Animal Sciences

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Protein and Amino Acid Requirements for Poultry

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Introduction

This fact sheet has been developed to support the implementation of the Natural Resources Conservation Service Feed Management 592 Practice Standard. The Feed Management 592 Practice Standard was adopted by NRCS in 2003 as another tool to assist with addressing resource concerns on livestock and poultry operations. Feed management can assist with reducing the import of nutrients to the farm and reduce the excretion of nutrients in manure.

Dietary crude protein (CP) requirements are somewhat of a misnomer as the requirement is based on the amino acids content of the protein. Once digested and absorbed, amino acids are used as the building blocks of structural proteins (muscle, skin, ligaments), metabolic proteins, enzymes, and precursors of several body components. Because body proteins are constantly being synthesized and degraded, an adequate amino acid supply is critical to support growth or egg production.

In poultry, 22 amino acids are needed to form body protein, some of which can be synthesized by the bird (non-essential), whereas others cannot be made at all, or in sufficient quantities to meet metabolic needs (essential). Essential amino acids must be supplied by the diet, and a sufficient amount of non-essential amino acids must also be supplied to prevent the conversion of essential amino acids into non-essential amino acid. Additionally, if the amino acids supplied are not in the proper, or ideal, ratio in relation to the needs of the animal, then amino acids in excess of the least limiting amino acid will be deaminated and likely used as a source of energy rather than toward body protein synthesis. This breakdown of amino acids will also result in higher nitrogenous excretions.

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The best way to reduce N in poultry excreta is to lower the amount of CP that is fed by supplementing diets with amino acids. Reductions in the non-essential amino acid pool, coupled with supplying a more “ideal” amino acid profile in the diet can substantially increase the efficacy of overall N retention by the bird. On a practical basis, however, bird performance can be hindered by these lower CP diets due to a number of factors that tend to be associated with dietary CP and amino acid reductions.

Formulation based on bird amino acid requirements rather than CP can minimize N excretion by simply reducing total dietary N intake. For example, Ferguson et al., (1998) demonstrated with broilers that litter N could be reduced more than 16% when dietary CP was reduced by 2%, while maintaining similar levels of dietary amino acids.

Reduced Dietary Protein

Reducing the amount of CP and excess amino acids being fed is the most obvious method to curb N excretion and the amount of ammonia (NH_3) that can be formed and volatilized. However, the extent to which N reduction can be accomplished is largely limited due to meeting the most limiting amino acid after threonine and through economic decisions on ingredient selection.

Unfortunately, there is a widespread belief that whenever CP concentrations are lowered, performance is negatively affected. Burnham (2005) speculates that this belief stems from researchers (such as Neto et al., 2002; Bregendhahl et al., 2002) who lowered CP concentrations beyond practical formulation and then did not supplement back with sufficient amounts of limiting amino acids other than methionine (Met) and lysine (Lys). Reductions in the non-essential amino acid pool, coupled with supplying a more "ideal" amino acid profile in the diet can substantially increase the efficacy of overall N retention by the bird. On a practical basis, however, bird performance can be hindered by excessively lowering CP in diets due to a number of factors other than the reduction of CP itself.

According to Waldroup (2000), these factors can include: reduced potassium levels, altered ionic balance, lack of nonessential amino acids, imbalances among certain amino acids (e.g., branched chain amino acids), and/or potential toxic concentrations of certain amino acids.

Amino acids which are said to be essential cannot be synthesized by the bird. These essential amino acids must therefore be fed in order to supply the building blocks needed in the synthesis of body proteins thereby supporting growth. When supply of a single amino acid does not meet the bird's requirement, it is considered to be "limiting". At any given physiological stage of growth — or- age, a specific amino acid profile is needed to support optimal growth, with no limiting amino acids or surpluses. This profile has been termed an "ideal" ratio, or "ideal protein." Baker (1996) expressed this as an ideal ratio to lysine, from which the essential amino acid relationship to lysine remains relatively unaffected by diet, environment, gender, and genetic background. Therefore, to minimize N excretion, the "ideal" combination of essential and non-essential amino acids are needed to meet growth and/or egg production by the bird. However, due to available feedstuffs and a limited number of supplemental amino acids, it is difficult to provide this optimal ratio to the bird.

Amino Acid Requirements

Broilers

The NRC (1994) amino acid recommendations for broilers are based on peer-reviewed research published between 1947 and 1991 (Table 1). However, the present commercial bird is very different from commercial birds available prior to 1991, due in part to genetic selection as well as management practice and feed related changes (Havenstein et al., 1994; Williams et al., 2000).

For the past couple of decades, the broiler industry has utilized feeding strategies in phases that are shorter to more closely meet the nutrient needs of the developing bird. More recent research also suggests that the amino acid needs of the broiler differ substantial from that presented in the NRC (1994).

