SWINE FOCUS #004

Nutritional value of soy products fed to pigs

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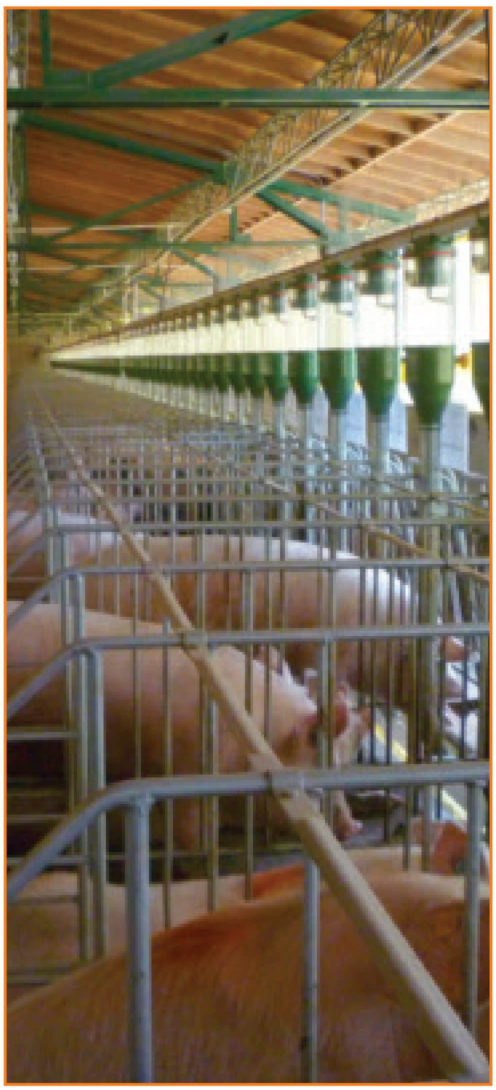


Summary

Soybeans is an important crop in the United States and are primarily used for animal feed, human food, and production of biofuels. Soybean meal **(SBM)** and other soy products contribute high-quality protein to diets fed to pigs because soy protein is rich in the limiting amino acids lysine, threonine, and tryptophan that are present in relatively low concentrations in the most commonly fed cereal grains. Amino acids in soy protein also have a greater digestibility by pigs than amino acids in most other commonly fed protein sources. Soy products are also a significant source of energy in diets fed to pigs and soybean meal contains as much digestible and metabolizable energy as corn. Although soy is usually fed to pigs in the form of soybean meal, full fat soybeans may be included in the diets to increase the energy density of the diet. Due to the high fiber content of soy hulls, the energy concentration in de-hulled soybean products is greater than in products containing hulls. The majority of the phosphorus in soy products is bound to phytic acid, which has a low digestibility to pigs, but the digestibility of phosphorus in soy products may be increased to more than 60% if diets are supplemented with microbial phytase.

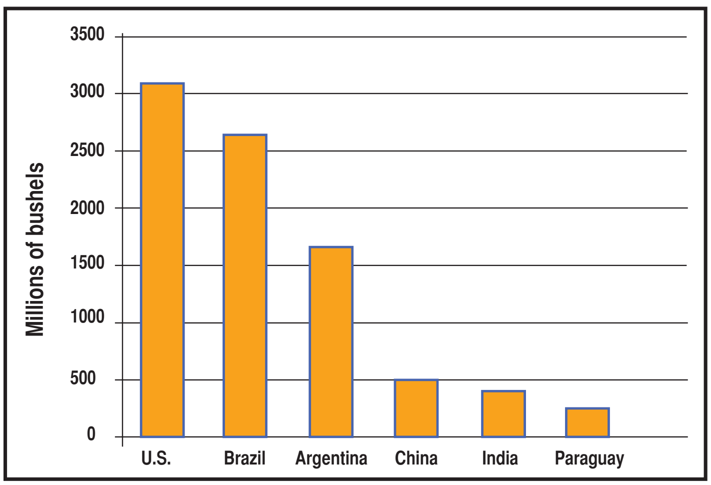
Soybeans contain anti-nutritional factors that may limit growth of pigs, but different technologies have been developed to reduce or eliminate the effects of anti-nutritional factors. All soybean products must be heat treated prior to inclusion in swine diets to destroy trypsin inhibitors and lectins. Fermentation and enzyme treatment eliminate or greatly reduce allergenic proteins and oligosaccharides. Oligosaccharides can also be reduced or eliminated by extracting the carbohydrates from soybean meal in an aqueous solution, which results in production of soy protein concentrate. Because of the low concentrations of oligosaccharides in fermented soybean meal, enzyme treated soybean meal, and soy protein concentrate, all of these products may be used in diets fed to weanling pigs.

