TURKEY GROWTH MODELLING:
METABOLIC APPROACH[1]

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Primary Audience: Nutritionists, Production Managers

SUMMARY

Modelling of animal growth is a topic with resurgent interest in the past few years little work has been performed in terms of modelling growth response and nutrient requirements of turkeys. A variety of factors may affect performance modelling of turkeys. These include genetic potential, sex, lean tissue accretion, feed intake, feedstuff digestibility, environmental conditions, variation and parts yield. The current state of turkey modelling is discussed as well as possible directions for the future.

Key words: Turkey, modelling, growth, tissue accretion, nutrient requirements
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INTRODUCTION

Modelling of animal growth has been a topic of varying interest over the past thirty years. With the relatively recent advances in computing power, there has been a renewed interest in the potential for modelling the growth of several species of economic importance. This computer modelling has the potential to provide information in a number of areas for the turkey industry, including prediction of growth rate and market weights; determination of more precise nutrient requirements for turkeys based on sex, strain, environmental conditions such as temperature and floor space, digestibility, disease state, lean vs. fat accretion, parts yield, and intake; determination of factors that are truly of economic importance to the operation; and general knowledge about the systems involved in turkey production. Because of the relatively long growing cycle and the high cost of re-search on turkey production and nutrition, the potential benefits from modelling growth in turkeys is excellent.

PREVIOUS MODELS

One of the first models used for turkeys was provided by Waibel [1]. With this model the protein/amino acid levels used in a diet could be adjusted based on the price of protein (as soybean meal) and the temperature (40–85°F) of the houses. A working formula for this model was:

$$x = 1.00 + 0.004 \, (F - 70) - 0.005 \, (S/P - 20)$$

where: x = coefficient of modification of usual amino acid level

F = average temperature during feeding period in °F

S = cost of dehulled soybean meal in $/100 lb

P = expected sale price of live turkeys in $/lb

Hurwitz and co-workers [2, 3] also published several articles relating to a model for

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turkeys. This model, based primarily on the need for protein deposition in carcass and feathers as well as the maintenance requirement for the amino acids, used a term for intestinal absorption of 85% to account for digestibility of the diet. Maintenance was determined by losses in intestine and skin, and creatinine lost in urine. Growth composition was determined by amino acid and protein analysis at different ages both for carcass and for feathers. A second series of experiments validated the model's determination of requirements for sulfur amino acids and lysine [3].

Fisher [4] and Emmans [5] described a modelling equation based on the Edinburgh growth model [6]. This model determined amino acid requirements based on growth rate and rate of protein growth of turkeys. The equation for lysine requirement is:

$$\text{LYS (mg/day)} = 86\, dP/dt + 69\, W$$

or

$$\text{LYS (mg/day)} = 86 \times \text{rate of protein growth in g/day} + 69 \times \text{Body Weight in kg}$$

The authors give an example calculation. For a 12-wk-old turkey consuming 3050 mg of lysine, 1640 mg accrete, 930 mg are lost to digestive processes, and 480 mg are used for maintenance. Gompertz growth functions predict body weight and body weight gain based upon the Edinburgh model. Emmans [5] provides a more complete description of this topic.

Nixey [7] described the Reading model [8] and applied experimental data from the turkey to determine amino acid requirements by this method:

$$\text{AA (mg/day)} = a\Delta W + bW$$

where: ΔW = potential body weight gain per day
        W = mean body weight
        a = the constant defined as the amino acid intake per unit of body weight gain
        b = the constant defined as the amino acid intake per unit of body weight maintained

Based on this model, the total sulfur amino acids based on a percentage of the lysine requirement changes from 65 to 147% while the NRC [9] suggests a 65 to 69% change from the starter period to the 16–20 wk period.

