Multi-State Poultry Meeting
May 20-22, 2003
Jeffre D. Firman, Ph.D.

Computer Formulation of Low Protein Diets for Turkeys

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Introduction

When looking at nutrition research, feed costs and relative performance must be at the heart of the issue. I believe we must focus our efforts on where the dollars are spent in the field. It is also imperative that we continue to look to other species for new ideas, to avoid pitfalls that others have already encountered and to ascertain that we are keeping up if not staying ahead of the other industries. We have had a tendency to look for maximum growth. Maximum growth is relatively easy to achieve through overfeeding of nutrients. It is not, however, a cost effective strategy and somewhat negates all of the research on nutrient requirements. While overfeeding will reduce the potential for disaster it also will result in excess nutrient load being placed in our environment as well as the obviously higher costs. Given the new realities of the global economy and global competition, an industry must use every strategy available to remain viable.

When we look at nutrients that are of significant cost to the poultry industry, energy, phosphorus and protein/amino acids are the three that come to mind as potential money savers that could be modified. This is not to say that other nutrients lack significance, but merely to look at areas of concentration. There is a great deal of interest in phosphorus right now due to the industry funding of phytase research (a product to sell) while there is relatively little interest in amino acids and energy as the industry is the primary beneficiary (less chance for product sales). For the remainder of this session, we will look at protein/AA as one of the most important nutrients in terms of cost in poultry rations, some of the fundamental concepts that are poorly understood and how protein and energy may relate to each other.

Ultimately our discussion will focus on the decision making process which tends to get lost in the shuffle of our busy schedule. Since energy and protein provision account for as much a significant portion of the cost of the ration, the decisions surrounding the levels of these nutrients to feed are absolutely critical and in many cases made with little thought. Many folks feed a certain level of a nutrient based on poor decision making. Some examples of what these include:

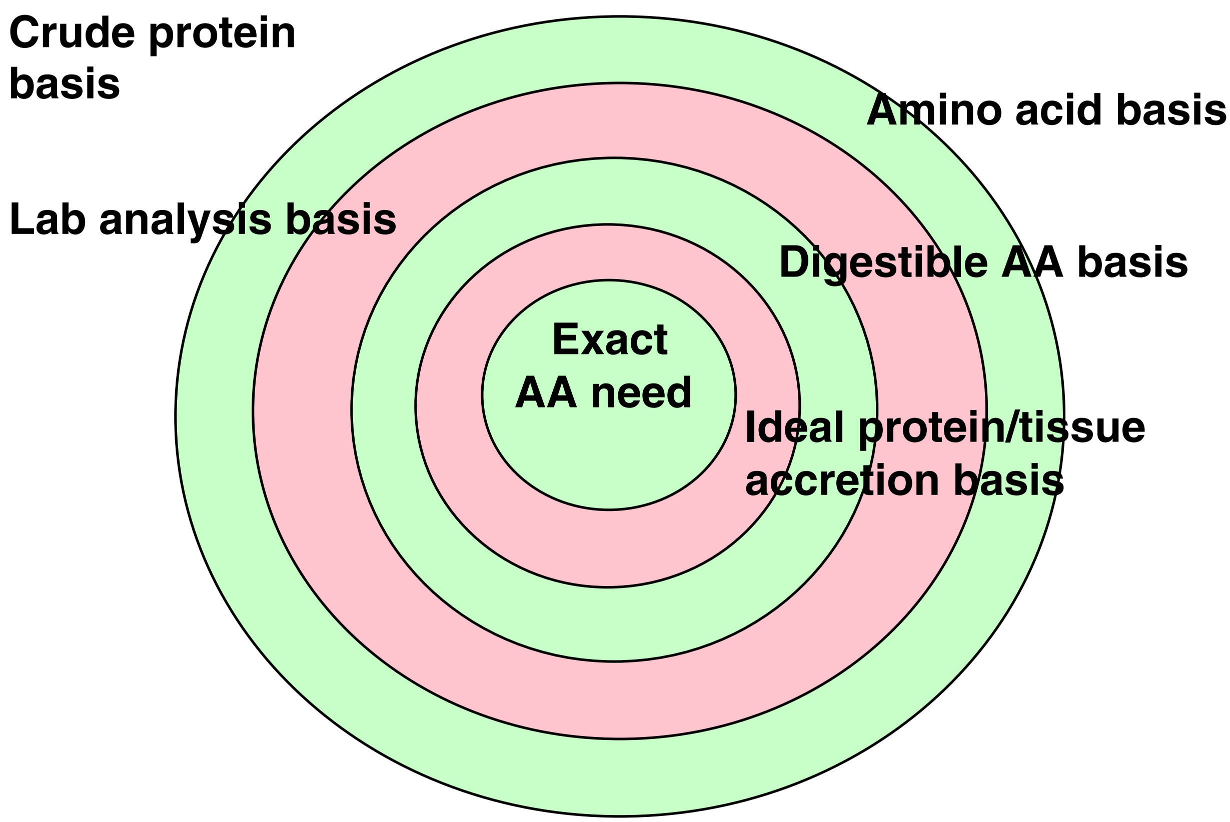
Tradition- this is what we have always done
The other guy- those folks at company X really know what they are doing so we'll do the same
Book values- this is what the book says (books generally have some good information, but tend to lack the ability to respond to changes that occur)

