Critical Amino Acid Value (CAAV)

Amino acid based assessment tool for soybean meal value

David R. Gast, Ph.D.

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The soybean has a long history, dating back over 5000 years to use as a human food source in China. The use and recognized value of soybean meal in livestock rations is a short, relatively recent addition to this history. Today, soybeans represent the pre- dominate oilseed crop in the world, utilized as a source of oil and protein for livestock and humans. High crude protein, high amino acid quality and high digestibility make soybean meal a preferred source of supplemental protein in the livestock rations.

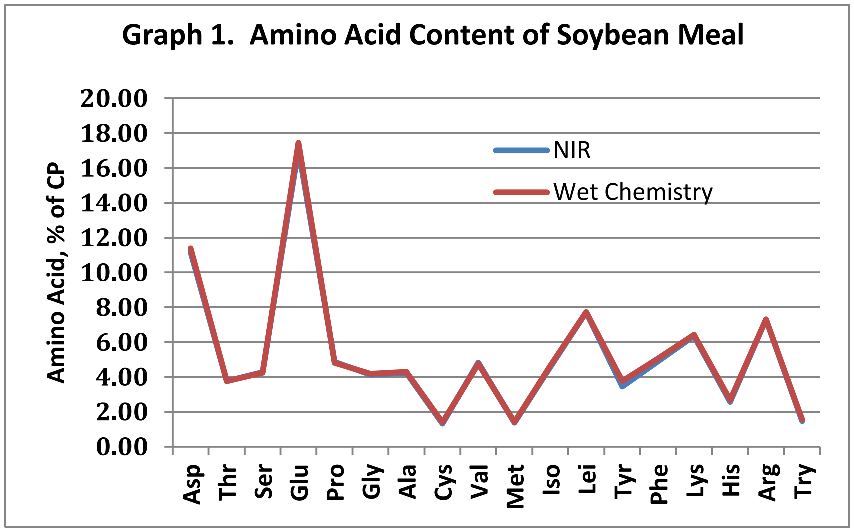
An early nutritional reference to what became known as protein was the concept of "animal substance" thought to make up animal tissues and required for survival. In the early 1830's Jean Boussingqult proposed the feeding value of plant products should be ranked based on their nitrogen content which had been identified as a critical component of feedstuffs fed to animals. Gerritt Mulder, in 1838, reported a similarity in the basic formula of animal substances relative to carbon, hydrogen, nitrogen and oxygen atoms, with the substances differing only in the number of sulfur and phosphorus atoms associated with them. As a result of this work the Swedish chemistry Jacob Berzelius first used the term "protein" to describe animal substances. Protein research of the late 19th century reported differences in livestock performance between various protein sources however it was not until the early 20th century that nutritional quality and amino acid content of proteins became an area of research. Research of Osborne and Mendel (1914) was among the first to discuss the essentiality of specific amino acids and the impact of limiting amino acids on animal performance. As stated in an early research report which provided amino acid data for numerous feed ingredients "It has become quite evident that the nutritive value of the proteins of feeding stuffs depends upon the quality and the quantity of the amino acids which compose the proteins and not upon the total nitrogen which they contain" (Grindley, 1917). Grindley further stated the importance of accurately identifying amino acid levels in feedstuffs for the purpose of formulating efficient rations for maintenance and growth in animals. The research of Rose (1938) and his associates represented a monumental effort including: the isolation and identification of the previously unknown amino acid threonine; the addition of seven amino acids to the indispensable amino acid classification and established minimum amino acid requirements for growing rats. The indispensable nature of specific amino acids was known for numerous livestock species however minimum requirements had not been identified. Methods employed by Rose and associates helped to stimulate the ongoing effort to establish amino acid requirements for a broader range of livestock species. Research over the next several years resulted in proposed minimum dietary amino acid levels requirements for poultry (Almquist, 1947) and swine (Shelton, et al., 1943; Beeson, et al., 1949; Mertz, et al., 1949; Shelton, et al., 1951). Research during the 1950's continued to expand and refine the amino acid requirement data however this information was slow to be adapted by the commercial feed industry which continued to rely on multiple ingredient rations, formulated by hand and developed from past performance experience.