EXAMPLE CALCULATIONS

If a similar period of growth is selected and example calculations run through the Edinburgh model and the Reading model, some differences become apparent. Given one set of circumstances, the Edinburgh model predicts a daily lysine need of 3908 mg at 112 days of age. Sulfur amino acids are then required at 2607 mg, or 67% of this value. If one next uses the Reading model with a similar lysine need, the sulfur amino acid needs are calculated to be 3800 mg/day, or 97% of the lysine needs. Obviously, both models cannot be correct.

PROBLEMS WITH CURRENT MODELS

Both Emmans [5] and Nixey [7] made amino acid requirement comparisons based on previously mentioned models and found significant differences in results. Neither of these authors expressed confidence in the ability of current models to predict nutrient requirements for the practicing nutritionist. To the author's knowledge, there are no models currently in use by the major portion of the commercial turkey industry. Some of the problems to be addressed include the lack of accounting for feedstuff digestibility, the need for economic data to be correlated with the growth and requirement information, and the need to project parts yield in the models.

FUTURE APPROACHES

Since determination of future directions in a field such as turkey nutrition and modelling is fraught with controversy, the reader is cautioned that much of what follows is somewhat subjective and in fact may not come to pass. The first question that must be answered concerns what the industry wants from a model. The ability to predict weight for age is, relatively speaking, easy, while the ability to determine nutrient requirements is relatively difficult. Based on discussion with industry nutritionists and a good deal of thought on the subject, this researcher will attempt to predict the directions for the future and some potential problems.

The first problem that must be noted and will affect our thoughts on directions is the species under discussion: the turkey. However, it is shocking how little data is available on the nutritive requirements of turkeys. Much of the data collected has focused on pro-

tein/amino acids and energy, generally the most expensive portions of the diet.

There are a number of reasons for this paucity of data. The life cycle is long and the growth rate rapid. With the amount of variation between birds, a large number of birds is necessary to achieve usable data. This situation increases the cost because of the logistics of weighing, feed mixing, etc. Data has been collected mostly in the early period of growth, so the extrapolation to later periods is less than ideal. Also, titrations of a given nutrient become difficult at later ages. There are also significant differences between the sexes, with the implication that different requirements need to be calculated for toms vs. hens. Since the growth cycle is long, there is sufficient time for environmental effects to come into play and provide significantly different results from two flocks of birds raised on similar dietary regimes. It is the author's opinion that we do not have sufficient data to do a good job of modelling at this time.

The current expression of nutrient requirements is based on a percentage of the diet basis with changes occurring at three- to four-week intervals. This practice will result in overfeeding of the majority of the birds much of the time as the protein requirement decreases with age (as a percent of the diet). This situation is illustrated in Figure 1. The areas of potential overfeeding are also areas of potential feed cost savings. In other words, the

challenge is to determine the actual nutrient requirements of the turkey and to utilize models accurately to predict the most economical formulations given changing environmental, genetic, and economic considerations. Most approaches to this problem have involved some form of nutrient partitioning with a variety of methods involved in these determinations.

The first piece of information needed in nutrient partitioning schemes is feed intake data. General feed intake data and rough estimates of intake can be obtained on the farm. However, there is little specific data on the intake of turkeys under various conditions; the little data available would suggest that while it may appear that requirements change with age, in fact these are merely reflections of differing intake patterns [10]. For modelling to be of value, we will need good information about flock intake levels as well as about expressing requirements based on these statistics (i.e., g of nutrient/day).

