Implications of corn and soybean meal quality on swine production

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1. Abstract

Corn and soybean meal are the main sources of energy and amino acids in swine diets. Although there are other sources of nutrients, corn and soybean meal will maintain the same importance for several years because the majority of the production systems are working on their basis. Therefore, animal producers have to explore these ingredients the best they can, since external markets have become a dark cloud to Brazilian swine and poultry production chains due to the millions of tons exported, in the last decade.

Corn, soybeans and any other grain are very susceptible to climate challenges, water stress, soil fertility, and insect and fungi attack. Besides, there are differences in the genetic potential of seeds and the consequences of harvesting and processing the grains. All these factors affect the final quality of grains and it happens in a different way for each batch. Therefore, the reduction in animal production costs starts with the detection of quality differences between batches of corn and soybean meal.

The objective of this paper is to discuss some of the aspects of control and improve nutritional quality of corn and soybean for swine.

2. Introduction

The feed industry is one of the largest and most dynamic segments of Agriculture. The evolution of this industry in the American continent was linked to increased production of poultry, pigs and cattle. These sectors require more than 90% of feed produced. The expectation is for continuous growth in the coming years, as the domestic per capita meat and egg consumption is growing in developing countries. At the same time, there is a strong tendency to increase meat exports in the coming years, especially for Asian countries.

The development of quality concepts in production and the focus on customer satisfaction are already internalized in most companies, under the penalty of falling outside the market. In the case of grain producers in Brazil, the feed industry is the largest end customer, primarily swine and poultry productive chains. However, these two sectors do not always manifest contentment with the grains used in animal nutrition. There is a constant concern about problems that occur after the grain is harvested, such as insect attacks and fungi proliferation. Animal breeding improvements lead to the selection of animals that show higher rates of weight gain and feed efficiency, and these have forced the use of diets with a higher nutrient density. This demand is due not only to increased levels of nutrients required by the animals to increase protein synthesis, but also because there is a tendency to occur reducing voluntary feed intake when there is selection to best feed conversion animals. This drives the nutritionist to use ingredients with higher density of nutrients such as soybean oil and industrial amino acids that may or may not increase the feed and production costs.

Due to the damage caused by the action of insects and fungi on corn quality, geneticists sought to improve the characteristics of sanity and architecture of plants, giving them better husk coverage of corn cobs and preferring hard or semi-hard grains than soft grains. While these characteristics may be useful in animal feed, they are not the only ones which should be of plant breeders concern. There is a gap of communication in this field. From the point of view of nutritionists and producers of pigs and poultry, grains are the major sources of energy and amino acids for animals. In addition, the nutrition value of an ingredient is not only related to the total concentration of nutrients but also to the degree of digestibility and metabolizabilility of these nutrients by the animal.

There are many points that allow the improvement of grain quality between crop planting and the conversion of grains into meat and eggs. However, there is a strong influence of climatic factors and management of the grains that complicate the final quality.

The approach to quality improvement through exploitation of the genetic potential of grains has great potential for success, which may result in improved animal performance and increased profitability for both animal and grain producers. New cultivars with different characteristics reach the market annually, obtained either by quantitative conventional breeding or by the use of molecular biology techniques.

Grains with different quality characteristics, meeting the specific demands of buyer sector, such as the feed industry, have promoted changes in trade relations. These grains are no longer being considered just as commodities, sold in large lots, but they became specialized ingredients with characteristics desired by processors and producers.

Poultry, swine and grain productive chains have large areas of intersection and should seek common goals to address the growing of all these sectors together.

It has been observed a great variation in the nutritional quality of corn, soybeans and soybean meal in Brazil. Few research projects, focusing on grain quality oriented to livestock needs, have been conducted in order to improve the nutritional quality of the grains used in diets.

However, not all the grain that nutritionists have available is of poor quality. A question must be asked: if we classify our final product such as pig carcasses, for example, why not classify both the corn and soybean meal used to feed the animals? With the use of NIR (near infrared reflectance spectrophotometry), classification of grains based on its nutritional value is not a utopia any more. It is up to managers and the ones responsible to buy grains for swine production to make viable the use of this tool. When this happens, everyone wins: grain farmers, poultry and swine producers, the Brazilian Agriculture and whole society.

3. The knowledge of the nutritional value of the ingredients

In order to have greater accuracy in formulating diets for pigs, it is necessary to know the composition and energy content of each used ingredient, as well as their limitations. Research has been undertaken with the objective of updating the nutritional values of the traditionally used ingredients in diet formulation. Besides enabling the formation and training of technical personnel, the ultimate goal is to optimize the utilization of nutrients by allowing animals to reduce costs and increase the competitiveness of the production system. Corn and soybean meal have been extensively studied and today there is a great amount of information on their composition.

4. Chemical composition tables of ingredients

It is well recognized that the most valuable information regarding the composition of ingredients should be obtained locally, with the previous analysis of the ingredient that will be used for feeding animals. However, analysis of each batch of ingredient is expensive and difficult to handle. Therefore, summarizing data in tables is useful for nutritionists. Nutritionists usually develop nutritional programs based on tables such as NRC (2012), FEDNA (2003), INRA (2004) and the Brazilian Tables (2011), in addition to the recommendations of the feeding and management manuals of commercial lines, provided by companies of genetic material.

