Use of Novel Soybean Products for Swine

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ABSTRACT: Traditional plant breeding has resulted in the development of new high-protein varieties of soybeans that contain 46 to 48% crude protein. Soybean meal produced from these beans contains 56 to 58% crude protein and approximately 3.5% lysine. The digestibility of amino acids in high protein soybeans and in high protein soybean meal is comparable to that of conventional varieties, but because of the increased protein and amino acid concentration, more digestible amino acids are present in high protein soybeans and high protein soybean meal compared with conventional sources of soybeans and soybean meal. The inclusion rate of soybean meal can, therefore, be reduced if high-protein soybean meal is included in diets fed to swine in stead of conventional soybean meal. The concentration of digestible and metabolizable energy in high protein soybean meal is also greater than in conventional soybean meal. Low oligosaccharide varieties of soybeans have also been developed and soybean meal from these varieties contains fewer oligosaccharides, but more amino acids, than conventional soybean meal. The digestibility of amino acids and energy in low oligosaccharide soybean meal is comparable to conventional soybean meal. Fermentation of soybean meal in the presence of bacillus strains or treatment by enzymes results in soybean meal that contains no antigens, oligosaccharides, or sugars, but greater concentrations of amino acids than conventional soybean meal. These new sources of soybean meal are believed

to be better tolerated by young pigs than conventional soybean meal and may be used in diets fed to weanling pigs in stead of animal protein sources.

INTRODUCTION

Novel soybean products that are available to the feed industry include products that are produced from new varieties of soybeans as well as products that are a result of novel processing technologies applied to harvested soybeans. New varieties of soybeans are produced by modifying the genetic make-up of soybeans using biotechnological tools ("GMO-soybeans") or by using traditional plant breeding technologies (Stein et al., 2008). Genetic modification using biotechnology has primarily focused on modifying input traits by insertion of genes that infers *in planta* glyphosate tolerance to soybeans ("Round-up Ready" soybeans), whereas traditional plant breeding technologies primarily have been used to enhance output traits (Parsons, 2000). Modification of input traits of soybeans does not change the composition or the nutritional value of the soybeans or the soybean meal produced from these beans (Cromwell et al., 2002). In contrast, modification of output traits may change the composition of the beans as well as the nutritional value of the soybean meal produced from these beans (Baker and Stein, 2008; Cervantes-Pahm and Stein, 2008). Likewise, introduction of novel processing technologies that are applied to harvested soybeans may result in changes in both composition and nutritional value of the soybean meals that are produced.

It is the objective of this contribution to review current knowledge about new soybean products that are available to the feed industry as a result of changes in the genetic make-up of the beans and in post-harvest processing of soybeans.

COMPOSITION OF SOYBEANS AND SOYBEAN MEAL

Conventional soybeans contain on a DM basis approximately 41% crude protein, 5% ash, 18% acid hydrolyzed fat, and 34% carbohydrates (Table 1; Grieshop et al., 2003). Approximately 44% of the carbohydrates are nonstructural carbohydrates (Grieshop et al., 2003). The concentration of free glucose, galactose, and fructose is low, but soybeans contain 4 to 5% sucrose, 4 to 5% oligosaccharides, and 3 to 4% uronic acid (DM-basis). The oligosaccharides are alpha-galactosides and consist mainly of stachyose, although raffinose and verbascose are also present in soybeans, but at a concentration of less than 1% (Grieshop et al., 2003). Most of the fat is removed during crushing and soybean meal contains usually less than 5% ether extract. Soybeans are usually also de-hulled during crushing, which results in a reduced concentration of non-starch polysaccharides in soybean meal (Table 1; Grieshop et al., 2003). In contrast, soybean meal contains more protein, more ash, and more non-structural carbohydrates than soybeans (approximately 54, 7.5, and 20% (DM basis), respectively). The concentration of alpha-galactosides in soybean meal is between 6 and 7% (DM basis), and stachyose is usually 80 to 85% of all alpha-galactosides. On a DM basis, soybean meal also contains 6 to 7% sucrose and 3 to 4% uronic acid (Grieshop et al., 2003).

MODIFICATION OF SOYBEAN COMPOSITION

Most efforts in terms of changing the composition of soybeans have been directed towards increasing protein concentration and reducing the concentration of oligosaccharides in soybeans. New varieties of high protein soybeans that contain 45 to

48% crude protein (as-is basis) have been introduced and the concentration of amino acids in these high protein beans is increased to the same degree as the concentration of crude protein (Table 2; Cervantes-Pahm and Stein, 2008). The standardized ileal digestibility of amino acids in full-fat high protein soybeans is similar to that of conventional full-fat soybeans (Table 3), which means that the concentration of digestible amino acids in high-protein soybeans is increased to the same degree as the concentration of total amino acids. When high protein soybeans are crushed, a soybean meal containing 56 to 58% crude protein (as-is basis) is produced (Table 2; Baker and Stein, 2008). This soybean meal contains approximately 3.5% lysine and the standardized ileal digestibility of amino acids in high-protein soybean meal is comparable to the digestibility of amino acids in conventional soybean meal (Table 3). The concentration of digestible amino acids in high protein soybean meal is, therefore, increased to the same degree as the concentration of total amino acids. In addition, because of the increased concentration of protein, high protein soybean meal also has a greater concentration of digestible and metabolizable energy compared with conventional soybean meal (Baker and Stein, 2008).