The next partition of interest is the disappearance of nutrients from the gut, also known as digestibility. The excellent work of Sibbald [11] offers a description of the basic methodology: digestible amino acids in the cecectomized turkey, different ages of toms vs. hens, and comparisons with rooster, as well as how fat additions affect digestibility [12, 13, 14]. Certainly this work must constantly be checked as feedstuff sources change and as
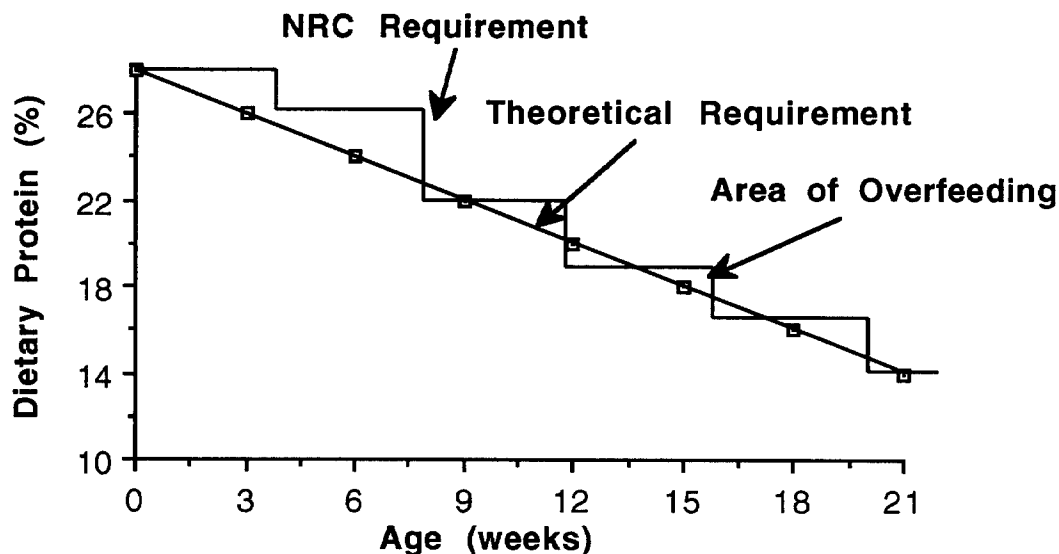

FIGURE 1. Potential areas of overfeeding

experimental diets are monitored. Since differences between digestibilities of feedstuffs do appear to occur between turkeys and chickens, turkey data should be utilized for experiments seeking to model turkey nutrient profiles.

The next partition is maintenance and retention. A significant portion of energy and amino acids is used for metabolic functions and is not deposited as muscle protein. Several methods have been employed for the determination of maintenance needs. Hurwitz and co-workers [2, 15] used losses in intestine, skin, and creatinine summed and divided by the 85% coefficient of absorption. Another method which may be more useful although more tedious, is to feed graded levels of the amino acid in question to animals in the linear portion of the growth curve, measuring retention of the amino acid. One can then extrapolate to the zero nitrogen retention point (Y = 0) to discover a requirement for maintenance as well as determine the efficiency of amino acid retention. This type of study has been done for other species such as the pig [16, 17], but to the author's knowledge has not been performed for the turkey. It would appear that at minimum, some comparative studies of the limiting amino acids must determine if these numbers differ significantly in the turkey.

The final partition, tissue deposition, suggests that we must have knowledge of the rate of protein deposition if we are to document

nutrient requirements based on feeding to maximize lean tissue accretion.

The Gompertz equation (Figure 2), originally described as a growth function [18], has been used extensively for fitting the growth of turkeys [5] as well as other poultry. It could be useful in models of deposition. Measurement of tissue deposition is simple in concept and both difficult and expensive in practice. Basically, animals of interest, grown and serially slaughtered at predetermined intervals, are treated such that all components of carcass are maintained with the exception of gut contents, are ground finely, and are then mixed prior to analysis for body composition. Needless to say, the more frequently samples are taken, the more accurate the data. This type of work is currently being done in the pig, but little recent work has been done in the turkey. However, this technique affects parts yield such as breast meat. Perhaps only a combination of protein deposition studies and yield studies will be sufficient to address this problem.