In the past, the main problem to use the foreign tables was the difference between table values and the chemical composition of ingredients available in Brazil. Investment in quality control laboratories and in research institutions led to knowledge that provided better decisions and greater safety in feed formulation.

Currently, nutritionists have several sources of information on feedstuffs composition to assist in the development of nutritional programs. It is up to them, however, to identify the most appropriate to their work conditions. Tables of feed ingredient composition have greater utility when variations in nutrient levels of raw materials are small.

5. Composition and variability of corn grain

The maize grain is formed by four physical structures, responsible for the variation in chemical composition: the endosperm, germ, pericarp (husk) and tip cap. Corn germ concentrates most lipid fraction (oil and vitamin E). The endosperm portion, where 98% of the total grain starch is present, presents also carotenoid pigments (zeaxanthin, lutein, alpha-and beta-carotenes, and others) responsible for the color of corn and pigmentation of egg yolk and the skin of poultry. Carbohydrates represent approximately 74% of the total dry matter of the grain. Among these, starch is the predominant, followed by cellulose, hemicellulose, pentosans, dextrins and sugars. The pericarp is a layer of cells that protects the grain against moisture, insects, fungi and other microorganisms, and the tip cap is the connection between the grain and cob.

The nutritional composition of corn has been extensively studied over the years, and their nutritional potential in animal feed is well known. From an economic standpoint, corn accounts for about 70% of the cost of the diets. It is the most important source of energy and its oil content and starch represent major impact on the nutritional value of this grain and diet costs. Thus, greater importance should be given to the differences in their nutritional composition, which has large variation, especially in oil content, and more efforts should be done in order to adjust the energy value of corn in diet formulation on the basis of these variations.

The quality of a batch of corn is heterogeneous. It is affected by the position of the grain in the ear, plant location in the crop field, and other variables such as seed genetics, soil fertility, climate, handling, processing and storage, batch mixing, among other factors that contribute to variation in the quality and chemical composition of the final ingredient denominated corn.

Differences in the rate of starch digestibility for various raw materials are known. However, variations in digestibility trials may be due to the methodology used in the study, a fact that should not be forgotten. Anyway, the variation in starch digestibility, justifies the need for greater control of the composition of raw materials used in Brazil, where very little is known about, although maize is massively used, which may result in significant economic loss.

Lima et al. (2000) analyzed 152 maize samples collected from different regions of Rio Grande do Sul (Table 1) and the authors found high variability in oil and amino acid contents.

Table 1. Composition of corn hybrids collected in the 1999/2000 harvest season in RS

	DM	CP	EE	Trp	Lys	Met	Thr
Mean (%)	86.60	9.09	3.97	0.09	0.27	0.29	0.28
Minimum value (%)	79.96	6.83	2.45	0.05	0.25	0.26	0.17
Maximum value (%)	93.91	12.33	5.29	0.14	0.28	0.31	0.40

Lima et al. (2000). DM = dry matter, CP = crude protein, EE = oil, Trp = tryptophan, Lys = lysine, Met = methionine, Thr = threonine.

In the state of Santa Catarina, Lima et al. (2001) found values of crude protein (CP) ranging from 8.65% to 13.80% and values of oil content between 1.77% and 5.73%. The results obtained by Passos (2004), from a bank in 1021 maize samples from different regions of Brazil, studied at Embrapa Swine and Poultry, are presented in Table 2.

Table 2. Composition of corn hybrids collected from different locations in Brazil

	Oil (%)	Crude Protein (%)	Lys (%)	Met (%)	Thr (%)	Trp (%)
Mean (%)	4.45	10.38	0.234	0.462	0.508	0.086
Minimum value (%)	2.87	7.70	0.153	0.275	0.325	0.057
Maximum value (%)	6.02	13.07	0.315	0.650	0.692	0.115

Passos (2004).

6. Causes of variation of the nutritional composition maize

The assessment of the concentration of nutrients in corn starts by the determination of dry matter content of the batch. This determination contributes to a fair negotiation between players and also serves as important information for the drying and storage of grain. On the other hand, crude protein content is not a good estimate of amino acid content in corn, because crude protein is calculated based on the amount of total nitrogen analyzed in the sample. Soil nitrogen fertilization increases nitrogen uptake by the plant, leading to an increase in nitrogen content of corn grain, as well as the crude protein content. However, this nitrogen will be stored predominantly in the form of ammonium and nitrate in the plant and grains, which are not used by monogastric animals such as swine. The use of N fertilizer is very important to increase corn productivity, but does not contribute to improve the nutritional quality of the grain. Furthermore, the increase in protein content of grain is related to the increase of zein, which has a lower biologic protein value. Since diets are formulated on the basis of digestible amino acids and not more for crude protein, analyzes for crude protein in corn are of little practical importance in the evaluation of batches and corn.

However, the oil content of corn can be used to estimate the energy value by considering that 1% increase in oil content above the average content in grain (about 3.5 %) provides 50 kcal of metabolizable energy increase in 1 kg of the grain (Lima et al., 2001). In general, the amount of energy released by the metabolism of fats and oils is 2.25 times greater than the amount of energy released by metabolism of carbohydrates.

Thus, increasing the oil content in corn reduces the cost of swine production. Usually, the increase in oil content is associated with the increase in the size of the germ or embryo. The oil is mainly concentrated in the germ of maize. Therefore, when there is more germ in the grain, there will be less endosperm.

