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Soybean Meal in Poultry Nutrition

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Soybean Meal is Ideal Protein for Poultry

Soybean meal dominates the market for protein supplements for poultry. There are a number of reasons for this, including its consistency in nutrient content, its ready availability year-round, and its high content of crude protein. Because poultry producers desire high-energy diets, soybean meal is a superior value because no other common plant protein feedstuff exceeds soybean meal in crude protein content. Soybean meal matches or exceeds all other common plant proteins in both total and digestible amino acid content (Table 1). Soybean meal is perhaps the only common protein supplement that is typically included in poultry rations with no limitation as to the quantity used. When properly toasted to denature the trypsin inhibitors, there are no antinutritive factors to consider when formulating diets.

With the single exception of methionine, soybean meal is an almost ideal protein supplement for all types of poultry. When blended with corn or grain sorghum, soybean meal provides a good balance of all the essential amino acids needed by poultry except for methionine. However, methionine is economically provided by supplements produced by the chemical industry, allowing simple corn-soybean meal diets to effectively meet the amino acid requirements of the chick.

History of Usage in Poultry Diets

Given the overwhelming use of soybean meal in poultry feeds today, it is difficult to imagine that not much more than 50 years ago soybean meal was not the predominant protein source. In the early 1940s, manufacture of poultry feed was dominated by large flour millers, who used poultry feed as an outlet for wheat bran and other milling byproducts. Animal feedstuffs such as meat and bone meal and fish meal were favored as protein sources, not only for the protein they provided but also because they were rich sources of vitamins and minerals. The onset of World War II caused an increased demand for meat production, but the supply of imported meat proteins was limited. This focused attention on soybean meal as a potential protein supplement. Development of processes to toast the soybean meal to denature trypsin inhibitors, along with development of systems to produce vitamins by chemical synthesis and fermentation, allowed for the rapid increase in the demand for soybean meal. The final factor that allowed for greater use of soybean meal was the discovery of vitamin B12 in 1948. This ended the necessity for the inclusion of animal protein sources in feeds for monogastrics animals.

Soybean Meal and the Integrated Broiler Industry

The development of the integrated system of poultry production began in the 1950s when progressive individuals set up systems where they controlled the production of poultry from hatchery, feed manufacturing and processing. As poultry entrepreneurs established their own feed mills, they had no ties to the use of milling byproducts and sought the least expensive and most reliable sources of protein. The development of the linear programming system of feed formulation in the mid 1960s gave further impetus to increased use of soybean meal. As nutritionists began to use the computer to formulate feeds, they quickly found that simple diets based on corn, soybean meal, a methionine supplement, vitamins and minerals were not only effective but also the least-cost way to produce chickens. The rapid rise in poultry consumption (Table 2) has created an even greater demand for soybean meal, both in the United States and in other developing countries.

Soybean Meal Usage by the Poultry Industry

The poultry industry, including broilers, turkeys and laying hens, is the major user of soybean meal in the United States. Broilers and turkeys consume about 44 percent of all the soybeans used by livestock in the United States, with layers consuming an additional 7 percent, for a total of 51 percent (Table 3). Soybean meal is by far the dominant plant protein produced in the United States (Table 4). Few of the other plant proteins such as cottonseed meal or sunflower meal are used by the poultry industry. It is estimated that more than 98 percent of the plant protein used in poultry feeds is from soybean meal, with more than 66 percent of all the protein in poultry diets provided from soybean meal. Broilers have a high demand for crude protein and amino acids (Table 5), and thus need a protein source high in amino acids. Results from a recent industry survey indicate that typical amounts of soybean meal added are 29.4 percent in starter feeds, 23.8 percent in grower feeds and 17.8 percent in finisher diets.

Declining Usage of Meat Byproducts in Poultry Feed

Because of consumer concerns about the health and safety of animals fed rendered meat byproducts, coupled with the desire to reduce excessive phosphorus in poultry excreta, the amount of supplemental meat products in poultry feeds has dropped rapidly in the last two years. A recent agricultural survey indicated that animal proteins were added at less than 3 percent in poultry feeds, compared with about 5 percent in previous years. This will place further demands upon soybean meal as a protein source for poultry.

