.16	16.83	16.11	16.39	0.620	0.842
ADG, kg/d	0.504	0.546	0.507	0.525	0.022	0.524
ADFI, kg/d	0.661	0.728	0.686	0.702	0.024	0.303
G:F	0.761	0.736	0.738	0.746	0.012	0.553
Overall, d 14 to 28 d						
ADG, kg/d	0.325	0.347	0.321	0.332	0.014	0.593
ADFI, kg/d	0.437	0.469	0.443	0.455	0.015	0.453
G:F	0.743	0.741	0.725	0.728	0.016	0.829

[£]Each least-squares mean represents 8 observations.

SPC-180 = 13.25% SPC ground to 180 µm without spray-dried protein plasma or fish meal.
No SPC = 5% fish meal, 5% spray-dried protein plasma, and no SPC
No plasma = 5% fish meal, 8% SPC-180, and no spray-dried protein plasma.
No fish meal = 5% spray-dried protein plasma, 5.25% SPC-180, and no fish meal

Unlike dietary SPC, high inclusion of soybean meal might result in a disruption of intestinal integrity in weaned pigs as a result of the presence of anti-nutritional factors in soybean meal (Li et al., 1990). Soybean meal contains raffinose family oligosaccharides (RFO) such as raffinose (trisaccharide) and stachyose (tetrasaccharide) in high levels, and trace amounts of verbascose (pentasaccharide) (Zhang et al., 2019). Verbascose has three molecules of α-d-galactose attached to sucrose; whereas stachyose has two, and raffinose one (Figure 1). In contrast to galacto-oligosaccharides, which are considered prebiotic, RFO may cause diarrhea and reduced growth performance of pigs (Liying et al., 2003, Van Kempen et al., 2006, Zeng et al., 2021).

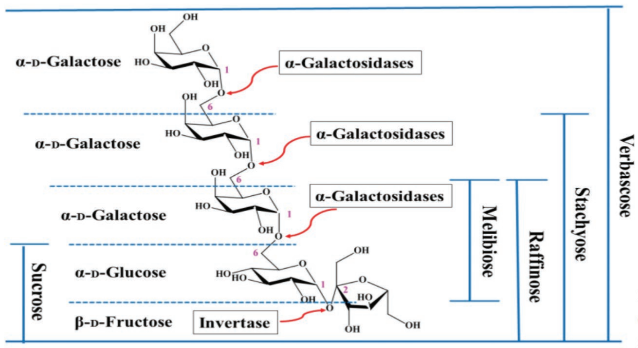
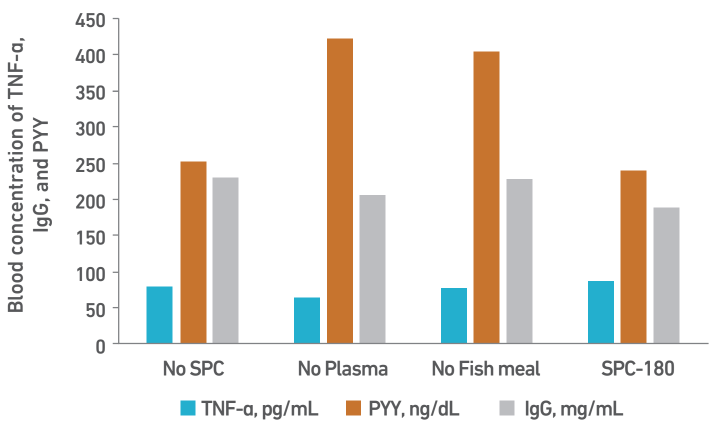


Figure 1. Raffinose family oligosaccharides (RFO) structure and their enzymatic degradation mechanism (adapted from Zhang et al., 2019). Monogastric animals do not express pancreatic α-galactosidase, which catalyzes the hydrolysis of RFO to sucrose and galactose. The hydrolysis of raffinose with invertase forms fructose and melibiose.

Pigs do not secrete α-galactosidase, which catalyzes the hydrolysis of RFO to sucrose and galactose. Therefore, the RFO presented in the soybean meal, are not enzymatically digested in the small intestine of pigs and can stimulate antigenic proinflammatory responses in the intestinal mucosa. TNF-α is a pro-inflammatory cytokine that triggers immune responses (Trowbridge and Emling, 1997). A recent study indicated that soybean raffinose increases serum concentrations of TNF-α and IgG and decreases growth performance in pigs (Zeng et al., 2021). Serum concentrations of TNF-α and IgG were not affected in weaned pigs when the dietary SPC replaced both spray-dried plasma protein or fish meal (Figure 2). This finding indicates that there is no inflammatory immune response in pigs fed diets containing SPC as a result of its reduced concentration of antigenic factors.

Peptide YY (PPY) regulates the appetite and feed intake (Nguyen et al., 2011). PYY is released from intestinal endocrine cells into the circulation in response to the direct contact of nutrients with L-cell, reducing the feed ingestion (Ballantyne, 2006). The PYY concentrations were not different among diets indicating that feed intake was not negatively affected by SPC in the diets. This affirmation can be corroborated with ADFI results, which were not different between the dietary treatments.



SPC-180 = 13.25% SPC ground to 180 μm without spray-dried protein plasma or fish meal.
No SPC = 5% fish meal, 5% spray-dried protein plasma, and no SPC
No plasma = 5% fish meal, 8% SPC-180, and no spray-dried protein plasma.
No fish meal = 5% spray-dried protein plasma, 5.25% SPC-180, and no fish meal

Figure 2. Blood concentration of tumor necrosis factor - α (TNF - α), IgG, and peptide YY (PYY) of weanling pigs fed soy protein concentrate (SPC), spray-dried plasma protein, and fish meal (Casas et al., 2016).

Final considerations

SPC is a selected refined soybean protein source with a high protein and amino acid digestibility for weaned pigs. SPC ground to 180 μ m can replace the inclusion of both fish meal and spray-dried protein plasma in diets fed to piglets without affecting growth performance during the initial 4 wk post-weaning. With a high nutrient digestibility and fewer anti-nutritional factors, SPC may improve intestinal mucosa development and nutrient utilization resulting in better intestinal health of weaned pigs.

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