7. Improving the standard quality of corn for animal feed

The improvement of the standard quality control of corn should be of constant concern. One suggestion to improve the classification is to increase the number of grades or classes in order to better discriminate different quality corn groups. This type of differentiation allows to a better use of corn, directing the top quality batches for the production of diets for young animals and sows. Corn defects and imperfections can contribute to the reduction in its energy value.

Corn density (mass/volume) is another parameter of great importance, but it not extensively used in practice. The higher the density, the greater the energy value of corn and lower the cost of swine production. The density is easily determined and used for many years for the marketing of winter cereals such as wheat, triticale and barley. Table 3 shows the relationship between the metabolizable energy of different types of corn according to the density.

Table 3. Metabolizable energy for poultry matches maize at different densities.

Density kg/hl	Damaged (%)	True Metabolizable Energy, kcal/kg
72	0.0	3962
71	0.3	3952
68	0.2	3900
62	0.2	3883
60	1.0	3681

In Table 4, it is presented a proposed classification for corn using current parameters and densities.

Table 4. Proposition classes for corn due to defects and density (Claudio Bellaver and Gustavo J. M. M. Lima).

Type	Maximum humidity, %	Minimum density, kg/m^3	(a) Damaged: insect attacked + sprouted grains (%)	(b) Fragmented and broken (%)	(a + b) Total damaged (%)
1	14	722	2	3	5
2	14	697	4	5	9
3	14	671	6	7	13
4	14	632	8	10	18
5*	above 14	below 632	> 8	> 10	> 18

*Class 5 corresponds to corn Below Standard.

8. Correlations between the nutrients in corn

Dorsey-Redding et al. (1991) collected 378 samples of corn hybrids for two years (1987 and 1988). They evaluated the correlation between the parameters crude protein, oil, starch, breakage susceptibility, density, water absorption index, hardness and 1000 grain weight. As it can be observed in Table 5, starch and oil showed positive correlation greater than 0.50.

Table 5- Correlation coefficients of chemical and physical parameters of maize produced in the years 1987 and 1988, respectively.

	EE	CP	CHO	SB	D	WAR	H
CP	0.16/SI						
CHO	0.58/0.48	-0.35/-0.44					
SB	-0.16/SI	-0.42/-0.42	SI/SI				
D	0.54/0.48	0.39/0.33	SI/-0.17	-0.15/ SI			
WAR	SI/-0.34	-0.29/-0.18	0.21/SI	SI/-0.14	-0.30/-0.48		
H	0.46/0.44	0.64/0.41	SI/-0.15	-0.23/-0.19	0.81/0.72	-0.32/-0.41	
P1000	-0.36/SI	SI/SI	-0.31/ SI	SI/SI	-0.16/SI	SI/-0.26	SI/SI

Dorsey-Redding et al. (1991).
Chemical analysis values adjusted to 15.5% moisture.
EE = Oil; CP = protein, CHO = carbohydrate, SB = susceptibility to breakage, D = density, WAR = water absorption ratio, H = hardness, SI = no information.

Parsons et al. (1998) evaluated the digestibility of amino acids with different levels of oil (3.8%, 5.2%, 6.0%, and 8.6%) in corn. These authors observed that samples with higher concentrations of oil (6.0% and 8.6%) had better true digestibility for aspartic acid, threonine, serine, glycine, proline, alanine, valine, leucine, arginine, cysteine and isoleucine. On average, samples with higher oil contents obtained a 10% difference in the values of true digestibility of amino acids. In the same experiment it was found that the availability of lysine and true metabolizable energy was higher in the sample with higher oil content. By analyzing the data of chemical analysis of corn samples, these authors found that the crude protein did not correlate with the levels of oil. However, increased levels of lysine (2.78%, 3.03%, 3.05% and 3.48%) were increased as the concentration of oil increased. The authors suggested the possibility that the germ protein presents better digestibility for poultry. Also, they suggested that it is possible that the higher oil content in the samples contributed to the increased availability of amino acids.

In a study conducted at Embrapa Swine and Poultry (Passos et al., 2004), 1021 corn samples (Table 6), were collected in different regions of Brazil, in 1999. These samples were individually homogenized and analyzed for dry matter, crude protein and oil through reflectance spectroscopy near infrared. Based on these results, the samples were classified in order of oil content and 80 samples were selected to represent the entire original population. These 80 samples were then sent for chemical analysis of oil, protein, crude fiber, ash and dry matter, according to methods recommended by AOAC (1995). They were also analyzed for amino acids by hydrolysis, followed by liquid chromatography. From the results, it was found that all correlation values analyzed between nutrients were low (Table 7).

Table 6 – Near Infra Red Spectroscopy Reflectance Analysis from 1021 maize samples collected at Embrapa Swine and Poultry

	Mean	SD	Minimum Value	Maximum Value
DM%	85.877	1.877	69.770	93.540
CP on DM%	10.534	1.328	6.591	15.886
EE on DM%	4.402	0.782	2.000	6.660

SD = standard deviation, DM = dry matter, CP = crude protein, EE = ether extract

Table 7 - Pearson correlation values between analyzed parameters in corn samples collected at Embrapa Swine and Poultry

	CP	EE	CF	Lys	Met	Thr	Trp	Val
CP		0.40	0.08	0.05	0.51	0.43	-0.31	0.60
EE	0.40		-0.09	-0.06	0.09	0.09	-0.02	0.26
CF	0.08	-0.09		0.03	0.05	-0.12	-0.20	0.10
Lys	0.05	-0.06	0.03		0.17	0.34	-0.13	0.62
Met	0.51	0.09	0.05	0.17		0.33	-0.04	0.47
Thr	0.43	0.09	-0.12	0.34	0.33		-0.14	0.55
Trp	-0.31	-0.02	-0.20	-0.13	-0.04	-0.14		-0.06
Val	0.60	0.26	0.10	0.62	0.47	0.55	-0.06	

CP = crude protein, EE = ether extract, CF = crude fiber; Lys = lysine; Met = methionine, Thr = threonine, Trp = tryptophan, Val = valine.