All of these sources have the ability to provide the correct decision. However isn't this important enough to spend some effort on? Lets take an example from several years back. A nutritionist from a major poultry company called back when corn prices were hitting $5 US/ bushel or more than double prices at the time this is written (we may be headed for a repeat of these high values in the future). The cost of feed was killing profitability for his company and what could he do. I suggested adding large amounts of fat which was relatively speaking still cheap compared to corn. Feed conversion was improved dramatically and he thus fed much less feed for the same body weight by increasing energy and shifting his energy costs from corn to fat. Apparently others figured this out a month later as the cost of fat increased dramatically. The point is that we must be constantly aware of what we are feeding and how things might change to keep things as profitable as possible. Lets look at some of the fundamentals on protein and then relate them to energy since they are so closely linked.

There are no protein requirements?

I'll start this way as I believe we sometimes need to back up and look at the fundamentals. Not to mention that almost all of us were taught repeatedly that there are in fact protein requirements. When we feed protein to a bird, the gut begins to break the protein down to its constituent amino acids (AA) and small peptides for absorption in the small intestine. Thus no protein per se is utilized by the bird. The bird does have the need for essential amino acids as well as the need for a nitrogen source to build the non-essential amino acids that the body will manufacture. Nitrogen is provided by non-essential amino acids that are fed as well as excesses of the essential AA that are not limiting. Protein requirements are really used merely as a convenience when formulating due to a lack of information. Over time we have made progress with diet formulation from feeding crude protein levels with no AA constraints or requirements at all to where we are today with much of the world looking at digestible formulation and perhaps computer models. However, after visiting a large number of countries the variation in formulation technology being utilized is vast.

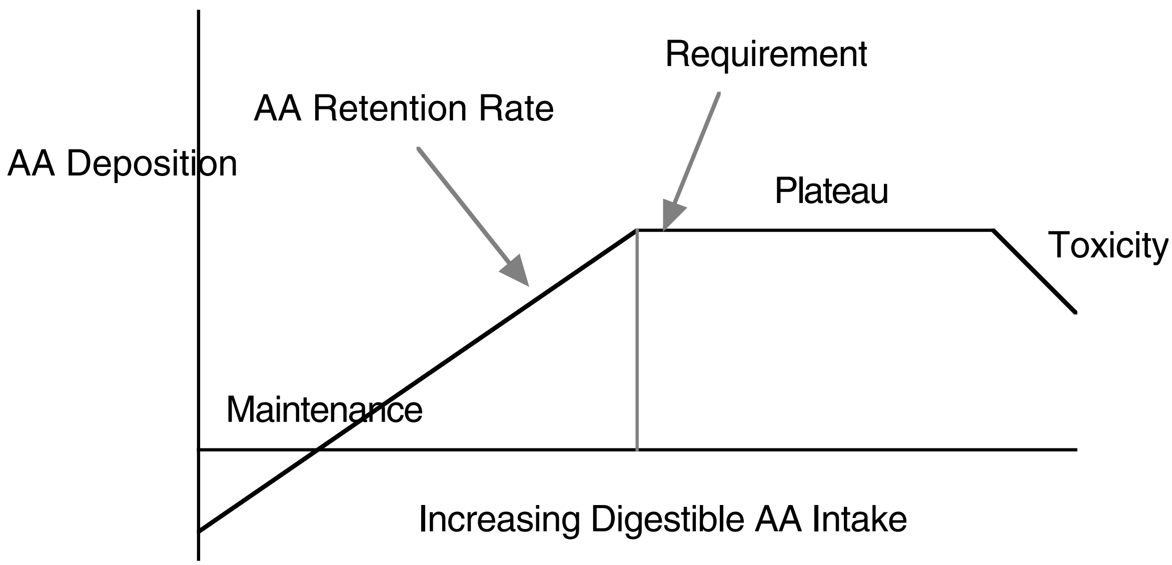
Figure 1. Progress of Protein/Amino Acid Nutrition



