Energy and nutrient concentration and digestibility in alternative feed ingredients and recommended inclusion rates

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Introduction

The traditional corn-soybean meal diet has served the US swine industry well for more than 50 years and corn and soybean meal complement each other better than most other ingredients in terms of meeting the nutritional need of growing and reproducing swine. With the recent increases in the costs of corn and soybean meal, it is, however, necessary to look for alternatives to these traditional ingredients – not to identify something that is better than corn and soybean meal, but primarily to identify ingredients that can be mixed to form a less expensive diet than the corn-soybean meal diet. Pigs are forgiving animals and they can perform well on many different combinations of ingredients so the challenge for nutritionists is to identify the combination of ingredients that most economically meet the needs of the animals. Other than corn and soybean meal, there are a number of ingredients that if utilized correctly, can be included in diets fed to pigs without changes in pig performance.

Corn co-products

The corn-industry in the United States results in production of a number of co-products that may be included in diets fed to swine. Usage of corn for production of ethanol, corn syrup, corn flour, or other products for industrial or human use, often results in production of co-products or by-products that cannot be used for the primary purpose and these products are, therefore, available for use by the animal feed industry. Fermentation of corn for production of ethanol or beverages results in production of distillers dried grains (DDG) that may or may not be blended with the solubles before drying. Distillers dried grains with solubles (DDGS) is the product produced if the solubles are added to the DDG before drying. Traditional DDGS contains between 9 and 12% crude fat, but if fat is skimmed off the solubles before they are added back to the DDG, a de-oiled DDGS is produced. Sometimes, the corn is de-hulled and degermed before fermentation. The distillers grains produced from this process is a high protein distillers dried grain (HP-DDG). The corn germ that is separated from the kernel may also be used in the feeding of swine.

If corn is used by the dry milling industry to produce corn grits, corn meal, or corn flour, a co-product called hominy feed is produced and this product may also be included in diets fed to swine.

The wet milling industry also results in production of co-products that are available for animal feeding. In this process, corn is cleaned and steeped and it may then undergo germ extraction resulting in production of corn oil for human consumption and corn germ meal for animal feed. The cleaned and steeped corn may also undergo milling and washing to obtain bran and a bran free product. The bran is further processed into corn gluten feed that is used for animal feeding. The bran free product undergoes centrifugation to separate gluten and starch. The gluten portion is further processed into corn gluten meal and sold for animal feed and the starch is washed and purified into corn starch for human consumption.

Thus, at least 8 different corn co-products are available for animal feeding. These products have different characteristics and contain different quantities of nutrients and energy when fed to pigs (Table 1). The major limitation for the use of these ingredients in diets fed to pigs is the concentration of fiber that is left in the products and inclusion rates are often determined by the amount of fiber in the ingredients. A relatively large number of experiments have been conducted with DDG, DDGS, and HP DDG and effects of different levels of inclusion have been documented (Cook et al., 2005; Whitney et al., 2004, 2006). Results of these experiments have documented that inclusion rates of 20 to 30% of DDG, DDGS, and HP DDG usually does not result in any changes in pig performance and under certain circumstances, inclusion of more than 30% can be recommended (Cromwell et al. 2010; Widmer et al., 2008; Kim et al., 2009).

For corn germ, only limited information is available, but at least 15% can be included in diets fed to growing-finishing pigs (Widmer et al., 2008; Lee et al., 2011). For other corn co-products such as hominy feed, corn gluten meal, corn gluten feed, and corn germ meal, titration studies have not been published. However, based on the concentrations of fiber and crude protein in these ingredients, it may be

Table 1: Chemical composition of corn and corn co-products fed to swine (as-fed basis).[1,2]