9. Formulating diets based on the variability of the nutritional composition of corn.

Based on the chemical composition of the 80 samples analyzed, Passos et al. (2004) formulated diets for pigs in phases 7-17 kg (pre-start), 17-30 kg (start), 30-70 kg (growing), 70-100 kg live weight (finishing), gestation and lactation. The formulations were done to meet the levels of ME, and digestible amino acids lysine, methionine, threonine and tryptophan. For gestation diets, crude fiber was also considered. Of the 80 samples of corn, twelve were discarded during the statistical analysis because they were considered out lier samples. To calculate the values of ME values, it was taken in account the study of Lima et al. (2001), in which every increase of 1% oil in the average composition of corn increased by about 50 kcal ME / kg. The prices of those ingredients were considered the ones practiced in August 18, 2003, for the state of Santa Catarina. Table 8 shows the mathematical models to explain the cost for each of the studied diet, as a function of the animal physiological stage and the nutritional composition of corn.

Table 8 - Models of feed prices obtained from the nutritional values of different batches of corn

Model for each physiological phase	R^2	Pr > F
lactation = 0.16953 – 0.04409×Trp – 0.01992×Lys – 0.00195×Thr – 0.00432×EE*	0.9866	<0.0001
gestation = 0.20364 – 0.00214×FB – 0.00280×FB²*– 0.00383×Lys – 0.00400×EE	0.9987	<0.0001
finishing = 0.15746 – 0.03286×Trp – 0.01594×Lys – 0.00304×Thr – 0.00318×Val - 0.00409×EE*	0.9771	<0.0001
growing = 0.17354 – 0.01296×Trp – 0.01438×Lys – 0.00557×Thr – 0.00433×Val – 0.00387×EE*	0.9717	<0.0001
start = 0.20744 – 0.02471×Trp – 0.01367×Lys – 0.00328×Thr – 0.00365×EE* – 0.00253×Val	0.9775	<0.0001
pre-start = 0.56609 – 0.01271×Trp – 0.01041×Lis – 0.00346×Thr – 0.00307×Val – 0.00289×EE*	0.9753	<0.0001

* Nutrients that contributes with more than 87% of the coefficient of determination (R2) of the respective model

Digestible amino acid values

Trp = tryptophan, Lys = lysine, Thr = threonine, Val = valine, EE = ether extract, CF = crude fiber.

The crude protein content did not influence the price of the diet. Diets were formulated to meet digestible amino acid requirements and these influenced the cost of the diet. The oil content of the grain was the parameter that had the most influence on the prices of diets (87% of the coefficient of determination of the models), except at the gestation phase, where the quadratic component of crude fiber was the most influent parameter. Thus, as the value of oil (EE) increased in the grain, the final price of the diet was reduced. The variation obtained from the highest to the lowest value of the diet, considering the production of 25 terminated pigs per sow /year, the difference between the higher cost (R$ 153.75) and lower cost (R$ 139.92), was R $ 13,83 per animal.

10. Variability of Soybean Strains

Soy is a legume cultivated in China since five thousand years ago. It was in the early twentieth century that it started to be grown commercially in the United States. In Brazil, the grain arrived with the first Japanese immigrants in 1908; however, the expansion happened in the 70s, with the growing interest of the oil industry and international market demand (Embrapa Soja, 2006).

Until 1975, the culture was produced in Brazil with seeds and technology brought from the United States, where climatic conditions are quite different from here. Therefore, it was only produced on a commercial scale in the Southern states, where Americans cultivars found similar conditions (Teixeira, 2003). From this stage, researchers have developed varieties adapted to cultivation in different latitudes, soil and climatic conditions, which allowed planting in all regions of the country.

Currently, it is found in the market numerous varieties of soybeans obtained after years of research in plant breeding. Table 9 shows the composition of the soybean and its parts, which according to Liu (1997) depends on many factors such as variety, planting date, geographic location and climate.

Table 9. Composition of soy and parts of grain

	Percent of grand total	Chemical Composition (% dry matter)			
		Protein	Carbohydrate	Oil	Ash
Grain	100	42	20	33	5
Cotyledon	90	43	23	29	5
Tegument	8	8.8	1	86	4.3
Hypocotyl	2	41	11	43	4.4

Adapted from Liu (1997)

Soybean grain has high nutritional value, because it contains sufficient amount of almost all essential amino acids in its proteins (Costa and Miya, 1972). Most cultivars of soybean have 30 to 45% protein, 15 to 25% oil, 20 to 35% carbohydrates and nearly 5% ash (Moreira, 1999).

Paula (2007), working with 34 different soybean genotypes, evaluated the concentrations of protein, oil, ash and carbohydrates in order to use the best cultivars in a soybean breeding program, observed that the percentage of protein and oil showed a negative correlation, which shows that selection for a particular character can cause a decline in another, constituting a problem to obtain materials with high concentrations of oil and protein (Table 10).