Introduction

The United States is the world's largest producer of soybeans (*Glycine max*), and approximately 33% of the world's soybeans are produced in the United States (ASA, 2012). In 2011, 75 million acres of soybeans were planted in the United States (Figure 1) and a total of 3,056 million bushels of soybeans were produced (ASA, 2012). Brazil produced 29% of the world's soybeans followed by Argentina with 19% (ASA, 2012). China, India, and Paraguay are other major producers of soybeans.

Within the United States, Iowa is the largest producer of soybeans (Figure 2). In 2011, over 9.3 million acres of soybeans were planted in Iowa, and 466.12 million bushels of soybeans were produced. Illinois was the next largest producer with 416.42 million bushels, followed by Minnesota, Nebraska, Indiana, and Ohio (ASA, 2012).

Figure 1. Top soybean producing nations in 2011[1]



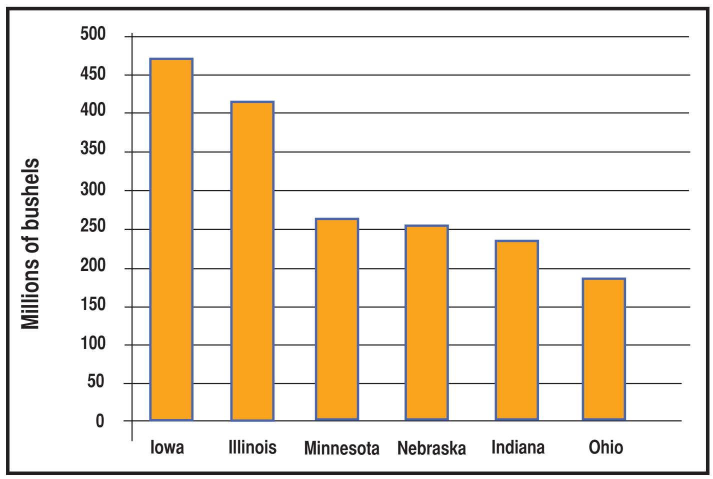
[1]Values obtained from ASA (2012).

The majority of soybeans are crushed into oil and soybean meal, and approximately 75% of the soybean meal that is produced in the world is fed to pigs or poultry. In 2011, over 27 million short tons of soybean meal were fed to livestock in the United States, with almost 7 million short tons of soybean meal fed to pigs (ASA, 2012).

Soy products used in swine nutrition

Most soy products are fed to pigs in the form of soybean meal and its derivatives. These ingredients contain little fat because they are co-products of oil production, and thus, the fat has been removed. Dehulled soybean meal contains less than 2% fat on an as-fed basis, compared with whole full-fat soybeans that contain approximately 20% fat (Table 1). Whole full-fat soybeans can be fed to increase the energy concentration of the diet, but because of the relatively high cost of soybean oil, this is usually not economical.

Figure 2. Top soybean producing states in 2011[1]



[1]Values obtained from ASA (2012).

Swine producers commonly feed toasted soybean meal without further processing. However, soybean meal may be processed in different ways to increase the protein concentration and to deactivate anti-nutritional factors. Soybean meal is produced from whole or dehulled soybeans.

Table 1. Nutrient composition (%) of soybeans, soybean meal (SBM), and other soybean products (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Extruded-expelled SBM	Enzyme treated SBM	Fermented SBM	Soy protein concentrate	Soy protein isolate
Dry matter	92.36	89.98	88.79	93.85	92.70	92.88	92.64	93.71
Crude protein	37.56	47.73	43.90	44.56	55.62	54.07	65.20	84.78
Ether extract	20.18	1.52	1.24	5.69	1.82	2.30	1.05	2.76
Carbohydrates and lignin	29.73	34.46	37.27	37.90	28.21	29.53	20.28	2.00
Ash	4.89	6.27	6.38	5.70	7.05	6.98	6.11	4.17

[1]Values obtained from NRC (2012).

Dehulled soybean meal contains approximately 47.5% crude protein on an as-fed basis, and is referred to as high-protein soybean meal. Non-dehulled soybean meal contains approximately 44% crude protein and is referred to as low-protein soybean meal.

Fermentation or enzyme treatment of soybean meal eliminates the oligosaccharides in the meal

Conventional toasted soybean meal, or solvent-extracted dehulled soybean meal, is produced by extracting the fat from soy flour with a solvent, usually hexane, with a subsequent toasting step to remove residual hexane and to deactivate trypsin inhibitors and lectins.