Item	Corn	Corn co-product								
		Corn DDGS	Corn DDG	Corn HP DDG	De-oiled corn DDGS	Corn germ	CGM	CGF	Corn germ meal	Hominy feed
Gross energy, kcal/kg	3,891	4,776	-	4,989	-	4,919	5,229	4,334	4,259	4,072
Crude protein, %	8.0	27.5	28.8	41.1	31.2	14.0	62.9	23.0	24.8	8.7
Calcium, %	0.01	0.03	-	0.01	0.05	0.03	0.05	0.22	0.02	0.05
Phosphorus, %	0.22	0.61	-	0.37	0.76	1.09	0.44	0.83	0.59	0.43
Crude fat, %	3.3	10.2	-	3.7	4.0	17.6	1.2	1.4	0.9	4.9
Crude fiber, %	-	6.6	-	-	-	-	-	-	-	-
Starch, %	-	7.3	3.83	11.2	-	23.6	8.3	21.5	16.0	53.6
Neutral detergent fiber, %	7.3	37.6	37.3	16.4	34.6	20.4	12.9	50.5	54.1	21.6
Acid detergent fiber, %	2.4	11.1	18.2	8.7	16.1	5.6	7.0	10.2	10.9	3.4
Total dietary fiber, %	-	31.8	43.0	-	-	-	8.7	38.2	42.0	13.4
Ash	0.9	3.8	-	3.2	4.64	3.3	2.47	4.27	2.30	2.11
Indispensable amino acids, %										
Arginine	0.39	1.16	1.15	1.54	1.31	1.08	2.26	0.95	1.55	0.47
Histidine	0.23	0.72	0.68	1.14	0.82	0.41	1.31	0.61	0.64	0.24
Isoleucine	0.28	1.01	1.08	1.75	1.21	0.45	2.60	0.79	0.84	0.30
Leucine	0.95	3.17	3.69	5.89	3.64	1.06	10.09	1.86	1.86	0.91
Lysine	0.24	0.78	0.81	1.23	0.87	0.79	1.18	1.02	0.94	0.33
Methionine	0.21	0.55	0.56	0.83	0.58	0.25	1.61	0.32	0.40	0.15
Phenylalanine	0.38	1.34	1.52	2.29	1.69	0.57	4.03	0.87	1.04	0.41
Threonine	0.26	1.06	1.10	1.52	1.10	0.51	2.03	1.21	0.83	0.30
Tryptophan	0.09	0.21	0.22	0.21	0.19	0.12	0.44	0.16	0.18	0.06
Valine	0.38	1.35	1.39	2.11	1.54	0.71	2.89	1.12	1.30	0.42
Dispensable amino acids, %										
Alanine	0.58	1.94	2.16	3.17	2.13	0.91	5.30	1.48	1.38	0.60
Aspartic acid	0.55	1.83	1.86	2.54	1.84	1.05	3.85	1.44	1.68	0.60
Cysteine	0.16	0.53	0.54	0.78	0.54	0.29	1.14	0.43	0.33	0.17
Glutamic acid	1.48	4.37	5.06	7.11	4.26	1.83	12.04	2.70	2.84	1.35
Glycine	0.31	1.02	1.00	1.38	1.18	0.76	1.84	1.03	1.23	0.37
Proline	0.70	2.09	2.50	3.68	2.11	0.92	5.68	1.61	1.09	0.61
Serine	0.38	1.18	1.45	1.85	1.30	0.56	2.54	0.73	0.80	0.35
Tyrosine	0.27	1.01	-	1.91	1.13	0.41	3.27	0.64	0.67	0.27

1 Data from NRC (1998); Sauvant et al., (2004); Bohlke et al. (2005), Stein et al. (2006c, 2009), Jacela et al. (2007, 2009), Pedersen et al. (2007a, b), Widmer et al. (2007), Pahm et al. (2008a), Kim et al. 2009, Urriola et al. (2009, 2010), and un-published data from the University of Illinois.

2 DDGS = distillers dried grains with soluble; DDG = distillers dried grains; HP DDG = high protein distillers dried grain; CGM = corn gluten meal; CGF = corn gluten feed.

speculated that 20 to 40% hominy feed can be included in diets fed to growing-finishing pigs, whereas the inclusion of corn gluten meal, corn gluten feed, and corn germ meal should be restricted to less than 20%.

Because of the greater concentration of fiber in corn co-products than in corn, the digestibility of energy is less in these products than in corn (Pedersen et al., 2007; Stein et al., 2009). However, the concentration of total energy is greater in DDG, DDGS, HP DDG, and corn germ than in corn and despite the reduced digestibility in these ingredients, the concentration of digestible energy is equal to or greater than in corn (Table 2). For corn gluten meal, corn gluten feed, hominy feed, and corn germ meal, only limited information about the energy digestibility is available, but all of these ingredients are expected to contain less digestible energy than corn.