Table 10. Composition of soybean cultivars (natural matter basis)

Cultivar	Crude protein (%)	Oil (%)	Ash (%)	Carbohydrates (%)
Monarca	41.43[a]	19.76[c]	4.47[c]	23.63[b]
Elite	41.30[a]	18.72[c]	5.00[a]	23.80[b]
CS 801	38.26[c]	23.20[a]	4.40[c]	23.37[b]
CS 02449	37.31[c]	22.39[b]	4.63[b]	25.00[a]

Means followed by different letters in the same column differ (P <0.05). Adapted from Paula (2007)

Sinova Coca et al. (2008) evaluated soybean meal from Argentina, Brazil, Spain and USA. These authors observed significant differences in apparent digestibility of dry matter and amino acids for broilers according to the place of production (Table 11). It is important to emphasize that, in this case, the observed differences were due to factors others than inherent from the plant. The main reasons for differences were caused by the conditions under which the different sources of soybeans were grown, but above all, the soybean meal processing. In the case of soybean meal produced in Argentina and Brazil had higher fiber content as a function of the amount of soybean hulls added, reducing the digestibility.

Table 11. Composition and nutrient digestibility of soybean meal produced from 4 different countries

Component		Argentina	Brazil			Spain	USA
		Rosario	Ilheus	Paranagua	Santos		
DM	%	88.9	88.2	88.4	88.5	89.4	90.2
EE	%	1.3	1.9	2.1	1.9	0.8	1.1
FDN	%	9.7	10.8	8.2	10.8	7.6	1.0
CP	%	46.1	45.5	47.2	45.2	50.6	48.6
Lys total	%	6.01	5.87	6.09	5.51	5.83	6.26
Met total	%	1.36	1.32	1.31	1.34	1.25	1.35
Cys total	%	1.41	1.46	1.48	1.45	1.49	1.47
TIA[1]	mg/g	6.5	5.1	4.1	5.1	2.4	1.8
AU[2]	mg/g	0.03	0.01	0.02	0.04	0.00	0.00
IDP[3]		12	14	12	15	11	10
KOH[4]	%	80.9	80.5	84.2	81.6	85.2	84.3
Coefficient of apparent ileal digestibility							
DM	%	75.6[b]	75.2[b]	76.7[b]	76.8[b]	81.8[a]	82.3[a]
N	%	77.9[c]	79.0[bc]	79.2[bc]	77.3[c]	82.1[ab]	85.5[a]
Lys	%	80.9[b]	83.5[a]	84.4[a]	77.8[c]	84.0[a]	85.1[a]
Met	%	84.1[c]	85.7[bc]	86.5[b]	81.9[d]	86.3[b]	88.8[a]
Cys	%	55.1[b]	55.5[b]	56.4[b]	56.9[b]	62.9[a]	65.8[a]

[1]Trypsin inhibitory activity
[2]Ureatic activity
[3]Index of protein dispersion
[4]KOH solubility

[a, b, c, d]Means with different letters in the same row differ by Tukey test (P ≤ .05). Sinova Coca et al. (2008).

11. Breeding to Improve Amino acid Composition of Soy Protein

Genetic improvement of soybean cultivars with the objective of increasing the total protein in the seed brought doubts about to the amino acid profile in soy proteins. Although research shows the amino acid profile of the protein is maintained almost constant, recent reports with various cultivars, showed some differences in the percentage of amino acids in relation to total protein.

Yaklich (2001) compared soybean lines and varieties of high protein and concluded that although there was increase in protein content, the amino acid profile kept a steady relationship. However, Moraes et al. (2006) analyzed the chemical composition of two strains selected for high protein content and a strain with normal protein. The authors found that the content of amino acids differed among strains, except for the amino acids glycine, alanine, tyrosine and methionine (Table 12).

Table 12. Content (%) of protein and amino acids of defatted soybean lines UFVTN 105 and Isolinha 1 and 2 [(1)] on as dry matter basis

Amino acid	UFVTN 105		Isolinha 1		Isolinha 2		
	AAF	AAP	AAF	AAP	AAF	AAP	F test
Protein[1]	40.68		47.78		46.56		*
Lysine	3.20	6.83	3.65	7.11	3.30	6.56	*
Methionine	0.62	1.31	0.67	1.31	0.66	1.30	Ns
½ Cystine	0.48	1.03	0.50	0.97	0.54	1.06	Ns
Threonine	2.17	4.62	2.22	4.33	2.22	4.41	*
Valine	1.91	4.07	2.42	4.71	2.35	4.67	*
Arginine	3.45	7.37	4.14	8.08	3.77	7.48	*
Isoleucine	1.98	4.23	2.48	4.83	2.38	4.73	*
Ac. glutamic	8.59	18.34	8.58	16.73	8.76	17.4	*
Glycine	2.15	4.58	2.35	4.58	2.37	4.71	Ns

1 Mean values of two replicates; AAF: percentage of the amino acid in the defatted flour; AAP: percentage of the amino acid in the protein; ns = not significant; * = Significant at 5% probability, F test.
Adapted from Moraes et al. (2006)

These results show the importance of monitoring the chemical composition of raw materials that will be used in the feed. Therefore, this information will help to get the precise formulation of animal diets to meet their requirements without loss in animal performance and providing best economic results in the production.