The development and eventual adaptation of linear feed formulation programs, beginning in the 1950's, provided a tool which allowed nutritionists to considered a wider range of ingredients and formulate rations with a larger number of specific nutrient requirements. The complexity of feed formulation has dramatically increased over the years with the availability of improved feed formulation programs and accurate/rapid feed analytical techniques. The availability of feed grade methionine and lysine in the

1960’s and tryptophan and threonine in the 1980’s provided additional tools for the commercial feed manufacturer to utilize the amino acid requirement data in formulating best cost rations that provide the required nutrients for optimum animal performance. Today, formulating rations to specific amino acid content is a widely accepted practice for many animals and yet crude protein remains a primary factor in determining initial market value of protein ingredients such as soybean meal.

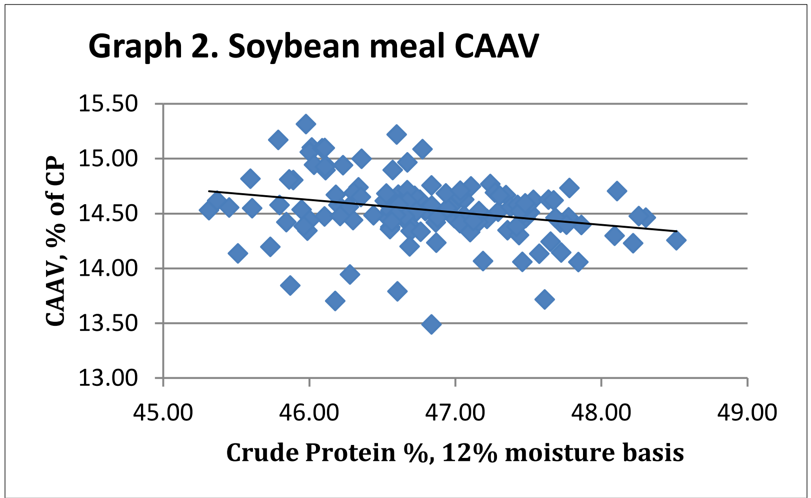
Research continues to improve the knowledge of amino acid requirements for a wider variety of animals though refinement of known requirements for specific growth/performance stages and increasing the number of amino acids for which requirements have been identified. Amino acid requirements have also been shown to differ between genetic strains of swine and poultry at the same production stage. Segregation of livestock by sex, stage of production and genetics enhance the opportunity to formulate specific amino acid density rations resulting in the level of efficient, high production realized in modern agriculture today. A critical component of amino acid ration formulation remains the accurate identification of amino acid content of feed ingredients, as stated by Grindley in 1917. Information on the amino acid content of feedstuffs has increased with the development and enhancement of laboratory analytical procedures. Initial amino acid analysis of feed ingredients was inhibited by procedures that were often complex, costly, and/or time consuming. As a result of these analytical challenges amino acid data for a feed ingredient was often based on as little as a single analysis. An early perception of the relationship between crude protein and individual amino acids assumed individual amino acids to be proportional to crude protein and increase or decrease in concentration in direct proportion to changes in the more easily analyzed crude protein content. Improvements in the accuracy, speed and cost of analysis has increased the amount of amino acid data for feed ingredients and shown the early concept of direct proportionality of crude protein content to individual amino acid content to be incorrect in many cases. However the application of this early proportionality concept continues to be widely utilized in assigning the amino acid profile of feed ingredients found in the ingredient libraries of feed formulation programs.

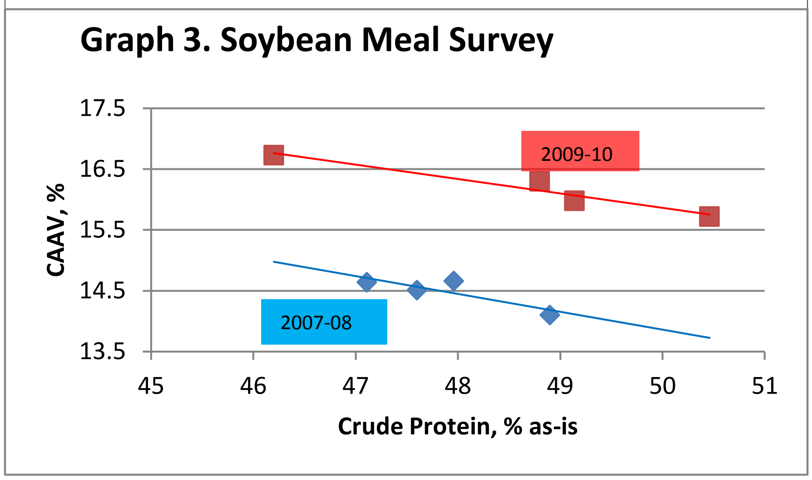
Crude protein analysis is a procedure which is relatively inexpensive, quick and readily available from commercial feed laboratories. Crude protein content, as a nutrient, continues to be used as a bench mark to differentiate value between different lots of the same ingredient, as evidenced by reference to crude protein levels in the trading rules for ingredients such as soybean meal which were initially adopted in 1933. At that time, availability of data and the simplicity of a single numeric nutrient value made crude protein a desirable benchmark. It has since been recognized the building blocks of crude protein (amino acids) are the critical component in meeting the animal’s requirement. The development of NIR (Near Infrared) technology has provided the feed industry a means to obtain analytical data for feed ingredients quickly. Concerns with accuracy of data have limited the use of this technology in the past, particularly in the case of amino acids. Wet chemistry procedures remain the standard bench mark methodology for determining the amino acid content of ingredients. Expansion and enhancement of NIR equations have resulted in improved accuracy and reliability in the prediction of amino acid content. Analytical results of 135 split soybean meal samples show strong agreement between the results generated by wet chemistry procedures and NIR procedures (Graph 1. USB Project 1303) and supports the use of NIR procedures for analyzing soybean meal amino acid content.