Proper Processing Necessary

Soybeans must be heat-processed to denature the various protease inhibitors, the chief of which are the trypsin inhibitors. Both over-processing, which ties up essential amino acids (especially Lysine), and under-processing are considered detrimental to the effective usage of soybean meal. The urease test, which measures the rise in pH when soybean meal is placed in a solution containing urea, is the most widely used method to monitor proper toasting of soybean meal for animal feed. Although there is no official urease level specified for poultry, the general recommendation is that the urease be less than 0.20 pH rise; however, recent studies have shown that as much as 0.50 pH rise is acceptable. Because the urease test does not detect over-processing, it is desirable to have some residual urease activity (0.01 to 0.05 units). Over-processing is best determined by measuring protein solubility in a KOH solution. It is suggested that KOH solubility in excess of 85 percent or less than 70 percent indicates under- or over-processing of the meal. However, studies are not consistent in this respect. Particle size of the meal plays a great role in the consistency of responses to the KOH solubility test.

Improving Nutritive Value Through Plant Breeding

As in many crops, the primary focus of plant breeders has been on increased yield or better resistance to disease. However, more attention is being focused today on improving nutritive value. Most of the focus has been on improving the methionine content, reducing the phytate-bound phosphorus, and reducing the oligosaccharide content.

Although the deficiency of methionine is often mentioned as a detriment to the use of soybean meal in poultry feeds, it is readily and economically produced by chemical synthesis, using toxic byproducts of the chemical industry to produce a desirable and economical feed supplement. Although plant breeders have expressed a desire to increase the methionine content of soybeans, it is not a high priority due to the economy of providing methionine in supplemental form.

Much of the phosphorus in soybeans is present in a complex, with phytic acid rendering the phosphorus in a poorly digested form for monogastrics animals. Phosphorus is one of the most expensive nutrients in a poultry diet, and livestock producers everywhere are becoming more concerned about the effects of phosphorus in the manure upon eutrophication of surface waters. Although commercial phytase supplements are available, their cost presently is greater than the amount of phosphorus they release. Genetic soybean mutants have been found with a lower percentage of their phosphorus bound in the phytate form. To date, however, the productivity of low-phytate soybeans has been poor. Soybean meal contains one of the highest levels of phosphorus of all plant proteins, so genetic improvements in this area would be highly beneficial to the poultry industry.

The other major factor that should be addressed by either selective breeding or by modifications in processing procedures is the soybean carbohydrate. Much of the carbohydrate in soybeans is present as the oligosaccharides known as raffinose and stachyose. These require the enzyme alpha-galactosidase that is absent in poultry. Because carbohydrates constitute approximately 35 percent of the soybean meal, the presence of these poorly digestible carbohydrates minimizes the amount of metabolizable energy the chick can derive from the meal. In addition, the excreted carbohydrates are very sticky, leading to a wet, sticky litter that may adhere to the bottom of the feet and possibly lead to leg disorders. These may be removed from the soybean meal by ethanol extraction, as done in the production of high-protein soy isolates. As it is unlikely that the soybean processing industry will markedly modify its processing procedures, breeding programs that concentrate on reducing oligosaccharides in the seed may be the most desirable route.

Conclusions

Soybean meal is and will continue to be the preferred protein supplement for poultry feeds. With the probable decline in the use of animal byproducts, even more soybean meal will be used. Genetic improvements in reducing the phytate-bound phosphorus, and reduction or elimination of oligosaccharide carbohydrates are the most important economical traits that should be addressed.

Table 1. Typical Nutrient Composition of Commonly Used Plant Protein Sources for Poultry