11.1. Soy Proteins

The total protein fraction of soybean and other legumes is a complex mixture of globulins (40-60%), albumin (8-20%), prolamines and glutelines. Globulins and albumins are the main components (Bhatty, 1982) and their proportions vary among species and cultivars (Neves, 1995). In soybean, this fraction is known as reserve and metabolic proteins. The metabolic proteins include enzymes and structural proteins, and they are related to common cellular activities, including the synthesis of other proteins. The storage proteins, along with oil deposits, are formed during grain development.

Most of the soy proteins belong to reserve type (Muller, 1981) and they belong to the globulin group.

Soy protein is inferior in quality when compared to animal protein in relation to the content of sulfur amino acids, which are present in this legume in limiting amounts. Globulins contain high levels of the amino acid glutamine, asparagine and arginine, but containing low levels of sulfur amino acids methionine and cysteine (Smith and Grierson, 1982).

The proteins glycinin and β-conglycinin constitute approximately 70% of soybean storage proteins. Generally glycinin and β-conglycinin constitute approximately 40% and 30% of soy protein, respectively (Nielsen et al. 1989; Harada et al. 1989).

Research has shown that the β-conglycinin is more deficient in sulfur amino acids compared to glycinin, and there are differences in the contents of components (subunits) of these proteins in soybean lines with high protein concentration (Yaklich, 2001).

Fehr et al. (2003) studied different soybean cultivars in order to evaluate the influence of genotype, location and environment on the protein components of soybean glycinin, β-conglicine and their relationship. Crop year and local of planting did not affect significantly protein components, but the environment has changed significantly the protein components as well as the relationship glycinin / β-conglycinin, which ranged from 1.26 to 2.10, illustrating the importance of the environment on the composition of soybeans.

According Imsande (2001), genetic selection for soybean genotypes with higher percentages of methionine and cysteine has been significant. According to the author, it has been possible to increase up to 22% methionine and 28% cysteine in certain genotypes when compared to the content of methionine plus cysteine of the control genotype (Table 13).

Table 13. Amino acid composition of soybean seeds and improved control (as % of protein)

Amino acid	Genotype 1	Genotype 2	Genotype 3	Control
Lysine	7.19	6.27	6.06	7.14
Methionine	1.49	1.85	1.83	1.51
Cysteine	1.86	1.68	1.69	1.32
Threonine	4.65	3.53	3.55	4.71
Glycine	7.00	6.87	7.41	7.46

Adapted from Imsande (2001)

Krishnan (2005), in a review of the comparisons of the amino acid content of storage proteins in soybean glycinin and β-conglycinin, showed that the content of sulfur amino acids methionine and cysteine, present in glycinin, is substantially larger than the β-conglycinin (Table 14). Several researches have established that the accumulation of β-subunit of β-conglycinin is promoted by excess nitrogen or the sulfur deficiency (Paek et al., 2000; Imsande, 2003). Increase in the accumulation of β-conglycinin lowers the content of methionine and cysteine protein of soybean which seems to change the nutritional quality. However the content of lysine may have increased.

Nakasathien et al. (2000) evaluated the possibility of increasing the protein concentration of soybean seeds with nitrogen supplementation. According to the authors, during the stage of plant development, it is possible to increase the concentrations of seed protein by supplementing with super-optimal nitrogen doses. The increase would be the β subunits with a reduction in the ratio of reserve proteins Glycine / β-conglycinin. Paek et al. (1997) also found changes in the composition of soybean seed proteins when they studied different forms of nitrogen supplementation.

Table 14. Amino acid composition of some of the storage proteins of soybean β-conglycinin and glycinin (% protein)

	β- Conglycinin			Glycinin				
Amino acid	α'	α	B	Gγ1	Gγ2	Gγ3	Gγ4	Gγ5
				%				
Lysine	7.2	6.2	4.8	5.0	3.9	3.9	4.8	3.7
Methionine	0.3	0.2	0.0	1.3	1.5	1.1	0.4	0.6
Cysteine	0.8	0.9	0.0	1.7	1.7	1.7	1.1	1.2
Threonine	2.0	1.9	2.4	4.2	3.9	3.9	3.5	3.9
Valine	4.5	4.1	5.8	4.8	5.6	5.4	6.5	7.1
Glycine	4.7	4.1	4.3	7.4	7.3	7.3	6.3	7.9

Adapted from Krishnan (2005)

Therefore, it would be desirable if the soy used as food for humans contained larger amounts of glycinin in relation to β-conglycinin, due to be essential amino acid methionine. In the case of poultry nutrition, although methionine is the first limiting amino acid, when improved cultivars with higher content of sulfur amino acids are compared to standard cultivars, there are not major differences in feed costs, due to the negative correlation between lysine and methionine in the studies. Whereas most diets are based on corn and soybean meal, these ingredients complement each other. In this way, deficiency of soybean meal methionine is supplied in part by corn, and the lysine deficiency of corn is supplied by soybean meal.

12. Soy Processing

The nutritional quality of soybeans and its co-products can be improved with proper heat treatment which reduces the activity of the protease inhibitor and lectin. In general, the magnitude of which these inhibitors can be inactivated by heating is a function of temperature, heating time, used pressure, humidity and particle size. The control of all these variables requires extreme care in order to obtain a product of excellent nutritional value.