The final area of concern is that of energy. Sell and co-workers [19] reported that there are independent effects of protein and energy in growing tom turkeys. While similar types of studies produced similar results, it appears logical that for a given level of energy there should be an appropriate level of protein/amino acids to maximize protein deposition with minimal fat deposition. Moving beyond this energy level without an appropri-
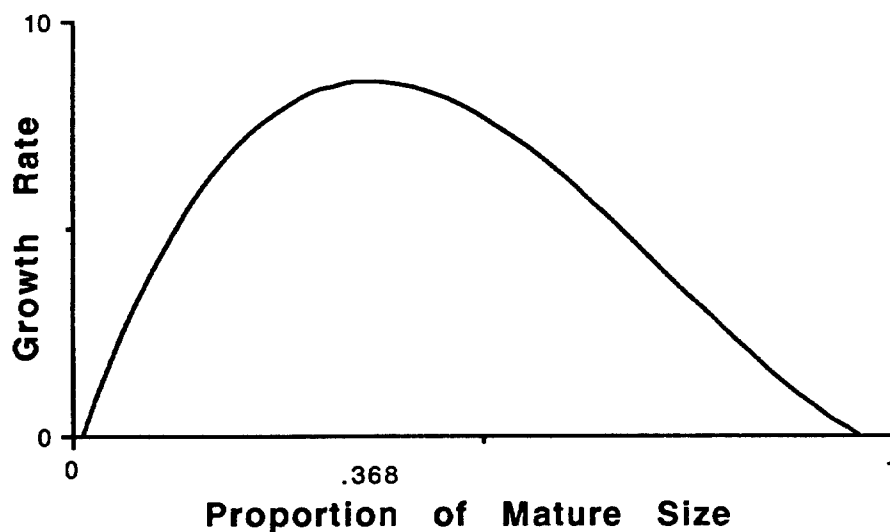

FIGURE 2. One form of the Gompertz equation

ate change in amino acids would result in no increase in lean tissue deposition, but a probable increase in fat deposition. Moving the other direction would probably result in increased utilization of protein for energy with a net loss in efficiency. It appears that we need to determine the level of amino acids needed on a daily basis to support maximal muscle growth . We would need to follow these with experiments titrating energy to come up with appropriate ratios for formulation. One must keep in mind that the ratios would need to be changed whenever factors affecting maintenance costs (such as temperature) changed.

CONSIDERATIONS FOR FUTURE MODELS

A number of factors affect the performance of turkeys. If the overall goal of a model is to optimize the operation, many of these factors will need to be incorporated into a model if it is to be of use:

Genetic Potential: Should be calculated for each of the major commercial strains.

Sex Differences: With the extreme differences manifested in mature body size, must calculate different requirements.

Lean Tissue Deposition: More difficult than actual growth rate to determine, but more accurate long term.

Intake Patterns: Need to be correlated with strains and environmental conditions.

Feedstuff Digestibility: More data is necessary for accurate modelling.

Environmental Conditions: With obvious effects of temperature on maintenance costs and intake, must also study floor space, feeder and waterer space, ventilation, etc.

Bird Variation: Measurements reflect significant differences with same conditions (*e.g.*, In a recent study [20], two poults starting at similar body weights ate 476 and 477 g of feed, but gained 280 vs. 312 g – over a 10% difference).

Parts Yield: Moving heavy hens into a light tom whole bird category, breast yield of toms will become increasingly important, so any model must acknowledge these factors.

Other Factors: There are a number of other factors that contribute to our lack of understanding of nutrient requirements and our ability to react to changing circumstances if we had more knowledge. Disease status may be an example. While producers monitor commercial turkeys for diseases, how different diseases affect nutrient needs is unknown. It would also be difficult to change diets quickly enough to react to these changes in status in the field.

CONCLUSIONS AND APPLICATIONS

1. Although there appears to be great potential for modelling with the turkey, there is currently insufficient data available to do a good job of it.
2. Previous models have been utilized, but are not in general agreement in terms of prediction of nutrient needs.
3. Future approaches may take a nutrient partitioning approach to modelling, basing the model on intake, digestiblity, maintenance costs, and tissue accretion levels.
4. While there are some unexplored areas that may be valuable (crystalline diets, ideal protein), sufficient information on methodology is available to form the basis of an effort towards a modelling approach.

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