AS-FED BASIS	Soybean Meal 44	Soybean Meal 46	Soybean Meal 48	Sunflower Meal 34	Rapeseed Meal 00	Peanut Meal	Sesame Meal	Cottonseed Meal	Safflower Meal
Dry matter %	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Crude protein %	43.50	46.00	49.00	34.00	35.50	50.00	45.00	40.00	26.00
Crude fat %	1.50	1.50	1.50	1.50	2.50	1.50	1.00	1.50	1.50
Crude fiber %	7.50	5.00	3.50	23.00	11.00	10.00	7.00	13.50	30.00
ME, kcal/g	2.21	2.33	2.46	1.30	1.79	2.18	1.93	1.57	1.15
TOTAL AMINO ACIDS (%)									
Lys	2.74	2.89	3.07	1.18	2.03	1.70	1.21	1.52	0.88
Met	0.60	0.63	0.68	0.72	0.75	0.50	1.26	0.60	0.43
Cys	0.63	0.67	0.71	0.55	0.89	0.62	0.73	0.64	0.42
Thr	1.72	1.82	1.94	1.21	1.53	1.28	1.57	1.28	0.82
Trp	0.59	0.62	0.66	0.45	0.43	0.50	0.63	0.49	0.52
Arg	3.28	3.45	3.66	2.68	2.13	5.68	5.01	4.12	2.50
Gly	1.86	1.93	2.07	1.92	1.77	2.75	2.29	1.60	1.48
Ser	2.25	2.40	2.54	1.40	1.52	2.25	2.04	1.68	1.17
His	1.17	1.23	1.31	0.82	0.94	1.16	1.08	1.08	0.73
Ile	2.13	2.28	2.45	1.25	1.47	1.73	1.71	1.36	0.99
Leu	3.40	3.55	3.83	2.12	2.46	2.98	3.02	2.28	1.69
Phe	2.22	2.36	2.52	1.50	1.40	2.44	2.02	1.92	1.27
Val	2.19	2.36	2.50	1.78	1.92	2.07	2.20	1.88	1.38
DIGESTIBLE AMINO ACIDS (%)									
Lys	2.38	2.58	2.74	1.02	1.62	1.30	1.10	0.91	0.61
Met	0.53	0.57	0.62	0.67	0.68	0.44	1.19	0.47	0.37
Cys	0.50	0.56	0.60	0.44	0.73	0.46	0.65	0.33	0.28
Thr	1.42	1.59	1.70	1.04	1.26	1.09	1.42	0.85	0.58
Trp	0.49	0.52	0.56	0.41	0.38	n.a	n.a	0.32	0.47
Arg	2.97	3.24	3.43	2.56	1.97	5.26	4.78	3.56	2.25
Gly	1.48	1.66	1.78	1.47	1.52	1.99	2.03	1.03	1.02
Ser	1.90	2.15	2.28	1.22	1.30	1.92	1.85	1.13	0.80
His	1.04	1.12	1.20	0.73	0.81	0.98	1.03	0.85	0.63
Ile	1.87	2.05	2.21	1.34	1.27	1.56	1.58	0.93	0.79
Leu	2.96	3.18	3.43	1.93	2.19	2.71	2.80	1.64	1.36
Phe	1.95	2.14	2.29	1.39	1.26	2.24	1.90	1.57	1.05
Val	1.82	2.08	2.21	1.56	1.54	1.84	1.98	1.35	1.10

Table 2. U.S. Meat Consumption (Pounds Per Capita)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
RED MEAT											
Beef	68.6	65.4	63.9	63.7	62.8	61.5	63.6	64.4	65.0	63.8	64.9
Veal	1.1	1.0	0.9	0.8	0.8	0.8	0.8	0.8	1.0	0.9	0.7
Pork	49.8	48.4	46.4	46.9	49.5	48.9	49.6	49.0	46.0	45.6	49.1
Lamb	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.9
POULTRY											
Chicken	39.6	40.9	42.4	44.2	46.7	48.5	49.3	48.8	49.8	50.9	51.6
Turkey	12.4	13.1	13.8	14.1	14.1	14.0	14.1	14.1	14.6	13.9	14.2
FISH AND SHELLFISH	15.1	15.6	15.0	14.8	14.7	14.9	15.1	14.9	14.7	14.5	14.5

Source: USDA and National Marine Fisheries Service

Table 3. Utilization of Soybean Meal by Livestock in the United States

SPECIES	MILLION METRIC TONS	PERCENT OF TOTAL
Poultry	12.36	44
Swine	6.69	24
Beef	3.45	13
Eggs	1.88	7
Dairy	1.61	6
Pet foods	0.74	3
Aquaculture	0.18	1
Other	0.65	2
TOTAL	**27.56**	**100**

Source:
United Soybean Board
1999/2000

Table 4. Production of Processed Protein Sources and Byproducts in the United States (1,000 metric tons)

FEED	1995	1996	1997
High Protein Oilseed Meals			
Soybean	24114	24786	26208
Cottonseed	2685	2815	2682
Linseed	104	99	111
Peanut	164	128	86
Sunflower	434	419	482
Canola	1171	1101	1552
Total oilseed meals	28672	29348	31121
Animal Protein			
Tankage and meat meal	2300	2525	2269
Fish meal and solubles	236	274	228
Milk products	408	336	375
Total animal proteins	2944	3135	2872
Grain Protein Feeds			
Gluten feed and meal	1064	3471	3247
Other			
Wheat millfeeds	6689	6601	6575
Rice millfeeds	602	495	378
Alfalfa meal	229	225	250
Fats and oils	1137	1157	1319
Miscellaneous byproduct feeds	1137	1432	1446
Total other	10075	9910	9968
GRAND TOTAL	41536	45864	47208

Source: Feedstuffs Reference Issue, July 30, 1999

Table 5. Protein and Amino Acid Requirements of Broiler Chickens[1]