The digestibility of phosphorus is greater in DDG, DDGS, and HP DDG than in corn because fermentation reduces the amount of P that is bound to the phytate complex (Table 2; Widmer et al., 2007; Almeida and Stein, 2010). However, for the other corn co-products, the digestibility of P is similar to that in corn.

The digestibility of most AA in corn co-products is less than in corn (Stein et al., 2006c), although that is not the case for

Table 2: Concentration of digestible energy (DE) and metabolizable energy (ME), apparent total tract digestibility (ATTD) of phosphorus and standardized ileal digestibility (SID) of amino acids in corn co-products (as-fed basis).[1,2]

Item	Corn co-product									
	Corn	Corn DDGS	Corn DDG	Corn HP DDG	De-oiled corn DDGS	Corn germ	CGM	CGF	Corn germ meal	Hominy feed
DE, kcal/kg	4,072	4,140	-	4,903	2,719	3,979	4,225	2,990	2,987	3,355
ME, kcal/kg	3,981	3,897	-	4,583	2,506	3,866	3,830	2,605	2,796	3,210
Phosphorus, ATTD, %	25	59	-	60	-	29	19	22	20	21
SID, Indispensable amino acids, %										
Arginine	87	81	83	83	82	83	94	90	90	96
Histidine	83	78	84	81	75	69	83	76	78	80
Isoleucine	81	75	83	81	75	57	86	77	77	71
Leucine	87	84	86	91	84	68	91	82	80	84
Lysine	72	62	78	64	50	58	79	69	68	59
Methionine	85	82	89	88	80	68	91	79	81	77
Phenylalanine	84	81	87	87	81	64	89	81	82	79
Threonine	74	71	78	77	66	53	84	75	71	66
Tryptophan	70	70	72	81	78	67	92	88	81	82
Valine	79	75	81	80	74	62	85	75	76	72
SID, Dispensable amino acids, %										
Alanine	83	78	82	86	77	64	88	78	76	79
Aspartic acid	80	69	74	76	61	60	83	66	66	69
Cysteine	82	73	81	82	64	64	81	65	64	76
Glutamic acid	80	80	87	88	78	72	88	77	78	83
Glycine	84	63	66	75	53	76	67	76	69	97
Proline	96	74	55	73	73	84	97	97	99	98
Serine	83	76	82	84	73	65	90	77	75	82
Tyrosine	82	81	-	88	81	59	90	81	79	78

[1] Data from Bohlke et al. (2005), Stein et al. (2006c, 2009), Jacela et al. (2007, 2009), Pedersen et al. (2007a,b), Widmer et al. (2007), Pahm et al. (2008a), Kim et al. 2009, Urriola et al. (2009), and un-published data from the University of Illinois.

[2] DDGS = distillers dried grains with soluble; DDG = distillers dried grains; HP DDG = high protein distillers dried grain; CGM = corn gluten meal; CGF = corn gluten feed.

corn gluten meal. In some products, the digestibility of Lys is relatively low because of heat damage during drying (Pahm et al., 2008).

Other cereals and cereal co-products

Although corn by far is the most widely used cereal grain in swine feeding in the United States, other cereal grains such as barley, wheat, and sorghum may also be used. While it is believed that wheat and sorghum can completely replace corn in the diets, inclusion of barley probably should be restricted to less than 60% of the diet fed to growing-finishing pigs, whereas barley may replace all the corn in diets fed to weanling pigs and sows. There is more fiber and less starch in barley than in corn and wheat, which is the reason for the lower inclusion rate in diets fed to growing-finishing pigs. Triticale and rye may also be used in diets fed to pigs by 20 to 40% and oats can be used by up to 30% in most diets fed to pigs. The production of triticale, rye, and oats is, however, very low in the United States, and these cereals are, therefore, usually not available for swine feeding in appreciable amounts.

Sorghum and wheat may be used for ethanol production, which will result in production of DDGS produced from these cereals. Sorghum DDGS and wheat DDGS may be included in diets fed to pigs at the same levels as inclusion of corn DDGS.

Wheat middlings is a co-product from the wheat flour industry that is often included in diets fed to pigs. It is high in soluble fiber and may be included in diets fed to pigs by at least 30% and some experiments have suggested that the nutritional value of wheat middlings is comparable to that of barley, but less than that of corn because of the lower starch concentration and the greater concentration of NDF. The nutritional value of wheat middlings may, however vary among different batches, and the concentration of NDF, CP, Lys, and P varies between 29.9 and 40.1%, 14.6 and 17.8%, 0.62 and 0.72%, and 0.70 and 1.19%, respectively (Cromwell et al., 2000). The digestibility of P is relatively high in wheat middlings, but the digestibility of AA and energy is low (NRC, 1998; Huang et al., 1999).