Fed protein is partitioned into various areas throughout the digestion and growth process. As protein is fed, it is broken down into its constituent **total AA** and absorbed across the lumen of the gut. A significant portion of the AA fed are not absorbed and will be excreted by the bird. Additional AA are excreted from gut sloughage and is referred to as **endogenous AA** loss. The proportion that is absorbed is referred to as the **digestible AA** portion and is calculated based on the relative intake of the AA, that which is excreted and that which is the result of endogenous loss. There are several methods of performing these assays with the quickest and easiest method being the precision fed rooster assay which we have modified for the turkey.

After absorption, AA are used for several functions including maintenance, tissue accretion, protein turnover, energy and precursors for other biological compounds. When fed increasing levels of AA the relative proportion of these uses changes as we move from maintenance functions to muscle accretion. If we feed sufficient quantities we will maximize growth response of the bird. The minimum fed level to achieve this is referred to as the minimum requirement. A bit of explanation on how these might be achieved is warranted.

Figure 2. Titration method for AA determination



The above figure shows the output of an AA titration experiment. This is how most of the data found today have been determined. Most of the values found in tables are on a total AA basis rather than digestible. I'll try to convince anyone that has not yet made the switch to digestible AA formulation to do so below. Now let's look a little closer at how these experiments are performed. Generally, a diet must be formulated which is low in a single AA which is being tested. There are several ways of doing this that may be acceptable, but it should be done on a digestible basis with assays of the feedstuffs used. One method is to use feedstuffs that are low in the AA being tested such as threonine in peanut meal. The downside of this is that most folks don't use peanut meal extensively so the ingredient itself may have an effect. Generally, this is probably adequate if digestibility assays are performed. The other method is to reduce the protein in the ration until the AA in question is deficient. This is my preference as one can utilize the same feedstuffs, just with different proportions. Recognize that the balance of AA and the relative contributions from each feedstuff will change as the proportions change (ie. More corn and less soy as protein is reduced). Personally I also like to keep my protein constituent ingredients few in number and well known products to reduce variability. I am also adamant that we do these experiments on a digestible basis. The reason for this is that the titration of the AA is going to be done with a product that is essentially 100% digestible and will give a true requirement on a digestible basis. If we do this on a total AA basis, we are mixing some lower digestibility feed with some 100% digestible feeds to get a value, which will then be used in a practical formulation using primarily ingredients with the lower digestibility and thus missing the requirement.

As the AA intake is increased we see a linear increase in growth beyond the maintenance point that goes up until we reach the requirement. The slope of the line is related to the proportion of the AA that is deposited as muscle (ie. 100 gms lysine intake results in 70 gms of lysine in muscle). Since muscle maintains a relatively constant AA profile, AA deposition and growth are closely related. At the point of the requirement, we should have performance similar to that of a control feed so that we are assured that maximum performance has been achieved. Feeding AA beyond this point has no positive aspects on performance. Basically this is because each bird will have a genetic potential for growth. Growth is based on the building of proteins from constituent AA. As long as sufficient AA are available for protein construction, this will not be a limiter of growth. Thus as long as all AA are in sufficient quantity, growth (from an AA standpoint) will be maximized. This is relatively easy to achieve by overfeeding all AA. Unfortunately, this is not cost effective or our job would be much easier. We must therefore feed at the minimum to achieve the desired outcome (maximum growth, breast yield, etc) at low cost. Feeding at exactly the requirement for all AA is also not cost effective as our ingredients are not ideal and a certain amount of overfeeding of the AA that are not limiting growth will occur. This leads to the concept of a limiting AA, those AA that will be most likely to limit growth. The most likely order of limitation is methionine, lysine, threonine, valine and isoleucine. However, the definition of the limiting AA is based on the AA that must be added at a given level of protein. If we change our protein sources, we can change the order of limitation. At higher protein levels, no AA may be limiting and the order of limitation is not discernable. It is only when we begin to reduce protein levels that limiting AA occur. The order of limitation and which AA are used in purified form then becomes of importance.