Expelled soybean meal is produced by extruding intact or dehulled soybeans followed by mechanical expelling of the oil. The extrusion-expelling process produces soybean meal with greater fat content than conventional soybean meal because the expelling process is less efficient than the solvent extraction process in removing oil from the soybeans (Wang and Johnson, 2001). Therefore, extruded-expelled soybean meal contains between 4 and 8% fat, whereas solvent extracted soybean meal contains less than 2% fat.

Full fat soybeans contain 36%–38% crude protein and 19%–20% fat, but dehulled soybean meal contains 46 to 48% crude protein and less than 2% fat.

Enzyme-treated soybean meal, a new product on the United States feed market, is produced by treating dehulled, solvent-extracted soybean meal for several hours with a proprietary blend of enzymes. Enzyme treatment reduces the concentrations of oligosaccharides and allergenic proteins to create a product that can be fed to weanling pigs. To improve digestibility of phosphorus in enzyme-treated soybean meal, it may be treated with phytase (Goebel and Stein, 2011).

Fermented soybean meal is produced by inoculating conventional soybean meal with the bacterium *Aspergillus oryzae* or other microbes. Fermenting the soybean meal eliminates the oligosaccharides and reduces the concentration of antigens in the meal (Cervantes-Pahm and Stein, 2010). Therefore, fermented soybean meal can be used instead of animal proteins in weanling pig diets without adversely affecting growth (Jones et al., 2010; Kim et al., 2010).

Soy protein concentrate is produced by aqueous ethanol extraction of water-soluble carbohydrates from defatted soybean meal. The ethanol extraction process removes the soluble carbohydrates, but the majority of the fiber in soybean meal is insoluble fiber and remains in soy protein concentrate. The resultant product contains at least 65% crude protein (NRC, 2012).

Soy protein isolate is produced by solubilizing the protein in soybean meal with water and precipitating the protein from the solution. This process removes the fat and carbohydrate components from the product (Cromwell, 2000); therefore, soy protein isolate contains at least 80% crude protein (Middelbos and Fahey, 2008). The allergenic proteins glycinin and ß-conglycinin are deactivated when soy protein concentrate and soy protein isolate are produced by extraction at temperatures greater than 50 °C (Sissons et al, 1982) and both products are well tolerated by weanling pigs (Li et al., 1991). However, because of the high costs involved in producing soy protein isolate, this product is usually not used in the feeding of pigs.

Nutritional value of soybean products

Energy

The energy concentration of soybeans and their derivatives depends on the concentration of fat, carbohydrates, and protein

Table 2. Concentration of energy (kcal/kg) in soybeans, soybean meal (SBM), and other soybean products (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Extruded-expelled SBM	Enzyme treated SBM	Fermented SBM	Soy protein concentrate	Soy protein isolate
Gross energy	5227	4256	4257	4692	4451	4533	4605	5386
Digestible energy	4193	3619	3681	3876	3914	3975	4260	4150
Metabolizable energy	3938	3294	3382	3573	3536	3607	3817	3573
Net energy	2874	2087	2148	2344	-	-	2376	2187

[1]Values obtained from NRC (2012).

in the product. The digestible energy and metabolizable energy concentrations in full-fat soybeans are greater than in dehulled soybean meal (4,193 and 3,938 vs. 3,619 and 3,294 kcal/kg; Table 2). The reduced concentration of digestible and metabolizable energy in soybean meal compared with full-fat soybeans is a result of the reduced concentration of fat in soybean meal.

Dehulled soybean meal contains the same amount of digestible energy as corn

Concentrations of digestible and metabolizable energy in enzyme-treated soybean meal are 3,914 kcal/kg and 3,536 kcal/kg, respectively. The energy content of enzyme-treated soybean meal is greater than that of conventional soybean meal because it has been further processed to remove anti-nutritional factors and antigenic proteins that decrease energy availability. The concentrations of digestible (3,975 kcal/kg) and metabolizable (3,607 kcal/kg) energy are also greater for fermented soybean meal than for conventional soybean meal because of the removal of oligosaccharides and other anti-nutritional factors.

Soy protein concentrate and soy protein isolate also have greater concentrations of energy than soybean meal because they contain a greater percentage of crude protein than soybean meal. Digestible energy values for soy protein concentrate and soy protein isolate are 4,260 kcal/kg and 4,150 kcal/kg, respectively, and metabolizable energy values are 3,817 kcal/kg and 3,573 kcal/kg (NRC, 2012).

Carbohydrates

Soybeans are thought of primarily as a protein source, but they also contain a total of 30 to 35% carbohydrates, making soybeans a major carbohydrate contributor to the diet. Soybeans contain two types of carbohydrates: structural and non-structural carbohydrates (Grieshop et al., 2003). The structural carbohydrates include cellulose and hemi-cellulose, and the non-structural carbohydrates include sugars and oligosaccharides (Table 3).