To reduce the negative impact of the alpha-galactosides that are present in normal soybeans and soybean meal produced from conventional soybeans, new beans with a low concentration of oligosaccharides have been bred. Soybean meal from these low oligosaccharide soybeans has a lower concentration of oligosaccharides, but a greater concentration of crude protein and amino acids than conventional soybeans (Baker and Stein, 2008). The standardized ileal digestibility of amino acids in low-oligosaccharide soybean meal is comparable to that of conventional soybean meal (Baker and Stein, 2008). Likewise, the concentration of digestible and metabolizable energy in low-oligosaccharide soybean meal is similar to the concentration in conventional soybean meal (Baker and Stein, 2008).

FURTHER PROCESSING OF SOYBEAN MEAL

Enzymatically treated or fermented soybean meal

In diets fed to growing-finishing and reproducing swine, all amino acids needed by the animals may be provided by soybean meal. However, newly weaned pigs do not tolerate soy protein as well as older pigs (Sohn et al., 1994), and they may develop allergenic reactions followed by immunological responses if they are fed large quantities of SBM (Li et al., 1990; 1991). 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 of amino acids in these diets. However, two new 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 believed that these products can be included in diets fed to weanling pigs without causing adverse allergenic reactions.

During the production of HP 300 (Hamlet Protein, Horsens, Denmark), a proprietary enzymatic preparation is used to digest the antigens in soybean meal. The oligosaccharides and sugars in the soybean meal are also removed and the resultant soybean meal contains approximately 53% crude protein (Table 4; Zhu et al., 1998; Pahm, 2008). The digestibility of amino acids in HP 300 is greater than in conventional soybean meal (Table 5; Pahm, 2008). Numerous experiments in Europe and Asia have demonstrated that inclusion of HP 300 in diets fed to weanling pigs results in pig performance that is similar to that obtained on diets based on animal proteins, but at this point, no data from the US are available.

PepSoyGen (NutraFerm, North Sioux City, SD) is produced by fermentation of soybean meal in the presence of *Apergillus oryzae* and *Bacillus subtillis*. Antigens, antinutritional factors, oligosaccharides, and sugars are removed from the soybean meal during fermentation (Table 4; Hong et al., 2004; Yang et al., 2007; Pahm, 2008). The proteins in the soybean meal is also hydrolyzed during fermentation, which results in reduced peptide size in PepSoyGen compared with conventional soybean meal (Hong et al., 2004). PepSoyGen contains approximately 10% more protein than conventional soybean meal, but the amino acid sequence is similar to the sequence in conventional soybean meal (Hong et al., 2004). The standardized ileal digestibility of amino acids in PepSoyGen is similar to the digestibility in conventional soybean meal (Table 5; Pahm, 2008), but the 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.

Extruded full-fat soybeans

Full-fat soybeans may be used in diets fed to pigs provided that they have been heat treated prior to feeding. The development of relatively small farm-size extruders makes home extrusion of soybeans and subsequent use of extruded full-fat soybeans an option for swine producers. Extruded full-fat soybean meal is an excellent feed ingredient that may be used in diets fed to all categories of pigs.

The concentration of energy in full-fat soybeans is greater than in soybean meal because of the greater concentration of oil in full-fat soybeans (Woodworth et al., 2001). Diets containing full-fat soybeans, therefore, usually contain more energy than if soybean meal is used. The digestibility of amino acids in full-fat soybeans is also greater than in soybean meal (Cervantes-Pahm and Stein, 2008), which may be a result of the greater concentration of oil in full-fat soybeans than in soybean meal because it has been demonstrated, that the inclusion of soybean oil in diets fed to swine results in improved digestibility of amino acids (Cervantes-Pahm and Stein, 2008). It is believed that this increase in amino acid digestibility is a result of a reduced rate of passage for diets containing soybean oil compared with diets containing no soybean oil (Cervantes-Pahm and Stein, 2008). It is, therefore, possible that diets containing extruded full-fat soybeans also have a reduced passage rate through the intestinal tract of pigs compared with diets containing soybean meal, but this hypothesis has not been tested.

Extruded full-fat soybeans are often included in diets fed to nursery pigs and weanling pigs tolerate extruded full-fat soybeans well (Qiao et al., 2003; Zarkadas and Wiseman, 2004). Extruded full-fat soybeans may also replace soybean meal in diets fed to growing-finishing pigs without any negative impact on pig performance (Leszczynski et al., 1992), but belly firmness may be reduced if full fat soybeans are used during the finishing period. However, if pigs are offered a diet containing no full-fat soybeans during the final 3 weeks prior to slaughter, belly quality is not impaired by feeding full-fat soybeans (Leszczynski et al., 1992). Extruded full-fat soybeans may also be included in diets fed to sows and can potentially replace all soybean meal in gestation and lactating diets.