Dozier et al., (2008) recently summarized the amino acid requirements of broilers in weekly durations

Table 1. NRC (1994) requirement for crude protein and the most rate limiting amino acids for broilers.

Nutrient %	Weeks of age		
	0-3	3-6	6-8
Crude protein	23.00	20.00	18.00
Methionine	0.50	0.38	0.32
Total sulfur amino acids	0.90	0.72	0.60
Lysine	1.10	1.00	0.85
Threonine	0.80	0.74	0.68
Tryptophan	0.20	0.18	0.16
Isoleucine	0.80	0.73	0.62
Arginine	1.25	1.10	1.00
Valine	0.90	0.82	0.70

based on studies conducted since publication of the NRC (1994) until 2007.

Requirements for a high-yielding strain of broiler are presented in Table 2.

Turkeys – The NRC (1994) amino acid recommendations for turkeys are based on peer-reviewed research published between 1949 and 1986 (Table 3).

Although these recommendations appear to be somewhat dated, feeding of 110% of the NRC (1994) requirements did not improve turkey tom performance or yields (Applegate et al., 2008).

Laying Hens

The NRC (1994) amino acid recommendations for turkeys are based on peer-reviewed research published between 1962 and 1989 (Table 4).

Ingredient Selection

Selection of feedstuffs with relatively high digestibility can help with overall reductions in amino acid formulation. Table 5 presents data for protein sources and their respective standardized and apparent digestibility. Notably, sources such as feather-meal are not typically considered due to their amino acid profile, and their digestibility.

Table 2. Dietary amino acid (% of diet) requirements for high-yielding broilers (Dozier et al., 2008).

Amino acid	Age, days						
	7	14	21	28	35	42	56
Total sulfur amino acids	0.94	0.90	0.85	0.81	0.77	0.74	0.70
Methionine	0.62	0.55	0.50	0.48	0.46	0.47	0.50
Lysine	1.36	1.26	1.19	1.12	1.06	1.01	0.97
Threonine	0.84	0.81	0.77	0.74	0.71	0.69	0.67
Isoleucine	0.91	0.86	0.82	0.78	0.75	0.72	0.70
Valine	1.03	0.98	0.94	0.90	0.87	0.84	0.82
Arginine	1.47	1.37	1.28	1.21	1.14	1.09	1.04

Table 3. NRC (1994) requirement for the most rate limiting amino acids for turkeys.

Nutrient, %	Weeks of age					
	0-3	3-6	6-9	9-12	12-15	15-18
Crude protein	28.00	26.00	22.00	19.00	16.5	14.00
Methionine	0.55	0.45	0.40	0.35	0.25	0.25
Total sulfur amino acids	1.05	0.95	0.80	0.65	0.55	0.45
Lysine	1.60	1.50	1.30	1.00	0.80	0.65
Threonine	1.00	0.95	0.80	0.75	0.60	0.50
Tryptophan	0.26	0.24	0.20	0.148	0.15	0.13
Isoleucine	1.10	1.00	0.80	0.60	0.50	0.45
Arginine	1.60	1.40	1.10	0.90	0.75	0.60
Valine	1.20	1.10	0.90	0.80	0.70	0.60

Table 4. NRC (1994) requirement for crude protein and the most rate limiting amino acids for laying hens.

Nutrient, %	Mg per 100 g feed per day
Crude protein	15,000
Methionine	300
Total sulfur amino acids	580
Lysine	690
Threonine	470
Tryptophan	160
Isoleucine	650
Arginine	700
Valine	700

Table 5. Standardized and apparent digestible lysine (Lys) from chickens for different feedstuffs.

	Standardized digestible Lys, %[1]		
Feedstuff	Mean	Range	Apparent digestible Lys, %[2]
SBM	90	85-93	86
Canola	80	64-84	72
Sunflower	84	- - -	- - -
Cottonseed	67	- - -	55
DDGS	67	35-84	- - -
Fish-meal	88	- - -	83
Blood-meal	87	50-91	- - -
Poultry byproduct-meal	80	68-90	- - -
Meat and bone meal	80	45-90	58
Feather-meal	65	34-80	54

[1]Parsons, 2005 utilizing cecectomized roosters.
[2]Ravindran et al., 1998. Apparent ileal digestible Lys.

Similarly, formulation for emission reduction should also consider the protein quality as exemplified in the range of apparent digestibility where processing temperatures could cause Maillard reactions as well as other conditions that would reduce amino acid availability.

Formulation on a digestible amino acid basis can a) reduce the total amount of CP fed, and b) limit the excessive amount of non-essential amino acids fed – particularly if higher digestible CP feedstuffs are available.