Oligosaccharides are considered anti-nutritional factors for young pigs because they reduce pig growth performance and increase the incidence of diarrhea in weanling pigs. Therefore, weanling pigs do not tolerate conventional soybean meal very well. However, most oligosaccharides are removed from fermented soybean meal and enzyme-treated soybean meal (Cervantes-Pahm and Stein, 2010) and these ingredients may, therefore, be included in diets fed to weanling pigs (Jones et al., 2010; Kim et al., 2010). Soy protein concentrate and soy protein isolate also have reduced concentrations of oligosaccharides compared with soybean meal because the water-soluble carbohydrates have been removed and these products may, therefore, also be included in diets fed to weanling pigs. Low-oligosaccharide soybean varieties are also being developed, but are not commercially available at this time.

Table 3. Concentrations (%) of carbohydrates and lignin in soybeans, soybean meal (SBM), and other soybean products (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Extruded-expelled SBM	Soy protein concentrate	Soy protein isolate
Sucrose	6.42	4.30	7.63	7.1	0.67	0.13
Raffinose	0.77	3.78	0.90	0.77	0.46	-
Stachyose	3.89	7.33	4.32	4.88	0.91	-
Starch	1.89	1.89	1.89	1.89	1.89	1.89
Lignin	-	1.10	-	-	-	-
ADF	6.17	5.28	6.66	7.35	-	0.00
NDF	10.00	8.21	9.82	13.84	8.10	0.19

[1]Values obtained from NRC (2012).

Dietary fiber has a reduced energy value compared with the energy of other nutrients. Fiber also may negatively influence the digestibility and absorption of other nutrients and will contribute to a faster rate of passage in the intestinal tract of pigs. Pigs do not ferment dietary fiber very well; therefore, ingredients with a high fiber concentration have reduced dry matter digestibility compared with ingredients containing less fiber. However, among plant protein ingredients, de-hulled soybean meal has the least dietary fiber content determined as the concentration of crude fiber, acid detergent fiber (ADF),

Table 4. Calcium and phosphorus concentrations and apparent (ATTD) and standardized (STTD) total tract digestibility of phosphorus in soybeans, soybean meal (SBM), and other soybean products (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Enzyme treated SBM	Fermented SBM	Soy protein concentrate	Soy protein isolate
Total P, %	0.53	.71	.064	0.75	0.80	0.82	0.75
ATTD P, %	39	39	39	60	60	39	39
STTD P, %	48	48	48	66	66	48	48
Phytate bound P, %	0.33	0.38	0.36	-	-	-	-
Phytate bound P, % of total P	62.3	53.5	56.3	-	-	-	-
Non-phytate P, %	0.2	0.33	0.28	-	-	-	-
Non-phytate bound P, % of total P	37.7	46.5	43.8	-	-	-	-
Total Ca, %	0.31	0.33	0.35	0.31	0.3	0.32	0.17
ATTD Ca, %	-	62.9	-	60.9	50.7	-	-

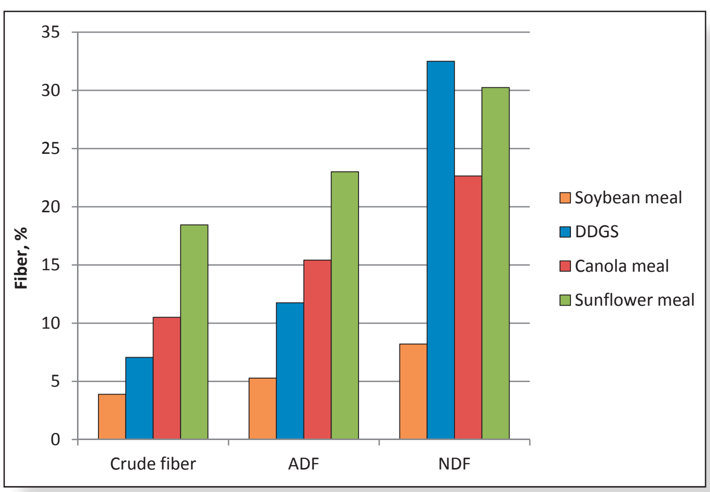
[1]Values obtained from NRC (2012).

or neutral detergent fiber (NDF; Figure 3). A consequence of the low concentration of fiber in soybean meal is that the energy concentration in soybean meal is similar to that of corn.