Practical Approaches to Reducing Protein/AA Costs

Lets assume that we are feeding total AA with protein constraints similar to what the NRC (1994) would recommend. First let me say that this will provide excellent performance in many situations with US style diets. From this diet set we should make some cost saving moves. I'll take these stepwise so that one can see my outlook on level of importance, where you may currently be in my scheme, what it will take to make the switch and also my reluctance to suggest big changes without trying things out a little bit. In other words, no experiments using 100 million birds. I'll also focus on the turkey though the strategies will be amenable to broilers or pigs as well. Let me also say that while I have been teaching computer formulation to college students for many years, most nutritionists are relatively speaking self-taught. It is very easy to get in a rut with our formulas and not look closely enough at what we are feeding.

Open your mind to new possibilities: This is the hard one for a lot of folks. Firman could in fact just be an idiot and thus listening to him will be of little value. However, if only one thing said today is correct and usable, money could be saved. First and foremost is the concept of formulation on a nutrient basis rather than an ingredient basis. This is not to say that the ingredients used are not important, but to say that they should be looked at merely as a method of providing nutrients at the correct levels.

Increase the number of feedstuffs available: What I mean by this is that one should start the formulation process with as many choices for the computer as possible. I would also suggest as many purified nutrient sources as possible. As more nutrients are made available to the formulation matrix, the computer can choose ingredients that more closely match the nutrient constraints set forth. As an example, some companies will put choline into the premix and then place a constraint on choline. The computer then searches for the cheapest source of choline in the available nutrient matrix. It may add extra of the premix or if it is constrained will add extra soy at relatively high cost. Depending on prices, etc I have seen as much as $5 US/ton saved by adding choline as a purified source. You may find that adding some new storage capacity may also be warranted.

Start with minimal constraints: Nutrient and ingredient constraints are part of the formulation process and one must be careful what one does, but constraints can be added back after we seen some of the effects of the constraint. As an example, meat and bone meal has been constrained at 7.5% of the diet based on several sources of information. This is quite a simplistic approach to formulation as it does not even account for the relative proportion of the protein being provided by the product (i.e. 7.5% of the diet from meat and bone meal provides relatively little protein in a starter ration and as much as 25% of the protein in a finisher ration). I would certainly argue that if it comes into the formula at 7.8%, there will be no detriments to performance and yet cost savings can be achieved.

Look for pressure on the matrix: This is what I refer to as the ingredient or nutrient bumps up against a constraint. As our example above we have a constraint at 7.5% of the diet on meat and bone. If the formula puts in 6.23% then no pressure. If however, the computer puts in 7.500%, we have pressure on the matrix at this point. Relieving the pressure in some fashion can result in cost savings. This can be done obviously by removing the constraint and see what happens (it may go to 25% of the diet which may be unacceptable) or one can look for other points of pressure and see what it is that the computer wants so to speak that meat and bone provides and then provide it.

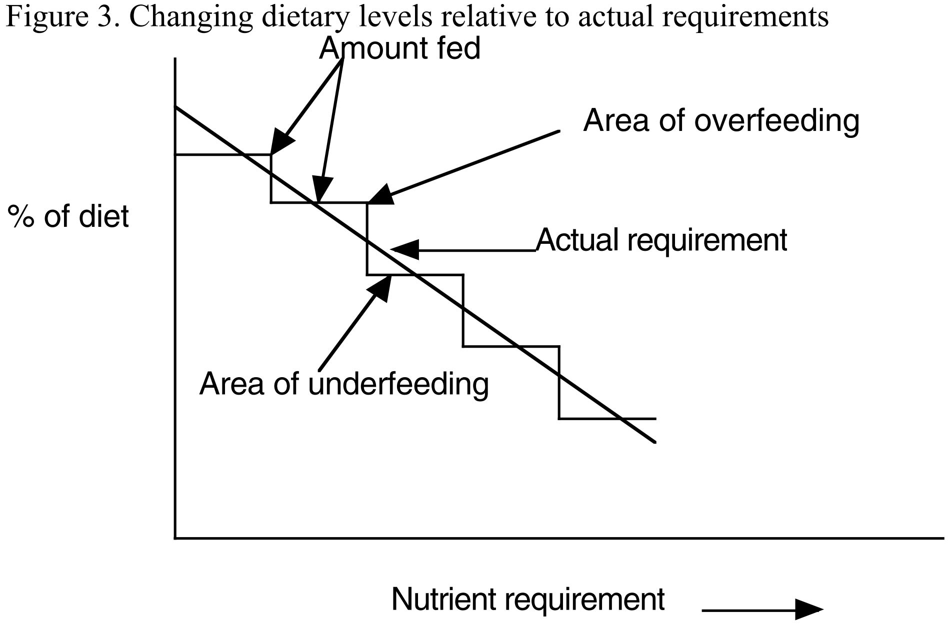
Reduce protein constraints: The NRC protein constraint for a starter ration is 28%. This can be safely reduced by several percentage units. In an experimental situation, we have reduced intact crude protein to less than 12% with similar performance and found a protein equivalency of about 16% needed for maximum growth in the starter period. In other words the 28% protein is not needed for performance per se. Keep an eye on amino acids that you don't normally look closely at so that no deficiencies occur as protein constraints are reduced.