NUTRIENT	UNIT	0 - 3 WEEKS	3 - 6 WEEKS	6 - 8 WEEKS
Metabolizable energy[2]	Kcal/kg	3200	3200	3200
Crude protein[3]	%	23.00	20.00	18.00
Arginine	%	1.25	1.10	1.00
Glycine + Serine	%	1.25	1.14	0.97
Histidine	%	0.35	0.32	0.27
Isoleucine	%	0.80	0.73	0.62
Leucine	%	1.20	1.09	0.93
Lysine	%	1.10	1.00	0.85
Methionine	%	0.50	0.38	0.32
Methionine + Cystine	%	0.90	0.72	0.60
Phenylalanine	%	0.72	0.65	0.56
Phenylalanine + Tyrosine	%	1.34	1.22	1.04
Proline	%	0.60	0.55	0.46
Threonine	%	0.80	0.74	0.68
Tryptophan	%	0.20	0.18	0.16
Valine	%	0.90	0.82	0.70

[1]Source: National Research Council, 1994

[2]These are typical energy concentrations. Different energy values may be appropriate depending upon local ingredient prices and availability.

[3]Broiler chickens do not have a requirement for crude protein per se. However, there should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of dietary dispensable amino acids. Suggested requirements for crude protein are typical of those derived with corn and soybean meal-based diets, and levels can be reduced when synthetic amino acids are fed.

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The United Soybean Board's Better Bean Initiative and the Poultry Industry

by Nick Bajjalieh, Ph.D.

As noted in Dr. Waldroup's article included in this newsletter, the poultry industry is the largest end-user of soybean meal within the United States. The needs of the poultry industry were an important consideration when the United Soybean Board (USB) began to identify soybean meal target traits as part of the Better Bean Initiative (BBI).

USB's goal of increasing demand for U.S.-produced soybean meal is based on further enhancing what Dr. Waldroup described as a product of "superior value." In fact, BBI is designed to address the three areas of improvement suggested by Dr. Waldroup, including improved carbohydrate characteristics, reduced levels of phytate-bound phosphorus and increased sulfur amino acid levels. The specific "primary" meal targets for BBI are outlined below.

As noted at the bottom of the table, a stipulation of BBI is that, as we focus on improving one or more compositional characteristics, we do not add cost by degrading other economically relevant components. These include other meal characteristics, oil level and its composition for the whole soybean, as well as crop yield per acre. As we move forward, appropriate evaluations will be an integral part of the process. USB encourages input from the feed industry throughout this ongoing process.

Costs associated with the system utilized to deliver the enhanced meal product to its end-user are another important consideration. A tenet of BBI is the commoditization of U.S. soybeans bearing BBI targeted traits. While the early phase-in period for each new generation of soybeans with enhanced traits will require some level of identity preservation (IP) and associated cost, the ultimate end game is its commoditization. Utilizing the commodity system will allow BBI enhanced soybean products to be brought through the value chain with significantly reduced system costs. Thus, more of the value actually created will be available to improve the value chain.

Better Bean Initiative Primary Meal Trait Targets

Primary Traits	Changes in High Protein Meal From	To	Coefficient of Change	Maximum Displacement of Selected Ingredient for Each 100 lbs of Meal Used
Increased Methionine + Cystine	1.4%	2.1%	1.5X	0.7 lb DL Methionine
Reduced Phytate-Bound Phosphorus	0.4%	0.2%	0.5X	0.95 lb Monocal Phos.
Increased Metabolizable Energy (ME)	^ 150 kcal ME/lb		Swine: Approx 1.1X	4.2 lbs Added Fat
(From Improved Carbohydrate Characteristics)			Broilers: Approx 1.13X	

NOTE: Must insure that improvements in one area do not result in overriding losses in others.

The above compositional improvements represent inherent added value. Such inherent value is translated into economic value only in the context of a given application. Depending on the specific trait, applications include nutritional, environmental and production/management opportunities, as pointed out by Dr. Waldroup relative to the association between soybean carbohydrate and wet sticky litter. The economic value represented by a trait is a function of the application(s) addressed and their economic value in the context of a defined situation.

Net economic value realized defines and drives this type of opportunity. Added costs dilute the gross value of a trait package, thereby reducing net added value. Therefore, added costs must be identified and controlled. Otherwise, traits that represent significant gross end-use value may become commercially unsustainable … an opportunity lost!

The marketplace ultimately determines economic value and how it is distributed throughout the chain. BBI seeks to add inherent value to soybean meal produced using U.S.-grown soybeans, and bring it to market with minimal added cost. If successful, BBI will add considerable value to the U.S. soybean value chain. The poultry industry stands to be a principal extractor of the meal value created and, with it, a beneficiary of this initiative.