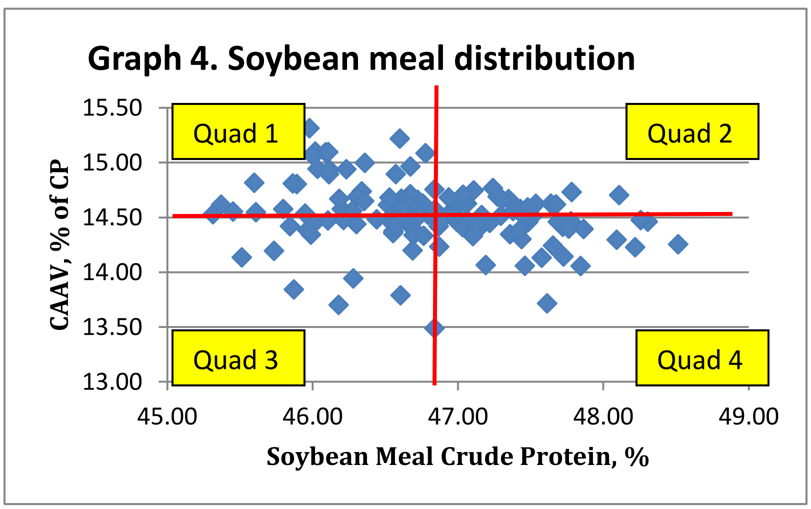
Crude protein provides a simple value with which to estimate ingredient value in the market place however is does not provide the complete story. Protein is fed to livestock to supply amino acids and crude protein data does not provide information of the amino acid content within that protein, unless the assumption of direct proportionality of amino acid to protein is made based on prior data. Analytical data of like ingredients with differing crude protein contents has shown the amino acid content is not directly proportional in many cases. Recognizing the short-coming of crude protein as an indicator of nutritional value, many attempts have been made to provide numeric indications of amino acid quality. Chemical score (Mitchell and Block, 1946) was an early calculation to provide information on the amino acid quality of a protein source. The chemical score of a protein represents the concentration of the most or first limiting amino acid contained in that protein relative to the requirement of that amino acid by the animal for which the ration is being formulated. Chemical score of a protein provides information on one amino acid relative to one specific requirement and provides no information regarding the concentration of other amino acids which may be only slightly more adequate or even excessive relative to the requirement. The chemical score will vary for different livestock species and possibly for different growth/production stages of the same species. Essential Amino Acid Index (EAAI) represents a more complex protein scoring method which evaluates the quantity of each essential amino acid in a test protein relative to the level of that specific amino acid in the target or reference protein to generate a single numeric value (Oser, 1959). EAAI is an improvement in describing the biologic value of a protein in that it considers all of the essential amino acids but still needs a calculation for each set of requirements.

Amino acid analysis reports typically provide data for 18 to 22 individual amino acids, 10 of which are generally classified as essential amino acids (EAA). Of these 18-22 amino acids, five can been considered of particularly critical importance. The five critical amino acids are lysine, methionine, threonine, tryptophan and cysteine. Lysine, methionine, threonine and tryptophan have been identified as EAA and among the first limiting of the EAA amino acids in rations. Lysine, methionine, threonine and tryptophan also represent amino acids which are commercially available, in synthetic form, for use in livestock feed formulation. Cysteine, classified as a non- essential amino acid, has a well documented sparing effect for methionine in the ration and more recently been suggested as a semi-essential based on data which indicates a requirement in the presence of specific heath disorders. The concentration of these five critical amino acids has a significant impact on the value of individual feed ingredients when used in livestock rations.