Look carefully at safety factors: Safety factors are a commonly used method of ensuring that all nutrient requirements are being met when there is inevitable variation in nutrient levels through a variety of mostly uncontrolled factors. One should look carefully at how high these are and whether they are even needed. In many cases feeding slightly less than the actual requirement will affect only those birds with the highest genetic potential and overall flock performance is not noticeably affected with a possible decrease in flock variation.

Add more crystalline AA to the matrix: Use of threonine can allow for some more reductions in protein. Frankly threonine will probably not come into a matrix without some reductions in protein. This has been one of the problems in threonine use. If we constrain our formulation matrix at high levels of protein, threonine will be adequate from intact protein sources, thus no value set to threonine.

Change diets more frequently: Basically the graph below shows what this means. Nutrient requirements change very frequently, while we may change diets and thus the fed nutrients far less frequently. The more diets we feed the more closely we will follow the requirements. I have seen everything from 2 diets to 5 diets fed to broilers. Turkeys, with a longer groth cycle have the potential for far more diets than we currently feed. As frequently as new feed is delivered would be the maximum frequency of diet changes.

Figure 3. Changing dietary levels relative to actual requirements



Move to digestible formulation: This one is a bit more difficult and will take some time and effort. There is a good bit of interest in this and I have been teaching this methodology a good bit recently. Basically one needs numbers for requirements as well as digestibility data. The topic is a presentation or two in and of itself, but let's summarize with a couple of things:

Digestible formulation saves money

Digestible formulation allows use of alternative ingredients more easily

Digestible formulation results in more accurately meeting the birds requirement

Digestible formulation allows for reduced protein and increased energy without fat additions

Digestible formulation allows for more precise determination of amino acid requirements

Digestible formulation is useful even if you just feed corn and soybean meal, and is more useful if you feed a number of ingredients

How does this work and how much can be saved? Below is a scenario where a 19% turkey ration was formulated with several different methods (Table 1). The first ration is a NRC ration. The second ration is reformulated with the same requirements as the first ration, but expressed on a digestible basis. Savings of something over $1 US. I then allowed the total by-product addition to increase due to my comfort that all AA requirements would be met (see also Table 2). I then used digestible requirements determined to provide similar growth from my research for a total cost saving of almost $5/ton. When ingredient prices change we have found as much as $15/ton savings. Table 2 shows a starter turkey ration and the effect of different ingredients on the actual digestible AA levels found in the diet.

Table 1. Comparison of different formulation methods. See text for explanations.

	Standard Diet	Same levels Digestible Basis	Added By-products	Digestible Requirements
Protein Ingredients				
Corn	71.04	72.01%	73.94	74.94
Soybean meal	18.71	18.46	15.64	14.80
Poultry by-product	6.00	1.50	6.90	2.40
Meat meal	2.00	6.50	2.40	6.95
Other ingredients	2.25	1.53	1.12	0.91
Cost/ton	$130.41	$129.23	$128.76	$125.63

Table 2. Comparison of two formulations based on total amino acid content and the effect on digestible amino acid values

	Corn-soybean diet		By-product addition diet	
	Total Basis	Digestible Basis	Total Basis	Digestible Basis
Lysine	1.72%	1.52%	1.72%	1.45%
Methionine	0.55%	0.52%	0.55%	0.44%
Threonine	1.05%	0.86%	1.05%	0.84%

Eliminate protein constraints entirely: This is also a big step and one needs to have good data on requirements for the next limiting AA past those added in pure form. In other words, if we have lysine and methionine available, we need to put a constraint on threonine if it is considered 3rd limiting. If crystalline threonine is available, we need a constraint on the 4th limiting AA (valine or perhaps isoleucine) to meet the rest of the AA requirements.