The concentration of nutrients and energy in other cereals and their co-products are presented in Table 3, while energy and nutrient digestibility is presented in Table 4.

Field peas

Field peas have been included in diets fed to swine in the Pacific Northwest for several decades, but in the Midwest, where the majority of the pigs are produced, very few field peas have been used. However, with recent increases in the production of field peas in the Upper Mid west, more field peas are now available for swine feeding in the Midwest. Field peas have a nutrient profile that is intermediate between corn and soybean meal (Stein et al., 2004; Stein and Bohlke, 2007). The digestibility of most amino acids in field peas is similar to that in soybean meal (Table 5), but pea protein has a relatively low concentration of methionine, cysteine, and tryptophan. Therefore, these amino acids may become limiting if peas are included in the formulations. The concentration of digestible energy (3,864 kcal DE per kg DM) in field peas is similar to that in corn, but peas contain slightly less metabolizable energy (3,741 kcal ME/kg DM) compared with corn (Stein et al., 2004). The concentration of phosphorus in field peas is approximately 0.44% and the apparent total tract digestibility of phosphorus in field peas is 55 and 65%, respectively, in diets without or with microbial phytase (Stein et al., 2006a).

Lysine and tryptophan are the first limiting amino acids in diets based on corn and field peas, but because of the relatively low concentrations of digestible methionine, cysteine, and threonine in field peas, it is also necessary to pay careful attention to the concentrations of these amino acids. It is often necessary to include crystalline sources of methionine, threonine, and tryptophan in diets based on field peas to formulate a diet balanced in all indispensable amino acids. In contrast, the inclusion of crystalline lysine and inorganic sources of phosphorus may be reduced because of the relatively high concentrations of these nutrients in field peas.

The concentration of most nutrients in field peas is intermediate between the concentration in corn and soybean meal. Therefore, if field peas are included in the formula, corn and soybean meal is reduced. As a rule of thumb, 3% field peas will replace approximately 2% corn and 1% soybean meal if crystalline sources of methionine, threonine, and tryptophan are included to balance concentrations of indispensable amino acids. At the same time, the inclusion of crystalline lysine and monocalcium phosphate (or dicalcium phosphate) is reduced. In experiments where field peas were successfully included in diets fed to swine, these principles for diet formulation were followed.

Pigs tolerate field peas well and the feed intake is not affected by the presence of field peas in the diets. Recent research with field peas indicates that field peas may be included in diets fed to nursery pigs from two weeks postweaning at an inclusion level of at least 36% and it is possible that up to 48% can be included in diets fed to weanling pigs (Stein et al., 2010). At this concentration, no negative effects on pig performance have been reported.

For growing and finishing pigs, field peas may be included in concentration of up to 60 to 70% of the diets without influencing pig performance (Petersen and

Table 3: Chemical composition of other cereals and cereal corn co-products (as-fed basis).[1,2]