Expressing the sum of these five critical amino acids, as a percentage of the crude protein, provides numeric value (CAAV= critical amino acid value) which provides an indication of protein quality and economic value in rations. A review of wet chemistry amino acid data (USB Project 1303) for soybean meal shows an inverse relationship of CAAV with crude protein (Graph 2). As the protein content of soybean meal increased the CAAV (% of CP) declined (slope = -0.1134). Average crude protein content of soybean meal samples collected from 63 northern and southern US soybean processing plants for the 2007-2010 crop years shows differences between crop years with higher average crude protein for the 2009 and 2010 crop years than 2007 and 2008 (Graph 3. Minnesota Soybean Research & Promotion Council). CAAV's, compared within years, shows a similar decline as crude protein increases in agreement with the USB Project results.



Sorting the USB data set into four quadrants based on median crude protein (46.74%) and CAAV (14.53%) percentages (Graph 4) shows distribution of soybean meal samples which were less than or equal to the median protein and above the median CAAV (Quad 1); above the median protein and CAAV (Quad 2); less than or equal to the median protein and CAAV (Quad 3) or above median protein and less than or equal to the median CAAV (Quad 4). The distribution of soybean meal samples was 31% in Quad 1, 18% in Quad 2, 19% in Quad 3 and 32% in Quad 4. Based

Table 1. Nutrient profile of soybean meals

	Protein	Lys	Met	Try	Thr	Cys	CAAV, %
Quad 1	46.24	6.55	1.42	1.60	3.79	1.41	14.79
Quad 2	47.25	6.45	1.42	1.57	3.83	1.39	14.67
Quad 3	46.28	6.36	1.38	1.54	3.68	1.35	14.32
Quad 4	47.43	6.33	1.39	1.52	3.74	1.36	14.35
Average	46.81	6.43	1.40	1.56	3.76	1.38	14.53

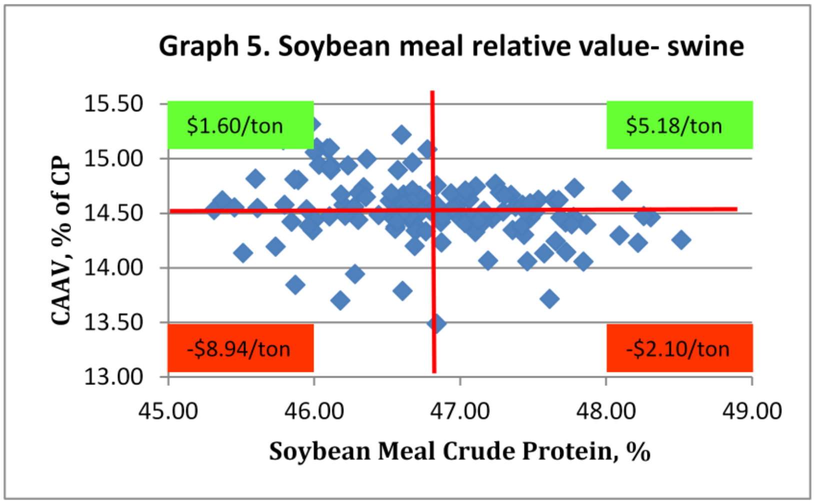
on the sorting criteria, the crude protein content is highest for samples in quadrants 2 and 4 and CAAV highest in quadrants 1 and 2 (Table 1). Soybean meal samples in quadrant 1 could be considered to have higher quality protein based on the amino acid content as these 5 critical amino acids which make up a higher proportion of the protein. Amino acids also make up a higher proportion of the crude protein nitrogen for the soybean meal found in the quadrant 1 at 97.91% compared to quadrants 2, 3 and 4 at 97.80%, 95.68% and 95.92%. Using the amino acid content of lean pork and broiler breast meat as reference protein targets the EAAI was calculated for the soybean meals from each quadrant. EAAI values indicates similar values for the quadrant 1 and 2 soybean meal and lower values for the soybean meals of quadrant 3 and 4 (Table 2). The soybean meal represented in quadrant 4 has the highest average protein content but may be lower in nutritional value compared to the lower protein meal of quadrant 1 which is similar in nutritional value to the high protein meal of quadrant 2 for swine and broiler rations based on the EAAI values.