Energy

Energy in feed comes from a variety of sources and has a multitude of effects on poultry nutrition. The major confounding factor is the changes in feed intake that occur as energy levels are changed. Since feed intake can basically affect all nutrient requirements, changes in energy have the potential to affect all aspects of nutrition. Again we'll look at the basics and then practical applications.

Energy is measured and expressed in several different fashions. Most poultry are fed based on Apparent Metabolizable or True Metabolizable Values (AME or TME) that have been adjusted for nitrogen excretion. Basically the differences in these two value should be small although the methodology for collection is quite different and this probably leads to as much of the differences seen as anything. In an AME the feed in question is fed (usually in a mix) to broilers for several days with either total excreta or ileal contents (through use of a marker) collected. Basically the energy taken in minus the energy excreted yields the AME value. The TME value is generally collected with the precision fed rooster assay where a known quantity of feed is tube fed and excreta collected. Similar calculations occur with the exception of an adjustment for the endogenous loss. In the AME it is generally assumed with the total collection method that the endogenous portion as a part of the total is so small as to be negligible. There are also several variations on both of these and academics argue a good bit on some of this. The main thing to realize is that we are really yielding a relative value for energy. Probably it is not the best idea to mix methodologies. As you know lots of things can affect these energy values such as cultivars, dry matter content, extraneous materials, etc. Probably some effort and expense on routine analyses will be valuable.

What happens as we feed increasing energy levels?

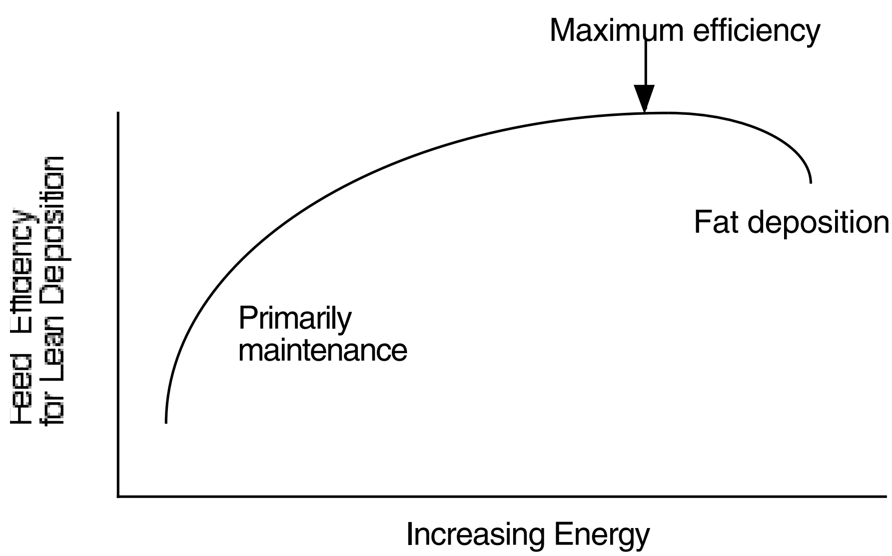
-Increases growth rates
-Increases feed efficiency
-Decreases feed intake
-Increased rate of gain can decrease age at market and increase throughput of housing systems
-Concentrated feeds can decrease transportation costs for feed delivery

Increasing levels of energy through fat additions may also have the following effects:

-Lower heat increment is useful during heat stress to keep caloric intake up (use care with this)
-May slow gut transit of other feeds, resulting in increased digestibility
-May show an 'extracaloric' effect
-May be more cost effective than other energy sources
-Use of higher levels of fat may negate the effects of pelleting
-Source of linoleic acid
-Decreases dustiness of feeds and reduces dust losses
-Lubricant for equipment in feedmills
-Increases palatability of feeds

The graph below gives an indication of what happens to the animal as we change energy from very low levels to very high levels.

Figure 4. Changing energy levels as they affect Feed efficiency for lean deposition



Recognize that a significant portion of the energy fed will go towards maintenance functions. This implies that as we increase energy fed we will have a more dramatic effect on energy used for growth and production since energy needed for maintenance will change little in the short term.

What level of energy should be fed?

The first part of this decision making process is to realize that this is in fact a process. One should have a good understanding of the above effects and then look at a calorie cost comparison as an initial step. This is relatively easy to do with a least cost feed formulation package. Basically one looks at the relative cost of the energy in feed. An example is shown below:

Table 3. Energy cost /mcal/ton

Energy Level	Cost /mcal/ton	Cost /mcal/ton
3000	48.00***	47.93^^^^^
3100	46.74	47.51
3200	45.99	47.38
3300	45.08	47.80
3400	44.28	47.69
	*** Low fat prices	^^^^High fat prices

Based on this one can feed as high an energy level as one feels comfortable with when fat is cheap and 3200 is the most cost effective energy level when fat is higher in price. Obviously this will change as prices of all ingredients change.