Formulation on a Digestible Amino Acid Basis

Digestible amino acid values are considered by many to be the best measure of the amino acid value of ingredients. Long-term reductions in CP formulation with adoption of the digestible amino acid concept should greatly reduce feed cost and N emissions. Further benefits of formulating on a digestible amino acid basis include decreasing safety margins, increasing the accuracy of predicting performance, and increasing the uniformity of product after processing. Unfortunately, knowledge of what the causes of variation in amino acid digestibility within and between ingredients is not sufficient. Additionally, inconsistent methodologies make it difficult to make the switch to using digestible amino acid values, especially for non-traditional feed ingredients.

Determination of ingredient amino acid digestibility from feedstuffs has traditionally been done with either cecetomized roosters or collection of ileal digesta from birds fed only the test ingredient or a semi-purified diet with the feedstuff being analyzed as the sole source of protein and amino acids. These assays have an obvious downside as they are expensive and have long turn-around times. Therefore, real-time formulation on known amino acid digestibility for any feedstuff is unrealistic. Other approaches to improve the turn-around time include correlation of bird digestibility studies with near-infrared reflectance spectroscopy (NIR) or *in vitro* assays (Erickson et al., 2000; Schasteen et al., 2007).

Most of the grow-out poultry studies focusing on use of digestible amino acid formulations have only focused on performance and economic considerations and not necessarily on N excretion or emission reduction (Fernandez et al., 1995; Rostagno et al., 1995; Dari et al., 2005). Formulation on a digestible basis can have large economic and environmental benefits, particularly when formulating with ingredients known to have lower digestibility. For example, unpublished data by Rostagno (University of Viscosa, Brasil) suggest considerable differences in body weight and feed/gain of birds fed either 6 or 12% cottonseed meal or sorghum when formulated on a total versus a digestible basis. Similarly, Pertilla et al., (2002) noted significant reductions in performance and yield when diets were formulated with lower digestible ingredients (rapeseed meals or meat and bone meal) when compared with those formulated on a total Lys basis versus a digestible Lys basis.

Lemme et al., (2004) provides an excellent review and commentary on application of the ileal digestibility concept and its application into broiler diet formulation. Notably, standardization of amino acid digestibilities from ingredients is needed to account for endogenous amino acid losses. Digestibility values that have not accounted for endogenous amino acid loss are termed as "apparent" values. The standardization accounts for factors such as amino acid concentration in the diet. For example, results from our laboratory suggest that the difference between apparent and standardized amino acid digestibility coefficients for SBM may differ by 1 to 3% whereas that for corn can differ by up to 14% (Adedokun et al., unpublished).

Possible Impact of Crude Protein Reduction

Broilers. Reducing CP content of broiler diets by less than 2 percentage units resulted in decreased litter N content but no significant differences in NH_3 concentration in the house (Ferguson et al., 1998). The 13.3% decrease in N intake did correspond to 18.2% reduction in litter N content. Elwinger and Svensson (1996) fed broilers diets containing 18%, 20% or 22% CP and measured NH_3 emissions from the litter bed. Total N losses in the houses averaged 18% to 20% of total N input.

Angel et al., (2006) also studied the possibility of reducing dietary N intake in broilers to 42 days of age. In their studies, an industry control 4-phase feeding program (corn-SBM based) with synthetic Met and Lys was compared with a 6-phase feeding program with supplemental Lys, Met, isoleucine (Ile), Thr, valine (Val), Trp, and arginine (Arg) (even though only Lys, Met, Thr, and Trp are commercially available). Birds were reared on the same litter for 5 consecutive flocks. Feed conversion was similar between groups after 5 flocks, but live body weight was 77 g lighter in birds fed on the 6-phase program. In a sampling of 40 birds per diet, however, dressing or breast yield (%) were not affected by diet in the third or fourth flocks (i.e., the only flocks where processing data was determined). Consumption of N with the 6- phase feeding program was 8.3% lower than those on the 4-phase feeding program (7.04 versus 7.68 g/bird) resulting in a 20% reduction in N excretion (2.3 versus 2.9 g/bird). The 6-phase feeding program resulted in a 15.4% reduction in daily NH_3 emission (1407 versus 1663 mg/d per 50 birds) over the first three flocks (Powers et al., 2006).

Pope et al., (2004) also has looked at the advantages to increasing the number of phases during the broiler growth cycle. By changing diets every other day to more closely meet the bird's amino acids from 21 to 63 days of age, performance and meat yield did not change, but N excretion was reduced by 7 to 13%.