Neto (1992) described seven methods of processing the whole soybean: toasting in rotating drum, toasting by wet steam, toasting by dry steam, jet exploder, micronization, wet or dry extrusion and microwave. The extrusion is a very effective type of processing; it causes disruption of cell walls providing greater exposure of the nutrients and causing gelatinization of the starch component, protein denaturation and shear and restructuring of expanded products. In the processing of toasting, cooking is done using a heat source. The cooking time and temperature soybean vary according to the type of equipment used, requiring grinding of the final product. Micronization is the process where the raw soybean is subjected to indirect heating by steam at a temperature of ± 165 ° C for 2 to 3 minutes. After heating, the shell is removed from soybean grain which is then subjected to a milling process rolls (micronization) to achieve a final particle size ± 30 microns.

13. Nutrient Composition of Soy Products

The main source of protein and amino acids in poultry and swine diets is soybean meal. Because of its high quality protein, soybean meal is used as a comparative standard in the evaluation of alternative protein ingredients.

The nutritional quality of soybean products is not determined solely by the amount and availability of amino acids. However, it is highly affected by the processing conditions used to obtain these products.

Tables 15 to 21 present the major soy products and their nutritional values referenced in different composition tables.

Table 15. Composition of roasted whole soybean (on natural basis)

Nutrient	NRC 94-98	INRA 04	Degussa 06	UFV 11
DM (%)	90.00	88.60	88.00	89.94
CP (%)	35.20	35.20	35.89	36.42
EE (%)	15.00	19.20	-	18.32
CF (%)	-	5.60	-	6.03
ME Poultry kcal/kg	3300	3277/ 3373[1]	-	3263
ME Swine kcal/kg	3660	3636/ 3923[2]	-	3706
Total amino acids (%)				
Lysine	2.22	2.18	2.17	1.96
Methionine	0.53	0.53	0.47	0.45
Met + Cys	1.08	1.10	1.00	0.87
Tryptophan	0.45	0.45	0.48	0.47
Threonine	1.41	1.42	1.40	1.22
Arginine	1.66	2.60	2.64	2.45
Valine	1.66	1.68	1.70	1.47
Isoleucine	1.61	1.62	1.62	1.46

[1]Chickens and Roosters respectively

[2]Growing pigs and sows, respectively

Table 16. Composition of extruded whole soybean (on natural basis)

Nutrient	INRA 04	Degussa 06	UFV 11
DM (%)	88.10	88.00	89.94
CP (%)	34.80	35.79	36.42
EE (%)	17.90	-	18.32
CF (%)	5.20	-	6.03
ME Poultry kcal/kg	3349/ 3445[1]	-	3409
ME Swine kcal/kg	3564/ 3852[2]	-	3913
Total amino acids (%)			
Lysine	2.16	2.18	2.04
Methionine	0.53	0.48	0.46
Met + Cys	1.09	1.04	0.90
Tryptophan	0.44	0.48	0.50
Threonine	1.40	1.40	1.27
Arginine	2.57	2.61	2.51
Valine	1.66	1.70	1.56
Isoleucine	1.61	1.60	1.51

[1]Chickens and Roosters respectively
[2]Growing pigs and sows, respectively

Table 17. Composition of micronized soybean (on natural basis)

Nutrient	Biasi[1]	UFV 11
DM (%)	93.48	92.62
CP (%)	38.53	39.14
EE (%)	23.23	21.50
CF (%)	0.10	1.36
ME Poultry kcal/kg	-	3660
ME Swine kcal/kg	4136	4330
Total Amino acids (%)		
Lysine	2.31	2.26
Methionine	0.52	0.53
Met + Cys	1.05	0.97
Tryptophan	-	0.47
Threonine	1.53	1.31
Arginine	2.78	2.86
Valine	1.98	1.74
Isoleucine	1.87	1.71

[1]Informative Perdigão

Table 18. Composition of soy protein concentrate (on natural basis)

Nutrient	NRC 98	Degussa 06	UFV 11
DM (%)	90.00	88.00	90.22
CP (%)	64.00	62.55	63.07
EE (%)	3.00	-	0.45
CF (%)	-	-	2.77
ME Poultry kcal/kg	-	-	2621
ME Swine kcal/kg	3180	-	3586
Total Amino acids (%)			
Lysine	5.26	3.92	3.77
Methionine	0.90	0.84	0.85
Met + Cys	1.90	1.71	1.69
Tryptophan	0.65	0.81	0.80
Threonine	3.17	2.45	2.29
Arginine	3.40	4.67	5.02
Valine	3.40	3.00	2.85
Isoleucine	3.30	2.85	2.75

Table 19. Composition of soybean meal 45% (on natural basis)

Nutrient	NRC 94-98	INRA 04	Degussa 06	UFV 11
DM (%)	89.00	87.80	88.00	88.75
CP (%)	43.80	45.30	46.29	45.22
EE (%)	1.50	1.90	-	1.69
CF (%)	7.00	6.00	-	5.30
ME Poultry kcal/kg	2230	2573/ 2273[1]	-	2254
ME Swine kcal/kg	3380	3205/ 3373[2]	-	3154

Total Amino acid (%)				
Lysine	2.83	2.78	2.81	2.57
Methionine	0.61	0.64	0.62	0.55
Met + Cys	1.41	1.31	1.30	1.13
Tryptophan	0.61	0.59	0.63	0.58
Threonine	1.73	1.77	1.81	1.57
Arginine	2.06	3.36	3.37	3.17
Valine	2.06	2.18	2.18	1.97
Isoleucine	1.99	2.09	2.07	1.92