Minerals

Most of the phosphorus in soybeans is bound to phytic acid (Table 4). Pigs cannot utilize most of the phytic acid bound phosphorus because they produce little intestinal phytase. Therefore, to make sure that there is enough digestible phosphorus in the diet, it is often necessary to add supplemental phosphorus in the form of monocalcium phosphate or dicalcium phosphate, which increases diet costs. Because the pig cannot utilize the phytic acid bound phosphorus, it is excreted in the pig's manure. Phosphorus run-off from the manure into aquatic ecosystems can lead to algal blooms and fish kills. Phytic acid also binds calcium, decreasing the amount of available calcium in the diet.

Figure 3. Fiber content of feed ingredients, %[1]



[1]Values obtained from NRC (2012).

Table 5. Concentrations of minerals in soybeans, soybean meal (SBM), and soy protein isolate (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Soy protein isolate
Cl, %	0.03	0.49	0.05	0.02
K, %	1.64	2.24	1.96	0.16
Mg, %	0.28	0.27	0.29	0.05
Na, %	0.03	0.08	0.01	1.14
S, %	0.3	0.40	0.39	-
Cu, ppm	16	15.13	17.38	12.9
Fe, ppm	80	98.19	235	15.16
Mn, ppm	30	35.49	40.64	11.9
Se, ppm	0.11	0.27	0.32	0.14
Zn, ppm	39	48.81	50	40.26

[1]Values obtained from NRC (2012).

Table 6. Concentrations of crude protein and amino acids (%) in soybeans, soybean meal (SBM), and other soybean products (as-fed basis)[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Extruded-expelled SBM	Enzyme treated SBM	Fermented SBM	Soy protein concentrate	Soy protein isolate
CP	37.56	47.73	43.90	44.56	55.62	54.07	65.20	84.78
Indispensable AA								
Arg	2.45	3.45	3.17	3.13	3.95	3.70	4.75	6.14
His	0.88	1.28	1.26	1.17	1.41	1.37	1.70	2.19
Ile	1.60	2.14	1.96	1.97	2.48	2.55	2.99	3.83
Leu	2.67	3.62	3.43	3.29	4.09	4.25	5.16	6.76
Lys	2.23	2.96	2.76	2.85	3.20	3.14	4.09	5.19
Met	0.55	0.66	0.60	0.56	0.71	0.75	0.87	1.11
Phe	1.74	2.40	2.26	2.19	2.78	2.87	3.38	4.40
Thr	1.42	1.86	1.76	1.73	2.13	2.09	2.52	3.09
Trp	0.49	0.66	0.59	0.67	0.72	0.69	0.81	1.13
Val	1.73	2.23	1.93	2.06	2.57	2.67	3.14	4.02
Dispensable AA								
Ala	1.59	2.06	1.92	1.89	2.41	2.45	2.82	3.54
Asp	3.89	5.41	4.88	4.84	6.14	5.98	7.58	9.64
Cys	0.59	0.70	0.68	0.70	0.78	0.77	0.90	0.98
Glu	6.05	8.54	7.87	7.56	9.62	9.12	12.02	16.00
Gly	1.52	1.99	1.89	1.89	2.32	2.34	2.75	3.54
Ser	1.67	2.36	2.14	2.11	2.66	2.51	3.33	4.37
Tyr	1.20	1.59	1.55	1.50	2.03	2.08	2.26	3.08

[1]Values obtained from NRC (2012).

Supplementation of the diet with microbial phytase improves phosphorus digestibility, with maximum efficiency at 500 to 1000 phytase units per kg of diet (Jongbloed et al., 2000; Almeida and Stein, 2010). Some studies have also shown an improvement in calcium digestibility as phytase was added to the diet (Adeola et al., 2004; Veum and Ellersieck, 2008; Almeida and Stein, 2010). Improvements in growth rate, feed efficiency, and bone strength (Adeola et al., 2004; Veum and Ellersieck, 2008), and a decrease in phosphorus excretion (Hill et al., 2009) have been reported in pigs fed corn-soybean meal diets supplemented with microbial phytase. The use of microbial phytase can reduce or eliminate the need for inorganic phosphorus in the diet (Almeida and Stein, 2010) and diet costs are, therefore, often reduced if microbial phytase is used. The digestibility of phosphorus in soybean products is relatively high if microbial phytase is added to the diet; soybean products are, therefore, rich sources of digestible phosphorus, which reduces the need for adding expensive inorganic phosphorus to the diets.

Soybean meal and other soybean products contain relatively high amounts of potassium, magnesium, and sulfur (Table 5), and pigs fed diets containing soybean products and a cereal grain do not need additional supplements of these minerals in their diets. The concentration of micro minerals may vary according to the geographical area where the soybeans were grown because the concentration of micro minerals in the

soybeans to some degree reflects the concentration of these minerals in the soil, where the beans were grown. It is, therefore, common practice to supplement diets for pigs with the amounts of micro minerals needed by the animals and disregard the quantities supplied by soybean meal and cereal grains.