Protein / energy relationships

While there are a number of publications related to this topic, there is really not a good answer to the question. There are two basic problems with doing work in this area that have not been addressed adequately for more definitive answers to be had. The first of these is that energy modifications affect feed intake. Thus when one feeds differing levels of energy, we get different levels of intake of the other parameter being studied which is protein. This can lead to some erroneous conclusions. We also can see some differences based on if energy is provided as fat or another source. The other problem has been the lack of definition of the protein. While some may say that corn-soy is standard, we tend to change the relative proportions of these ingredients to get differing levels of protein, thus creating a new set of problems. There are three basic schools of thought relative to the protein/ energy relationship. Each will be discussed separately.

No relationship: The researchers that believe this base this on the fact that a factorial approach with protein and energy in which different levels of protein are combined with different levels of energy yield no interactions that can be statistically noted. While our lab has produced some data like this it does not yield the conclusion that there are in fact no interactions, but only that this form of experiment will not produce interactions. Thus I believe this is not the correct case.

Protein/ energy interaction is found: This school of thought is based on the fact that when one feeds a given level of energy and thus intake, a protein requirement can be found. This is an intellectually sound approach and I believe that this is basically correct. My problem and why this isn't found prominently in the literature is that the protein is undefined and thus research has shown mixed results as to what the relationship is.

Protein/energy interaction must be more carefully defined: This is where I am at with this topic. To define what relationship there is we must start by defining what we are in fact relating. Protein per se is very difficult to define. We have done some of this work in the turkey and hope to do some of this work soon in the broiler. Basically we have titrated lysine in an ideal protein based diet at different energy levels to find a relationship of 0.43% digestible lysine/ mcal expressed on a kg basis in the starter period. In other words if we feed a diet with 3000 kcal/kg our requirement is 1.29% digestible lysine with all other AA in ratio to lysine based on our Missouri Ideal Turkey Protein.

Summary: Basically I hope that I have covered some of the ideas about using the computer to help control fed costs in a practical way. With feed being such a large part of the total picture and global competition heating up, one must be constantly looking at the package to maintain the competitive edge needed to remain a part of global poultry industry. Some of our data on digestible requirements for turkeys is also attached for your use.

Table 4 Digestible Requirements and Missouri Ideal AA Ratio for Toms

Weight (kg)	0.25	0.50	1.00	1.60	2.20	3.10	4.00	5.00
Toms				*(%Diet/Ratio)*				
Amino Acid								
Lysine	1.38/100	1.35/100	1.31/100	1.25/100	1.20/100	1.12/100	1.04/100	.97/10
SAA	.84/61	.85/63	.82/63	.79/63	.75/63	.65/58	.60/58	.56/58
Thr	.76/55	.74/55	.72/55	.69/55	.66/55	.63/56	.58/56	.54/56
Val	.84/61	.83/55	.80/61	.76/61	.73/61	.68/61	.63/61	.63/61
Arg	1.45/105	1.45/105	1.40/107	1.34/107	1.28/107	1.18/105	1.09/105	1.02/10
His	.50/36	.50/37	.48/37	.46/37	.44/37	.40/36	.37/36	.35/36
Iso	.83/60	.98/73	.94/72	.90/72	.86/72	.77/69	.72/69	.67/69
Leu	.95/69	.93/69	.90/69	.86/69	.83/69	.77/69	.72/69	.67/69
Phe + Tyr	1.45/105	1.48/110	1.42/109	1.36/109	1.30/109	1.18/105	1.09/105	1.02/10
Trp	.22/16	.22/16	.21/16	.20/16	.19/16	.18/16	.17/16	.16/16
Energy kcal/kg	3100	3150	3200	3250	3250	3300	3300	33