[1]Chickens and Roosters respectively

[2]Growing pigs and sows, respectively

Table 20. Composition of soybean meal 48% (on natural basis)

Nutrient	NRC 94-98	INRA 04	Degussa 06	UFV 11
DM (%)	90.00	87.60	88.00	89.18
CP (%)	47.50	47.20	47.64	48.10
EE (%)	3.00	1.50	-	1.45
CF (%)	-	3.90	-	4.19
ME Poultry kcal/kg	2240	2320/ 2368[1]	-	2295
ME Swine kcal/kg	3500	3301/ 3421[2]	-	3253
Total Amino acids (%)				
Lysine	4.20	2.89	2.85	2.71
Methionine	0.90	0.66	0.61	0.60
Met + Cys	1.90	1.35	-	1.22
Tryptophan	0.90	0.61	0.63	0.61
Threonine	2.80	1.83	1.83	1.65
Arginine	3.40	3.50	3.46	3.26
Valine	3.40	2.28	2.22	2.08
Isoleucine	3.30	2.17	2.12	2.05

[1]Chickens and Roosters respectively

[2]Growing pigs and sows, respectively

Table 21. Composition of soybean hulls (on natural basis)

Nutrient	INRA 04	Degussa 06	UFV 11
DM (%)	89.40	88.00	89.13
CP (%)	12.00	13.24	13.88
EE (%)	2.20	-	3.00
CF (%)	34.20	-	32.70
ME Poultry kcal/kg	-	-	858
ME Swine kcal/kg	1866/ 2488[1]	-	2207
Total Amino acids (%)			
Lysine	0.71	0.83	0.54
Methionine	0.14	0.15	0.11
Met + Cys	0.33	0.36	0.19
Tryptophan	0.14	0.15	0.06
Threonine	0.43	0.47	0.24
Arginine	0.59	0.74	0.65
Valine	0.51	0.60	0.38

Isoleucine	0.44	0.50	0.34

[1] Growing pigs and sows, respectively

13.1. True digestibility coefficients

The values of true digestibility coefficients are usually found in the tables of feed composition. However, due to the variation in experimental conditions (animal age, genotype, and feeding level) many of these tables present different information, which suggests the need to use suitable values obtained on Brazilian conditions to allow expression of the maximum growth potential of the animals (Table 22). The nutritional value of a feed protein depends on the amino acid composition, the digestibility and availability.

Table 22. True digestibility of amino acids of roasted soybean (ST), extruded soybeans (ES) and of soybean shelled (FS) for chickens[1]

Amino acids	NRC 94	INRA 04			UFV 11		
	FS	ST	ES	FS	ST	ES	FS
Lysine	91.00	81.00	88.00	91.00	86.8	90.4	92.5
Methionine	92.00	82.00	86.00	91.00	86.8	89.6	92.5
Met + Cys	87.00	79.00	81.00	88.00	83.6	86.0	89.8
Tryptophan	-	-	-	-	84.9	90.3	90.9
Threonine	88.00	79.00	88.00	89.00	83.6	87.4	88.7
Arginine	92.00	85.00	91.00	92.00	91.4	93.6	93.8
Valine	91.00	77.00	86.00	91.00	84.2	88.8	90.1
Isoleucine	93.00	79.00	87.00	92.00	86.8	89.8	90.8

[1]Coefficient expressed in %.

The composition and classification of Brazilian soy meal according to the Brazilian Compendium of Animal Nutrition (2005) is presented in Table 23.

Table 23. Composition and classification of Brazilian soy bean meal according the crude protein.

Composition	Soy bean meal (% CP)					
	42	44	45	46	47	48
Dry matter, min.	87.50	87.50	87.50	87.5	87.50	87.5
Crude protein, min.	42.00	44.00	45.00	46.00	47.00	48.00
Crude fiber, max.	9.00	8.00	7.00	6.00	4.50	3.50
Mineral matter, min.	8.00	7.00	7.00	7.00	6.00	6.00
Urea activity, max.	0.20	0.15	0.15	0.15	0.15	0.15
Solubility KOH, min.	80.00	80.00	80.00	80.00	80.00	80.00

14. Conclusions.

- There is not a good reason to do analysis of crude protein in maize when you consider swine nutrition. Information about oil, moisture and density will help to get good estimates of the energy value of corn. Determination of fractions by grain classification and monitoring mycotoxins will be very helpful;

- Once determined the oil content of corn in the batch, modify the composition of corn matrix in the formulation software, Consider that each 1% increase in the average content of oil, above 3.5%, is equivalent to increase 50 kcal per kg of maize;
- Improvement in the process of cleaning by separating integral corn grains from other fractions is desired. Whole cleaned grains, very dense and free of mycotoxins, should be considered as premium grains and directed to feeding sows and piglets;
- Segregation of corn for quality should be implemented. It is very economical if there is a set of bins which allows segregating different types of corn. It is better to have several small silos than just one big silo;
- Part of the variation in performance of the animals is caused by the lack of adjustment of the composition of ingredients;
- Currently, they are found in the market numerous varieties of soybeans. The composition of soybean grain depends on many factors such as genetics, fertilization management, geographic location and climate.
- The products from the soybean grain must be properly processed to obtain high biological value protein and digestible.
- The control of food quality allows formulating rations more efficient and economic.

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