Soybean meal is the premier source of digestible amino acids in diets fed to pigs

Protein and amino acids

Soybeans are the gold standard of high quality protein for pigs because their amino acid profile complements the amino acid profiles of several cereal grains. In particular, soybean protein is rich in lysine, threonine, and tryptophan (Table 6). These are the most limiting amino acids in corn, wheat, sorghum, and barley (Lewis, 1985). The proteins in soy products are also highly digestible (Table 7).

Lysine is the first limiting amino acid in several cereal grains; therefore, diets are formulated to contain adequate concentrations of lysine. Diets are most correctly formulated based on values for standardized ileal digestibility (SID) of amino acids because values for SID of amino acids are additive in mixed diets (Stein et al., 2007). The SID tryptophan:lysine ratios for soy products range from 19.1 to 23.0%, compared with the ideal ratio of 18.2% (Petersen, 2011).

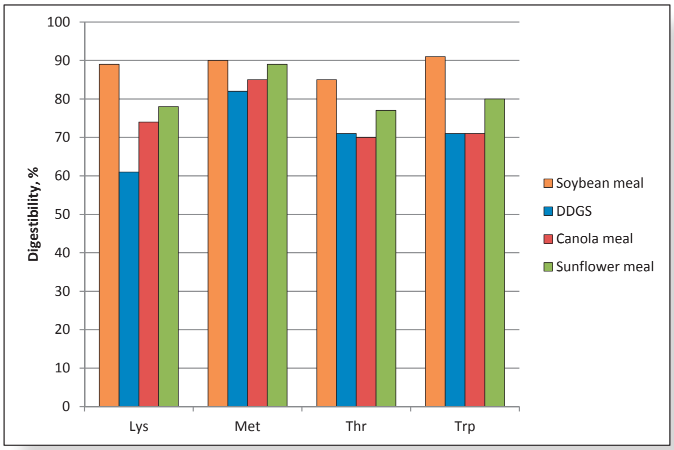
The concentration of crude protein and amino acids is greater in soybean meal than in full-fat soybeans. Enzyme treatment or fermentation increases the concentration of crude protein in soybean meal because of the removal of oligosaccharides (Cervantes-Pahm and Stein, 2010). The SID for most amino acids in enzyme-treated soybean meal does not differ from that of conventional soybean meal; however,

Table 7. Standardized ileal digestibility (%) of crude protein and amino acids in soybeans, soybean meal (SBM), and other soybean products[1]

Product	Full-fat soybeans	Dehulled SBM	Nondehulled SBM	Extruded-expelled SBM	Enzyme treated SBM	Fermented SBM	Soy protein concentrate	Soy protein isolate
CP	79	87	85	89	88	79	89	89
Indispensable AA								
Arg	87	94	92	96	96	90	95	94
His	81	90	86	91	90	81	91	88
Ile	78	89	88	91	90	81	91	88
Leu	78	88	86	89	89	82	91	89
Lys	81	89	88	90	86	75	91	91
Met	80	90	89	91	91	88	92	86
Phe	79	88	87	90	86	80	90	88
Thr	76	85	83	85	83	73	86	83
Trp	82	91	90	89	83	78	88	87
Val	77	87	84	88	89	80	90	86
Dispensable AA								
Ala	79	85	86	88	86	79	89	90
Asp	80	87	86	88	86	78	88	92
Cys	76	84	84	83	73	64	79	79
Glu	84	89	88	90	88	78	91	94
Gly	81	84	83	84	89	75	88	89
Ser	79	89	89	89	87	80	91	93
Tyr	81	88	86	89	92	88	93	88

[1]Values obtained from NRC (2012).

Figure 4. Standardized ileal digestibility of amino acids in feed ingredients, %[1]



[1]Values obtained from NRC (2012).

increased concentrations of fat in diets fed to pigs usually increase the digestibility of amino acids because of a reduced rate of passage (Cervantes-Pahm and Stein, 2008).

Soybean protein has a better balance of indispensable limiting amino acids than other plant proteins

Soybean meal is the premier protein source for pigs and is used throughout the world. The reason for the popularity of soybean meal is that the quality of the protein in soybean meal is greater than the quality of protein in other protein meals. Protein quality is often evaluated by expressing the concentration of each amino acid as a percentage of crude protein. Based on this comparison, it is easily seen that soy protein has greater concentrations of lysine and tryptophan, which are the first limiting amino acids in corn protein when fed to pigs (Table 8). In contrast, corn protein has a greater concentration of methionine than soy protein, which is the reason corn and soybean meal complement each other.