Item	Barley	Sorghum	Wheat	Triticale	Rye	Oats	Sorghum DDGS	Wheat DDGS	Wheat middlings	Bakery meal
	Cereal or cereal co-product									
Gross energy, kcal/kg	3,855	3,848	3,830	3,752	3,752	4,110	4,334	4,817	3,990	-
Crude protein, %	12.9	9.8	12.44	12.5	11.8	11.5	31.0	38.2	15.9	11.3
Calcium, %	0.11	0.01	0.04	0.05	0.06	0.07	-	0.15	0.12	0.13
Phosphorus, %	0.39	0.24	0.38	0.33	0.33	0.31	0.64	1.04	0.93	0.25
Crude fat, %	1.8	-	2.0	1.8	1.6	4.7	7.7	3.6	4.2	11.3
Crude fiber, %	-	-	2.4	-	-	-	9.8	7.6	-	-
Starch, %	-	-	-	-	-	-	-	-	-	-
Neutral detergent fiber, %	16.1	7.3	14.2	12.7	12.3	27.0	40.7	32.4	35.6	2.0
Acid detergent fiber, %	6.0	3.8	2.9	3.8	4.6	13.5	22.8	17.0	10.7	1.3
Total dietary fiber, %	-	-	-	-	-	-	32.2	-	-	-
Ash	-	-	-	-	-	-	3.6	4.8	-	-
Indispensable amino acids, %										
Arginine	0.66	0.32	0.57	0.57	0.50	0.87	1.10	1.53	0.97	0.46
Histidine	0.29	0.23	0.29	0.26	0.24	0.31	0.71	0.92	0.44	0.27
Isoleucine	0.44	0.37	0.43	0.39	0.37	0.48	1.36	1.35	0.53	0.39
Leucine	0.87	1.25	0.83	0.76	0.64	0.92	4.17	2.66	1.06	1.10
Lysine	0.49	0.20	0.36	0.39	0.38	0.40	0.68	0.65	0.57	0.27
Methionine	0.21	0.18	0.21	0.20	0.17	0.22	0.53	0.53	0.26	0.18
Phenylalanine	0.64	0.47	0.53	0.49	0.50	0.65	1.68	1.92	0.70	0.52
Threonine	0.42	0.29	0.33	0.36	0.32	0.44	1.07	1.21	0.51	0.36
Tryptophan	0.11	0.07	0.16	0.14	0.12	0.14	0.35	0.40	0.20	0.10
Valine	0.63	0.48	0.55	0.51	0.51	0.66	1.65	1.70	0.75	0.52
Dispensable amino acids, %										
Alanine	0.53	0.86	0.44	-	-	-	2.90	1.48	-	0.65
Aspartic acid	0.78	0.60	0.62	-	-	-	2.17	1.92	-	0.65
Cysteine	0.24	0.18	0.27	0.26	0.19	0.36	0.49	0.73	0.32	0.22
Glutamic acid	2.86	1.92	3.57	-	-	-	6.31	9.81	-	2.01
Glycine	0.53	0.29	0.50	-	-	-	1.03	1.62	-	0.43
Proline	1.24	0.77	1.14	-	-	-	1.40	4.11	-	0.88
Serine	0.46	0.37	0.48	-	-	-	2.50	1.88	-	0.43
Tyrosine	0.31	0.25	0.27	0.32	0.26	0.41	-	-	0.29	0.36

1 Data from NRC (1998); Sauvant et al. (2004), Feoli et al. (2007), Pedersen et al. (2007 b), Widyaratne and Zijlstra (2007), Lan et al. (2008), Urriola et al. (2009), Widyaratne et al. (2009), and unpublished data from the university of Illinois.

2 DDGS = distillers dried grains with solubles.

Table 4: Concentration of digestible energy (DE), metabolizable energy (ME), apparent total tract digestibility (ATTD) of phosphorus, and standardized ileal digestibility (SID) of amino acids in other cereals and cereal corn co-products (as-fed basis).[1,2]

Item	Cereal or cereal co-product									
	Barley	Sorghum	Wheat	Triticale	Rye	Oats	Sorghum DDGS	Wheat DDGS	Wheat middlings	Bakery meal
DE, kcal/kg	3,050	3,380	3,400	3,320	3,270	2,770	-	-	3,075	-
ME, kcal, kg	2,910	3,340	3,250	3,180	3,060	2,710	-	-	3,025	-
Phosphorus, ATTD, %	32	25	30	30	30	32	-	52	25	-
SID, Indispensable amino acids, %										
Arginine	81	70	88	88	79	89	78	86	95	92
Histidine	77	65	86	84	78	85	71	77	94	73
Isoleucine	76	66	84	84	77	80	73	80	92	71
Leucine	77	70	86	86	79	83	76	83	93	78
Lysine	72	57	75	81	73	76	62	57	89	48
Methionine	78	69	86	89	81	84	75	81	93	76
Phenylalanine	78	68	86	85	82	86	76	86	95	78
Threonine	70	64	79	76	73	71	68	75	88	62
Tryptophan	79	57	86	88	75	78	70	86	91	83
Valine	74	64	81	84	75	79	72	82	90	70
SID, Dispensable amino acids, %										
Alanine	70	69	76	-	-	-	73	68	-	73
Aspartic acid	71	66	78	-	-	-	68	57	-	62
Cysteine	74	64	86	87	83	75	66	75	91	69
Glutamic acid	71	52	84	-	-	-	76	86	-	82
Glycine	84	71	92	-	-	-	67	68	-	89
Proline	99	50	105	-	-	-	83	81	-	99
Serine	75	72	88	-	-	-	73	77	-	76
Tyrosine	74	67	81	83	76	82	-	-	92	77

1 Data from NRC (1998), Sauvant et al. (2004); Pedersen et al. (2007b), Widyaratne and Zijlstra (2007), Lan et al. (2008), Urriola et al. (2009), and unpublished data from the University of Illinois.