CONCLUSIONS

New varieties of soybeans as well as new technologies for post harvest processing of soybeans and soybean meal has resulted in the development of several new soybean products for the feed industry. High protein soybean meal that contains 56% crude protein and 3.5% lysine is available and offers an opportunity for including less soybean meal in diets fed to swine without reducing the inclusion of digestible amino acids. High protein soybean meal also contains more digestible and metabolizable energy than conventional soybean meal. Soybean meal produced from low oligosaccharide soybeans contains more amino acids, but fewer oligosaccharides, than conventional soybean meal. Low oligosaccharide soybean meal may, therefore, be better tolerated by young animals than conventional soybean meal, but experiments to verify this hypothesis have not yet been conducted.

Post harvest processing of soybean meal using fermentation or enzymes removes the antigens along with oligosaccharides and sugars in soybean meal. This results in high protein soybean meal without antigenic properties, which is believed to be better tolerated by young pigs than conventional soybean meal. These new sources of soybean meal may, therefore, be used in diets fed to young pigs, and thus, reduce the need for using animal proteins in these diets. The development of on-farm extruders that can inactivate trypsin inhibitors in soybean meal has made it possible to use home-grown soybeans in the feeding of swine. Extruded full-fat soybeans may be used for all categories of swine and will often result in improved performance compared with diets containing soybean meal. However, because of the risk of reducing belly firmness, it is recommended that full-fat soybeans are removed from the diets during the final 3 weeks prior to slaughter.

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Table 1. Composition of soybeans and soybean meal (DM-basis) [1]

Item	Soybeans	Soybean meal
Dry matter, %	89.6	89.0
Crude protein, %	41.3	54.2
Acid hydrolyzed fat, %	18.6	4.4
Ash, %	5.5	7.5
Carbohydrates, %	34.6	33.9
Non-starch polysaccharides, %	20.2	14.1
Non-structural carbohydrates, %	14.4	19.8
Free sugars, %	0.8	-
Sucrose, %	4.8	6.6
Oligosaccharides, %	4.5	6.4
Raffinose, %	0.62	1.18
Stachyose, %	3.75	4.98
Verbascose, %	0.16	0.22
Uronic acid, %	3.4	3.7

[1]Adapted from Grieshop et al. (2003).

Table 2. Protein and amino acid concentration in conventional and high protein soybeans and soybean meal (%, as-is basis) [1]

Item	Conventional		High Protein	
	Soybean	Soybean meal	Soybeans	Soybean meal
DM, %	93.43	89.10	94.91	89.20
CP, %	35.78	48.40	47.64	55.70
Indispensable AA, %				
Arg	3.00	3.62	3.83	4.30
His	0.98	1.30	1.24	1.47
Ile	1.64	2.30	2.02	2.56
Leu	2.76	3.81	3.43	4.31
Lys	2.35	3.20	2.81	3.51
Met	0.59	0.70	0.64	0.78
Phe	1.84	2.50	2.31	2.85
Thr	1.39	1.86	1.66	2.09
Trp	0.33	0.69	0.33	0.75
Val	1.77	2.45	2.16	2.74

Dispensable AA, %				
Ala	1.57	2.14	1.89	2.35
Asp	4.08	5.58	5.25	6.47
Cys	0.61	0.77	0.66	0.91
Glu	6.39	8.93	8.31	10.39
Gly	1.54	2.11	1.89	2.35
Pro	1.7	2.51	2.17	2.86
Ser	1.74	2.25	2.21	2.64
Tyr	1.33	1.79	1.63	1.98

[1] Data from Baker and Stein (2008) and from Cervantes-Pahm and Stein (2008).

Table 3. Standardized ileal digestibility (%) of protein and amino acids in conventional and high protein soybeans and soybean meal [1]

Item	Conventional		High Protein	
	Soybeans	Soybean meal	Soybeans	Soybean meal
CP, %	92.1	87.3	94.1	88.3
Indispensable AA, %				
Arg	96.7	94.7	99.1	94.7
His	91.6	90.6	93.3	89.7
Ile	90.2	88.4	93.1	88.3
Leu	89.7	88.1	92.5	88.3
Lys	92.5	90.0	93.0	90.1
Met	92.2	89.3	94.0	88.6
Phe	90.7	88.6	93.7	88.7
Thr	86.4	85.5	87.6	85.3
Trp	89.4	93.8	90.1	89.6
Val	89.0	86.8	91.7	86.8
Dispensable AA, %				

Ala	91.1	85.0	92.7	84.9
Asp	89.7	86.0	91.0	86.1
Cys	85.0	83.0	84.9	82.9
Glu	90.7	87.7	91.0	87.5
Gly	89.2	88.2	93.9	88.1
Pro	153.7	114.4	153.6	117.1
Ser	88.6	89.0	91.1	89.2
Tyr	90.9	88.7	93.6	88.3

[1] Data from Baker and Stein (2008) and from Cervantes-Pahm and Stein (2008).

Table 4. 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 Pahm (2008).

Table 5. 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 Pahm (2008).

[2] Data are means of seven observations per treatment.