The requirements for amino acids by pigs are expressed as grams or percentages of digestible amino acids in the diets. These values are calculated by multiplying the concentration of amino acids in feed ingredients by the digestibility of that amino acid. The amino acids provided by soy protein are highly digestible (Figure 4). The concentration of digestible amino acids in soybean meal is greater than in other protein sources that are available to pigs (Figure 5).

One of the challenges in producing diets for pigs is to account for the variability in digestibility that always exists among different batches of the same feed ingredient. This variability makes it more difficult to predict the concentration of digestible amino acids in the diet that is mixed for the pigs. However, there is less variability in the digestibility of amino acids in soybean meal than in other protein meals. This can be illustrated by calculating the standard deviation of digestibility values in feed ingredients. Such calculations indicate that there is less variability in the digestibility of amino acids among different batches of soybean meal than among different batches of other protein meals (Table 9). A reduced variability in digestibility values for soybean meal will give users confidence that the desired levels of digestible amino acids in the diets will be achieved if soybean meal is used.

Fatty acid composition of soybean oil

Soybean oil contains mainly unsaturated fatty acids and less than 15% of all the fatty acids in soybean oil are saturated fatty acids (Table 10). Approximately 50% of all the fatty acids in soybean oil is linoleic acid (C18:2) and an additional 22% is present as monounsaturated fatty acids, primarily oleic acid (C18:1). Soybean oil does, however, also contain more than 6% linolenic acid (C18:3), which may have anti-inflammatory properties in the diets (NRC, 2012).

Table 8. Quality of protein in soybean meal and other protein meals expressed as the percentage of each amino acid as a percentage of crude protein (CP)[1]

	Soybean meal[2]		DDGS[3]		Canola meal[4]		Sunflower meal[5]	
Item	%	% of CP	%	% of CP	%	% of CP	%	% of CP
Crude protein	47.73	-	27.33	-	37.50	-	39.86	-
Amino acid								
Isoleucine	2.14	4.5	1.02	3.7	1.42	3.8	1.54	3.9
Lysine	2.96	6.2	0.77	2.8	2.07	5.5	1.45	3.6
Methionine	0.66	1.4	0.55	2.0	0.71	1.9	0.78	2.0
Threonine	1.86	3.9	0.99	3.6	1.55	4.1	1.37	3.4
Tryptophan	0.66	1.4	0.21	0.8	0.43	1.1	0.48	1.2
Valine	2.23	4.7	1.35	4.9	1.78	4.7	1.76	4.4

[1]Values obtained from NRC (2012).
[2]Soybean meal, dehulled, solvent extracted.
[3]DDGS = distillers dried grains with solubles.
[4]Canola meal, solvent extracted.
[5]Sunflower meal, dehulled, solvent extracted.

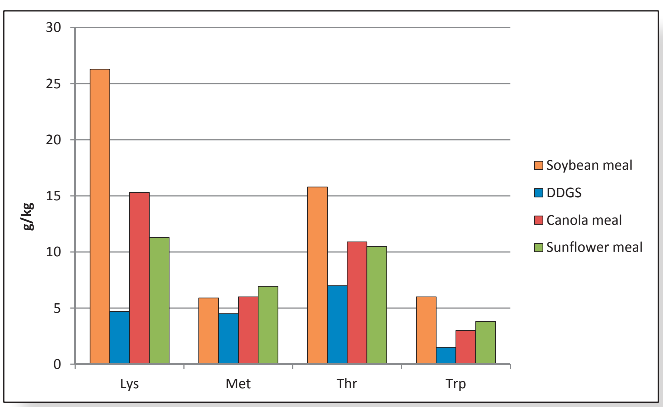
Table 9. Variability in digestibility values for amino acids in soybean meal and other protein meals expressed as standard deviation (SD) for each digestibility value[1]

	Soybean meal[2]		DDGS[3]		Canola meal[4]		Sunflower meal[5]	
Amino acid	SID[6]	SD	SID	SD	SID	SD	SID	SD
Arginine	94	3.12	81	5.25	85	5.56	93	3.35
Histidine	90	4.15	78	4.75	78	10.24	85	6.28
Isoleucine	89	3.79	76	4.87	76	8.34	80	6.15
Leucine	88	3.45	84	4.00	78	6.44	80	5.27
Lysine	89	3.44	61	8.75	74	9.65	78	5.13
Methionine	90	4.70	82	4.13	85	4.06	89	-
Phenylalanine	88	3.65	81	3.96	77	8.42	81	7.11
Threonine	85	4.47	71	5.73	70	9.64	77	8.54
Tryptophan	91	3.32	71	8.16	71	-	80	-
Valine	87	4.16	75	4.95	74	9.78	79	8.06

[1]Values obtained from NRC (2012).
[2]Soybean meal, dehulled, solvent extracted.
[3]DDGS = distillers dried grains with solubles.
[4]Canola meal, solvent extracted.
[5]Sunflower meal, dehulled, solvent extracted.
[6]SID = standardized ileal digestibility (%).