2 DDGS = distillers dried grains with solubles.

Spencer, 2006; Stein et al., 2006b) (Table 6). At these inclusion levels, all the soybean meal in the diet is replaced by field peas. Field peas do not influence feed intake, average daily gain, or the gain to feed ratio. Lower carcass drip losses and a more desirable color of the longissimus muscle have been reported for pigs fed diets containing field peas, but other carcass characteristics have not been influenced by field peas in the diets. Likewise, the palatability of pork chops and ground pork patties are not changed by the inclusion of field peas in the diets (Stein et al., 2006b).

Processed soybean meal

While soybean meal may be used as the only protein supplement in diets fed to growing-finishing and reproducing swine, animal protein sources are usually used in diets fed to weanling pigs because soybean meal may elicit antigenic effects (Li et al., 1990; 1991; Sohn et al., 1994). It is, therefore, common practice to limit the inclusion of soybean protein in diets fed to weanling pigs and more expensive animal protein sources such as milk protein, fish meal, and blood proteins are used as the primary sources

Table 5: Amino acid composition of the protein and amino acid and protein digestibility in field peas and soybean meal (as fed basis).[a]

Ingredient	Field peas			Soybean meal		
Item	% of ingredient	% of crude protein	SID[b]	% of ingredient	% of crude protein	SID[b]
Nutrient						
Crude protein	22.8	100	79.9	47.5	100	84.5
Arginine	1.87	8.20	92.8	3.48	7.32	93.0
Histidine	0.54	2.37	88.3	1.28	2.70	89.7
Isoleucine	0.86	3.77	83.4	2.16	4.55	86.3
Leucine	1.51	6.62	85.7	3.66	7.71	86.1
Lysine	1.50	6.58	88.1	3.02	6.36	88.4
Methionine	0.21	0.92	77.9	0.67	1.41	89.1
Cysteine	0.31	1.36	67.3	0.74	1.56	83.9
Phenylalanine	0.98	4.30	86.9	2.39	5.05	86.9
Tyrosine	0.71	3.11	84.7	1.82	3.83	87.2
Threonine	0.78	3.42	80.2	1.85	3.90	85.9
Tryptophan	0.19	0.83	54.3	0.65	1.37	78.5
Valine	0.98	4.30	78.2	2.27	4.78	82.7

[a]Data for amino acid concentration and composition are from NRC (1998). Data for SID of protein and amino acids are from Stein et al., 2004.

[b]SID = standardized ileal digestibility (%).

Table 6: Growth performance and carcass quality of growing-finishing pigs fed diets without or with field peas.[a]

Field peas (%)[b]	0/0/0	36/36/36	66/48/36	SEM	*P*-value
Response					
Initial weight, kg	22.9	22.7	22.7	0.55	0.49
Average daily feed intake, kg	2.74	2.60	2.82	0.079	0.12
Average daily gain, kg	0.872	0.860	0.889	0.0247	0.59
Average gain:feed ratio, kg/kg	0.319	0.332	0.318	0.0087	0.38
Final weight, kg	129.0	124.1	129.2	3.18	0.59
Dressing, %	76.2	75.4	75.8	0.34	0.20
10th rib back fat, cm	2.32	2.40	2.41	0.134	0.81
Lean meat, %	51.8	51.0	51.3	0.636	0.67
Drip loss, %	3.38	2.51	1.95	0.322	0.02

[a] Data from Stein et al. (2006b). Each mean represents eight observations with two pigs per pen.