Table 2. EAAI Values for Soybean Meals

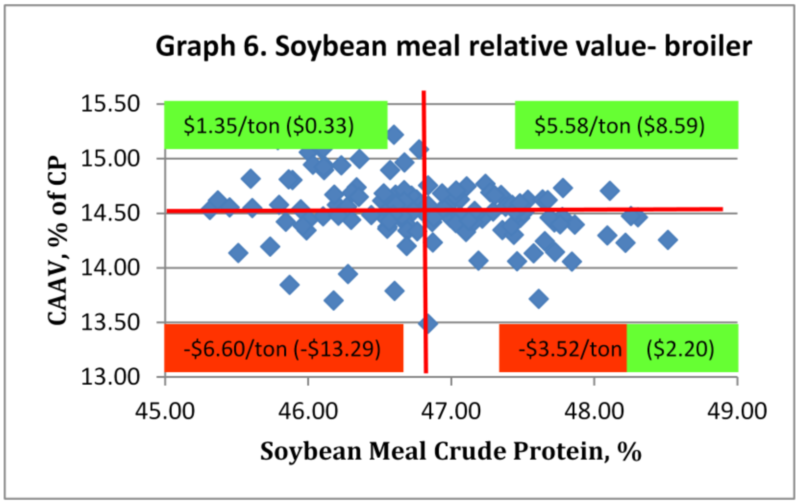
	Quad 1	Quad 2	Quad 3	Quad 4
Pork	85.0	85.0	84.0	84.0
Broiler	79.0	78.9	77.9	77.7

Crude protein and protein scores, such as chemical score or the more complex EAAI, have been and continued to be used as benchmarks to compare value of ingredients. As a result of the feed formulation programs used today, feed protein sources are seldom fed to livestock as single ingredients but as part of a multiple ingredient ration. Feed formulation programs allow the nutritionist to create a blend of ingredients which will provide the desired nutrient content in a cost effective manner. Formulation programs select a blend of ingredients that will compensate for the nutrient deficiencies and excesses of individual ingredients to create a ration which meets the established minimum and maximum nutrient specifications of the formula. The value of an ingredient in a formula is based on the cost of that ingredient and how well the content and balance of nutrients of that ingredient match the ration nutrient specification relative to the cost and nutrient content and balance of the other ingredients offered to the formula. In the process of generating formulas, formulation software provides value assessments of individual ingredients relative to other ingredients for each set of formula specifications. For ingredients included in a ration, information is provided on the amount of price increase or decrease needed to result in a decrease or increase in the inclusion rate of that particular ingredient. Ingredients offered but not included in a formula are priced above their nutrient value for that particular formula. For these ingredients the price required for it to be included in the formula is provided. This price is referred to as the ingredient's shadow price which represents the maximum value of that ingredient based on its nutrient profile relative to the nutrient profile and price of the other ingredients offered.

The shadow price of each individual soybean meal represented in Graph 1 was determined when offered to a swine grower and a broiler starter ration. Prices used for all ingredients reflect upper Midwest market prices for the week of December 2, 2013. Individual soybean meals were compared to a base soybean meal which was assigned the average nutrient content of all soybean meal samples in the data set. Higher protein content soybean meal is generally considered to be greater in value by the marketplace. As single selection criteria, crude protein may lead to incorrect conclusions of value. It should be apparent that soybean meal containing high protein and high CAAV content would be of higher value as was determined in swine grower and broiler starter formulations (Quad 2 of Graph 5 and 6). As a result of the protein content and amino acid profile of the soybean meals in quadrant 2 (high protein and high CAAV) the average value of those soybean meals was $5.18/ton greater in value than the soybean meal containing the overall average amino acid content (Graph 5). Lower protein has been assumed to mean lower in value, however soybean meals with an above average CAAV had a $1.60/ton greater value than the average meal despite being lower in protein (Quad 1). High crude protein content of soybean meal does not guarantee higher feeding value as indicated for the higher protein soybean meals of Quad 4 which had a $2.10/ton lower value in the swine grower ration as a result of the low CAAV in those soybean meals. In this evaluation soybean meals with low protein and low CAAV, as would be expected, did have lower value suggesting an $8.94/ton discount to the average soybean meal. Reviewing the data in Graph 5 may appear to favor simply selecting on the basis of crude protein as the added value of meals in Quad 2 was the greatest and the discounted value of the Quad 4 soybean meals is substantially less than the lower protein meals in Quad 3. However it is important to remember the distribution of soybean meal samples across the quadrants. Of the soybean meals in this data set 67 are represented in the high protein Quads 2 and 4 with 68 samples in the low protein Quads 1 and 3. Within the high protein meals nearly two thirds (64%) of those high protein soybean meals had a low CAAV and lower economic value to the formula. Sixty two percent of the low protein soybean meals had above median CAAV and greater economic value than the average soybean meal.