The high concentration of unsaturated fatty acids in soybean oil may result in deposition of unsaturated fatty acids in back fat and belly fat of pigs fed soybean oil, full fat soybeans, or extruded-expelled soybean meal. This may result in increased iodine values in the fat depots, which may create problems in the processing of bellies and loins and potentially reduce the shelf life of these products. It is, therefore, not recommended to feed high levels of soybean oil in diets for pigs during the last few weeks before slaughter.

Figure 5. Digestible amino acids in feed ingredients, g/kg[1]



[1]Values obtained from NRC (2012).

The digestibility of amino acids in soybean meal is greater than in other plant proteins

Table 10. Fatty acid profile (% of ether extract) and iodine value of full fat soybeans[1]

Fatty acid	Abbreviation	%
Myristoleic acid	C-14:0	0.28
Palmitic acid	C-16:0	10.62
Palmitoleic acid	C-16:1	0.28
Stearic acid	C-18:0	3.57
Oleic acid	C-18:1	21.81
Linoleic acid	C-18:2	49.79
Linolenic acid	C-18:3	6.67
Saturated fatty acids	-	14.46
Monounsaturated fatty acids	-	22.09
Polyunsaturated fatty acids	-	56.46
Iodine value	-	128.24

[1]Values obtained from NRC (2012).

Usage of soybean products

Soybean meal is the most commonly used source of amino acids in diets for pigs around the world. Diets that contain a source of cereal grains, soybean meal, and microbial phytase will satisfy the needs for all amino acids, all the energy, and most of the phosphorus for growing and finishing pigs and there are usually no needs for other sources of energy and amino acids in these diets. In diets for weanling pigs, the concentration of conventional soybean meal should be less than 20% to limit the inclusion of antigens and oligosaccharides, but fermented soybean meal, enzyme treated soybean meal, or soy protein concentrate can be included in these diets to satisfy the requirement for most of the additional amino acids. Soybean meal can also satisfy the needs for all amino acids in diets fed to both gestating and lactating sows.

Conclusions

Soybean products are excellent sources of protein for pigs because their amino acid profiles complement those of cereal grains. Amino acids in soy protein are more digestible than amino acids in most other plant proteins, which results in less nitrogen being excreted in the manure from pigs fed diets containing soybean meal than if other protein sources are used. Processing of soybean meal to reduce anti-nutritional factors improves the digestibility of nutrients and energy, and soybean meal that is fermented or enzyme treated may be used in diets fed to weanling pigs as replacement for fishmeal and other animal proteins.

Soybean meal contributes approximately the same quantity of digestible energy to the diets as corn, but the energy contribution from full fat soybeans and from extruded-expelled soybean meal is greater than from conventional soybean meal. Soybean products have a relatively high concentration of phosphorus and if microbial phytase is used in the diet, the digestibility of the phosphorus in soybean products is relatively high. Inclusion of inorganic sources of phosphorus can, therefore, be reduced if soybean products are used together with microbial phytase. Soybean meal can satisfy the entire requirement for amino acids in diets fed to growing and finishing pigs and to gestating and lactating sows. However, inclusion of conventional soybean meal in diets fed to newly weaned pigs should be restricted to less than 20%, but enzyme treated or fermented soybean meal may be used in these diets as additional sources of amino acids.

Fermented or enzyme treated soybean meal can replace fish meal in diets fed to weanling pigs

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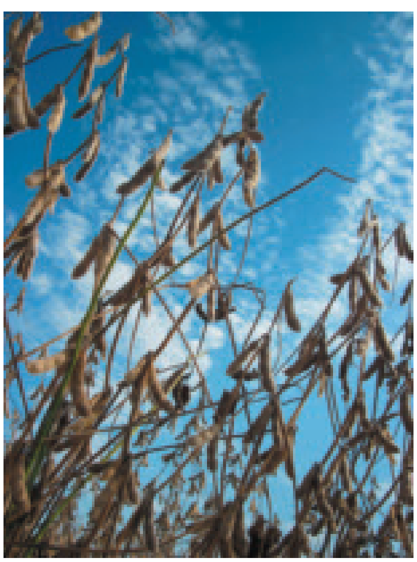

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