[b] Values represent the inclusion rate (%) of field peas in diets fed from 22 to 50 kg, 50 to 85 kg, and 85 to 125 kg, respectively.

of amino acids in these diets. New research has, however, demonstrated that processing of soybean meal may result in removal of the antigens, and processed soybean meal may, therefore, be included in diets fed to weanling pigs as the primary protein source. Two new processed soybean products, HP 300 and PepSoyGen, respectively, that are expected to be devoid of soy allergens were recently introduced to the North American marked. It is

Table 7: Analyzed nutrient composition of soybean meal, HP 300, and PepSoyGen (%, as-is basis).[1]

Item	Soybean meal	HP 300	PepSoyGen
DM	89.32	91.48	91.33
CP	45.07	54.40	53.74
Ether extract	1.07	1.13	0.80
Crude fiber	2.78	3.75	3.31
Ca	0.26	0.35	0.29
P	0.67	0.74	0.82
Glucose	0	0.49	0.36
Sucrose	7.81	0	0
Fructose	0.63	1.11	0.70
Stachyose	5.17	0.71	0
Raffinose	1.08	0.16	0
Indispensable AA			
Arg	3.06	3.75	3.50
His	1.13	1.35	1.30
Ile	1.89	2.31	2.48
Leu	3.37	3.98	4.09
Lys	2.77	3.06	3.11
Met	0.63	0.71	0.76
Phe	2.23	2.74	2.71
Thr	1.71	2.02	1.98
Trp	0.62	0.69	0.67
Val	1.96	2.40	2.69
Dispensable AA, %			
Ala	1.86	2.25	2.29
Asp	4.80	5.71	5.67
Cys	0.67	0.76	0.77
Glu	7.48	8.75	8.56
Gly	1.77	2.26	2.23
Pro	2.08	2.46	2.45
Ser	1.97	2.35	2.24
Tyr	1.67	2.03	1.97

[1] Data from Cervantes-Pahm and Stein, 2010.

believed that these products can be included in diets fed to weanling pigs without causing adverse allergenic reactions. HP 300 is produced by incubating soybean meal in the presence of a proprietary enzyme blend, which results in the removal of soy antigens (Cervantes-Pahm and Stein, 2010; Goebel and Stein, 2011). The oligosaccharides and sugars in the soybean meal are also removed and the resultant soybean meal contains approximately 53% crude protein (Table 7; Zhu et al., 1998; Cervantes-Pahm and Stein, 2010). The digestibility of amino acids in HP 300 is greater than in conventional soybean meal (Table 7; Cervantes-Pahm and Stein, 2010) and it is, therefore, believed that HP 300 may be tolerated in diets fed to weanling pigs.

PepSoyGen (NutraFerm, North Sioux City, SD) is produced by fermentation of soybean meal in the presence of *Apergillus oryzae* and *Bacillus subtillis*. Antigens,

Table 8: Standardized ileal digestibility (%) by weanling pigs of crude protein and amino acids in soybean meal, HP 300, and PepSoyGen.[1,2]

Item	Soybean meal	HP 300	PepSoyGen
CP	80.3	92.2	82.2
Indispensable AA			
Arg	90.9	98.2	93.5
His	84.0	88.9	84.4
Ile	82.9	89.8	85.8
Leu	82.0	89.3	85.4
Lys	79.2	88.3	77.2
Met	85.5	92.2	88.3
Phe	84.1	91.9	87.2
Thr	77.4	85.8	78.5
Trp	84.8	87.5	83.5
Val	81.9	89.5	84.3
Dispensable AA			
Ala	77.0	88.7	81.0
Asp	79.5	88.3	81.7
Cys	73.4	85.2	69.7
Glu	81.1	93.7	84.2
Gly	65.0	94.9	74.6
Pro	120.7	149.4	132.5
Ser	82.5	89.4	82.2
Tyr	86.1	92.1	87.7

[1] Data from Cervantes-Pahm and Stein, 2010.
[2] Data are means of seven observations per treatment.

antinutritional factors, oligosaccharides, and sugars are removed from the soybean meal during fermentation (Table 7; Hong et al., 2004; Yang et al., 2007; Cervantes-Pahm and Stein, 2010). PepSoyGen contains approximately 10% more protein than conventional soybean meal, but the amino acid sequence is similar to the sequence in conventional soybean meal (Table 7) and the standardized ileal digestibility of amino acids in PepSoyGen is also similar to the digestibility in conventional soybean meal for most amino acids (Table 8; Cervantes-Pahm and Stein, 2010). Inclusion of PepSoyGen in diets fed to weanling pigs at the expense of conventional soybean meal improves pig performance (Feng et al., 2007). It is, therefore, possible that PepSoyGen can be used in weanling pig diets as a substitute for more expensive animal protein sources.

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