Turkeys. Reducing CP content (particularly by formulating to essential amino acid needs rather than setting of a CP minimum) of turkey diets can have considerable economic benefits. When the studies were conducted, several researchers have noted that when essential amino acid requirements are met, NRC (1994) CP recommendations are not warranted (Sell and Jeffrey, 1994; Waibel et al., 1995; Boling and Firman, 1997; Kidd et al., 1997; Waldroup et al., 1997). Depending on phase feeding programs, these studies indicate that 100 to 107% of NRC (1994) recommendations for essential amino acids were needed to maximize growth and breast meat yield. Little if any work has been done with turkeys, however, with consideration to loss of N to the environment.

Laying Hens. In the case of laying hens, CP and amino acid formulations are largely over-formulated with the hopes of getting a return in either egg size or egg number. Unpublished research from by Applegate et al., however, suggests that 15.3 g of CP (858 mg Lys, 450 mg Met, 585 mg Thr, and 638 mg Ile) is sufficient to maximize egg weight and production from 25 to 45 weeks of age versus birds fed corn/SBM diets containing 16.15 g of CP (874 mg Lys, 409 mg Met, 627 mg Thr, and 684 mg Ile). Although this 5.6% reduction in N intake doesn't seem like much when the lower CP diet is fed, it results in a $1024 USD/100,000 hens difference in daily feed cost (ingredient pricing similar to turkey example) and a 13.6 kg reduction in daily N intake per 100,000 hens.

Conclusions

As a general guide, for each 1% reduction in dietary CP, estimated NH_3 losses are reduced by 10% in swine and poultry (Sutton et al., 1997; Kay and Lee, 1997; Blair et al., 1995; Jacob et al., 1994; Aarnink et al., 1993). As animals are fed closer to true N requirements, further reductions in dietary CP may result in less pronounced reduction in N excretion and NH_3 losses.

When poultry are fed closer to requirements and strategies are implemented to improve CP and amino acid digestibility, reductions in the amount of N excreted by the bird can be 10 to 20% depending on how much N is currently being fed. The poultry industry, however, currently utilizes substantial safety margins for formulation of N, due in large part to uncertainty of nutrient requirements and variability in ingredient amino acid content and digestibility. Reduction of N consumed, use of ingredients with complementary amino acid profiles, and use of ingredients with higher amino acid digestibility, therefore, can have dramatic impacts on the amount of N excreted.

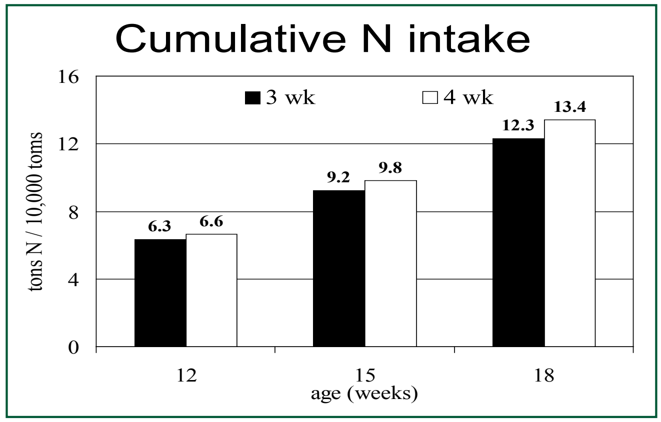

Figure 1. Formulated CP diet phases for male turkeys, as adapted from Waldroup et al. (1997). Diets were fed in either 3 or 4-week phases. Concentrations indicated maximized growth and meat yield when fed at 105% of NRC (1994) recommended amino acid concentrations for 3-wk phases and 100% of NRC (1994) recommended amino acid concentrations for 4-wk phases.

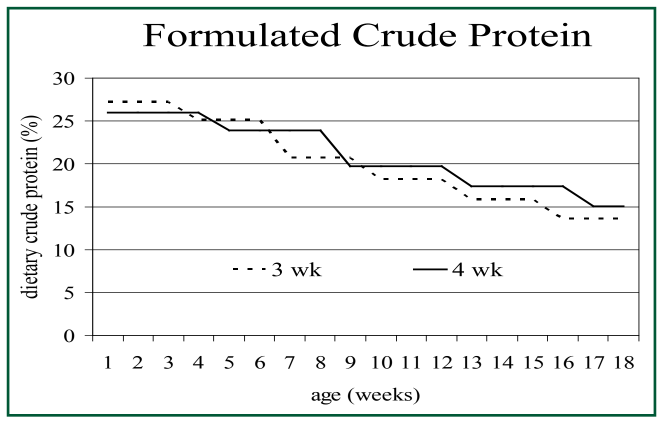

Figure 2. Cumulative nitrogen (N) intake of turkey toms as adapted from Waldroup et al. (1997) for maximizing body weight and breast yield. Feed intakes were predicted using optimum of Nicholas 700.

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Project Information

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