The value of a specific soybean meal to a formula will be dependant of the nutrient profile of that soybean meal and the nutrient minimums and maximum restrictions established for that formula. The ingredient value will change when nutrient restrictions change, which is demonstrated in the broiler starter evaluation (Graph 6). The value of soybean meal was determined in a 0-14day broiler starter ration using the nutrient specifications of two different genetic strains. The projected value of the soybean meals from the quadrants followed a similar pattern previously observed in the swine grower evaluation (relative value of soybean meals for second genetic strain listed in parenthesis on Graph 6). The soybean meals of Quad 1 had increased value over the average soybean meal for both broiler strains, at $1.35/ ton for strain 1 and $0.33/ton for strain 2. The value of high protein meals in Quad 4 was significantly different for stain 1 which suggested a discounted value of $3.52/ ton compared to value in a starter ration for stain 2 which suggested a value $2.20/ton greater than the average nutrient profile soybean meal. In this evaluation the potential of CAAV as a tool to assess soybean meal value is demonstrated. Selecting soybean meals based on high CAAV resulted in selecting soybean meals with above average value when used in swine grower and broiler starter rations. Crude protein, used as sole selection criteria, would not result in consistently selecting the higher value soybean meals.



For soybean meal to be efficiently and cost effectively included in rations a complete nutrient profile, including full amino acid profile, is needed by the nutritionists. While a necessity for the nutritionist a full nutrient profile is cumbersome to be utilized in the daily trading of soybean meal. Crude protein has been utilized to provide a simple straight forward numeric value to compare the feed value of one soybean meal with another. The early feed industry formulated most rations to minimum crude protein levels and therefore the crude protein content of an ingredient had a direct effect on the value of that ingredient in a formula. Today, most rations, particularly those for non-ruminant animals, are formulated to provide specific levels of critical amino acids and less emphasis is placed on minimum crude protein. In addition, it is becoming more evident excess crude protein can have a negative effect on livestock performance and the environment. In swine grower rations, the projected soybean meal value was found to be more highly correlated to the CAAV of that soybean meal (r=53.7) than to the crude protein content of that soybean meal (r=27.7). CAAV and crude protein had similar correlations to projected soybean meal value in broiler starter rations at r=51.2 and 53.6, respectively. In the broiler starter rations, it was observed that the amino acid arginine was frequently in minimal supply. This resulted in selection pressure based on the arginine content of the ingredients, in addition to the other amino acids already mentioned. In this formulation example, the full amino acid profile for each soybean meal was updated so differences in arginine content of the various soybean meals had the potential to impact the shadow prices determined for those meals however arginine was not included in the CAAV discussed in this paper. The inclusion of arginine in the CAAV, generating a value representing the summation of 6 amino acids, improved the correlation to equal that observed for crude protein (r=53.7).

Like crude protein, CAAV is a simple numeric descriptive which can provide an indication of soybean meal value in swine and broiler rations. Unlike crude protein, CAAV is more descriptive in providing an indication of critical amino acid content. In preparing this report the median values of the data set, 14.53% CAAV and 46.74% crude protein, were used as sorting criteria to separate the soybean meal samples into quadrants for the purpose of differentiating value. Previously reported amino acid data for soybean meal of United States origin (Thakur and Hurburgh) would generate CAAV's of 14.3-14.5, suggesting the soybean meals of this data set to be within the range of normal values. Further study and evaluation of soybean meal amino acid profiles may provide information on specific sorting criteria or suggest modifications, such as inclusion of arginine for a poultry specific CAAV. Based on this evaluation CAAV provides a single data point which appears to have equal or greater value than crude protein in assessing soybean meal value in swine and broiler rations. Will CAAV data replace crude protein as a single value estimator of soybean meal is not known? However CAAV improves our understanding of the soybean meal nutrient content to a greater extent than crude protein. The majority of soybean meal included in livestock rations is in rations balanced for amino acid content. Consideration of crude protein level in the ration is increasing related to the avoidance of excess due to increasing environmental nitrogen pollution concerns around the world. Soybean meal CAAV's provides a simple numeric indication of amino acid quality to a feed industry which is placing increased emphasis on formulating rations which meet the amino acid requirements and avoid excess total nitrogen, with respect to nitrogen pollution.

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