Weight (kg)	6.00	7.10	8.20	9.30	10.50	11.50	12.60	13.50
				(%Diet/Ratio)				
Amino Acid								
Lysine	.90/100	.82/100	.76/100	.70/100	.64/100	.60/100	.56/100	.53/10
SAA	.54/60	.49/60	.46/60	.41/59	.38/59	.35/59	.36/64	.34/64
Thr	.51/57	.47/57	.43/57	.41/58	.37/58	.34/58	.33/59	.31/59
Val	.55/61	.50/61	.46/61	.87/61	.39/61	.37/61	.34/61	.32/61
Arg	.95/105	.86/105	.80/105	.74/105	.67/105	.63/105	.59/105	.56/10
His	.32/35	.29/35	.27/35	.26/37	.24/37	.22/37	.21/38	.20/38
Iso	.61/68	.56/68	.52/68	.48/69	.44/69	.41/69	.40/72	.38/72
Leu	.62/69	.57/69	.52/69	.48/69	.44/69	.41/69	.39/69	.37/69
Phe + Tyr	.92/100	.84/102	.78/102	.73/104	.67/104	.62/104	.72/128	.68/12
Trp	.14/16	.13/16	.12/16	.13/19	.12/19	.11/19	.12/21	.11/21
Energy kcal/kg	3400	3400	3450	3500	3500	3550	3600	36

Weight (kg)	14.40
Amino Acid	
Lysine	.50/100
SAA	.32/64
Thr	.30/59
Val	.31/61
Arg	.53/105
His	.19/38
Iso	.36/72
Leu	.35/69
Phe + Tyr	.64/128
Trp	.11/21
Energy kcal/kg	3600

Table 5 Missouri Ideal Digestible Amino Acid Ratio For the Hen Turkey

Weight (kg)	0.24		0.46		0.90		1.40		1.80		2.30	
Hens												
Amino Acid	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio
Lysine	1.27	100	1.25	100	1.22	100	1.18	100	1.16	100	1.12	100
SAA	0.74	58	0.74	59	0.72	59	0.71	60	0.68	59	0.68	61
Thr	0.41	55	0.40	54	0.39	54	0.39	55	0.38	55	0.38	56
Val	0.30	74	0.30	76	0.29	75	0.30	76	0.29	76	0.03	7
Arg	0.32	107	0.32	105	0.31	106	0.32	107	0.31	107	0.03	107
His	0.40	125	0.39	124	0.39	125	0.40	125	0.38	124	0.04	126
Iso	0.15	37	0.14	36	0.14	37	0.15	37	0.14	37	0.01	37
Leu	0.10	70	0.10	69	0.10	69	0.10	70	0.10	72	0.01	70
Phe + Tyr	0.11	105	0.10	105	0.10	106	0.11	106	0.11	109	0.01	107
Trp	0.02	16	0.02	16	0.02	16	0.02	16	0.02	16	0.00	16
Energy kcal/kg	3100		3150		3200		3250		3300		3350	

Weight (kg)	3.00		3.70		4.40		5.20		6.00		6.80	
Amino Acid	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio
Lysine	1.07	100	1.02	100	0.96	100	0.90	100	0.84	100	0.79	100
SAA	0.65	61	0.61	60	0.60	62	0.57	63	0.52	62	0.52	66
Thr	0.37	56	0.34	56	0.34	57	0.32	57	0.30	57	0.30	58
Val	0.29	78	0.26	76	0.27	80	0.26	81	0.23	77	0.25	84
Arg	0.31	107	0.27	105	0.29	106	0.28	106	0.24	105	0.27	105
His	0.38	126	0.34	124	0.36	125	0.35	125	0.30	124	0.33	125
Iso	0.14	36	0.12	36	0.13	36	0.13	37	0.10	35	0.12	37
Leu	0.10	70	0.08	69	0.09	70	0.09	70	0.07	68	0.09	70
Phe + Tyr	0.10	107	0.09	105	0.10	108	0.10	108	0.07	102	0.09	109
Trp	0.02	16	0.01	16	0.02	17	0.02	17	0.01	16	0.02	18
Energy kcal/kg	3400		3400		3450		3450		3500		3550	

Weight (kg)	7.50		8.30		8.90	
Amino Acid	% Diet	Ratio	% Diet	Ratio	% Diet	Ratio
Lysine	0.73	100	0.67	100	0.63	100
SAA	0.50	69	0.48	72	0.46	73
Thr	0.29	58	0.29	60	0.27	59
Val	0.27	91	0.26	91	0.25	93
Arg	0.28	105	0.28	105	0.26	105
His	0.35	124	0.35	126	0.33	124
Iso	0.13	37	0.13	38	0.12	38
Leu	0.09	69	0.09	71	0.09	72
Phe + Tyr	0.09	104	0.11	114	0.12	128
Trp	0.02	19	0.02	19	0.02	21
Energy kcal/kg	3600		3600		3600	