A new tool to teach nutrition for understanding

R. GOUS¹ and C. FISHER²

¹Animal and Poultry Science, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa, and ²EFG Software, Leyden Old House, Kirknewton, Midlothian, EH25 8DQ, Scotland.
Corresponding author: gous@ukzn.ac.za

Abstract. An advanced non-ruminant nutrition course, used in the department of Animal and Poultry Science at the University of KwaZulu-Natal is described. The tools available consist of a windows-based feed formulation program and a model that simulates the food intake and growth of broilers. Students begin by formulating feeds based on NRC requirements, and then simulate the growth of broilers using these feeds. Using outputs from the Model as a guide, both the feeds and the feeding programme may be altered in an attempt to maximise or minimise a chosen objective function, such as margin/m² annum, breast meat yield, or feed conversion ratio. In this way students gain an understanding of the theory incorporated into the Model. During this process the lecturer assists by explaining important aspects of nutrition theory, and providing relevant literature.

Keywords: teaching nutrition; feed formulation; growth model; optimisation

Introduction

Poultry nutrition students at universities are seldom prepared for the work they will do as nutritionists for a feed supplier or an integrated broiler operation. They are taught the principles of nutrition, such as biochemistry and intestinal physiology, and may have been required to learn about nutrient requirements as defined by, for example, the National Research Council (NRC, 1994) or other review bodies. They may even have been given the opportunity of formulating a feed using least-cost feed formulation software. But do they fully understand the concepts, for example, of nutrient responses as opposed to nutrient requirements, of optimum economic dietary nutrient contents, and of the effects of dietary protein content on carcass fatness? And do they have confidence in the least-cost feed that they have formulated, knowing that it will perform successfully when fed to pigs or poultry? Many nutritionists working in the poultry industry have not had the opportunity of learning these concepts, and because they are so busy buying and testing ingredients and formulating feeds they have little time to read the scientific literature, let alone catch up with developments in these fields. There is no better time to prepare aspirant nutritionists to understand the practical aspects of nutrition than when they are studying at a university, but useful tools for such training have been lacking, until now.

A nutritionist should be able to follow the feeds that have been formulated through to the end product: the finished broiler or the carcass portions produced. However, in most cases there is little or no feedback except when performance is below expectation, at which stage the pressure on the nutritionist to put things right is enormous, but the tools available to assist in making the right decision are limited to the feed formulation program and previous experience. No wonder that nutritionists are reluctant to change a nutrient bound, or consider using different ingredients. This situation results in a stagnation of ideas, and an aversion to move away from the status quo. This goes against the philosophy of continually striving for improvement (Deming, 1986), a principle that, when applied, has resulted in enormous gains for the companies who have embraced this philosophy. How can this principle be taught to students of nutrition so that they can apply it once they are in business?
**Description**

Deming’s philosophy of continual improvement is illustrated in Fig. 1(A). He realised that by continually monitoring performance, seeking improvements and then implementing these, gains in performance could continue unabated. There is a great advantage in inculcating this philosophy into students of nutrition, and this would be quite possible if they had at their disposal some means of predicting the performance of broilers. They could formulate feeds, design a feeding programme making use of these feeds, predict performance, determine the shortcomings of the programme by viewing a ‘biological diary’ in which the constraints, if any, are identified and can be removed by altering the formulation, reformulating, and again predicting performance. It is obvious from the process outlined that Deming’s philosophy of continual improvement is being followed, as illustrated in Fig. 1(B).

![Diagram of Deming's philosophy](image)

**Figure 1. Deming’s philosophy of continual improvement (A), and as applied by nutritionists when formulating feeds for pigs or poultry (B).**

The three components of the formulation cycle illustrated in the figure have been developed by EFG Software (2006) and consist of a windows-based feed formulation program, a simulation model for broilers, and an optimisation routine. For students of nutrition the optimisation routine would not be made available to them, as they would learn more by conducting this process themselves. By continually striving for improvements in performance, or in one of the measures of profitability, the student would learn the practical aspects of nutrition through understanding, and there is no better way of learning than this.

The formulation program, WinFeed, was developed with nutrition students in mind and hence contains all the features needed to teach students the principles of feed formulation. Being windows-based, all the features of this platform are available to the student, plus there are many features that make feed formulation more interesting, such as the following:

- Digestible or total amino acid bounds may be specified, but whilst only one of these is used in the formulation, the results are displayed for both, thereby giving the student an easy insight into, and an understanding of, the difference between these values.
- Parameterisation, to determine the effect of change in ingredient price on its inclusion rate in the feed, of ingredient inclusion rate on the cost of the feed, and of nutrient bounds on feed cost.
- The relative contribution of each ingredient to the nutrient content in the feed is calculated, and it may surprise many students to learn, for example, that more than 20% of the protein, and 25% of the methionine and cysteine in a broiler feed is supplied by maize in a typical maize, soybean feed.
- Nutrients other than ‘cost’ may be set as the objective function, so a feed with minimum protein, but containing adequate amounts of the essential amino acids, may be formulated, to discover both the extent to which excess protein may be reduced with the ingredients available, and the consequence in terms of the cost of the feed. Alternatively, a more efficient method may be used to minimise the heat increment of the feed: the effective energy (EE) content (Emmans, 1994), a measure of the net energy in the feed, may be minimised, whilst maintaining the ME at the desired level. This is an important exercise when investigating methods that may be used to overcome heat stress in broilers and pigs.
Nutrients may be created as ratios of other nutrients or as linear expression of other nutrients. It is the latter method that is used to calculate the EE of an ingredient using a complex equation that includes the ME of the feed as well as its digestible crude protein and lipid contents, and its faecal organic matter, the latter itself being calculated from first-principles, a concept that would interest and benefit the nutrition student.

A network version of the formulation program is available, so each student is able to maintain his or her own database, and work from any computer linked to the network. This overcomes the obvious problems that would occur if more than one student had to work with the same database. A SQL server database is used, so the chances of database corruption are minimal, and as many universities make use of this database the expertise in installing and maintaining the database is usually available.

The broiler growth model used is based on the theory that an animal needs certain resources in order to maintain its current state and to grow according to its growth potential (Emmans, 1987; 1988; 1989; Emmans and Fisher, 1986; Emmans and Oldham, 1988). Because the animal is motivated to grow at this rate, the acquisition of food as a means of obtaining the required resources becomes a priority. Its desired food intake can be seen to be dependent on the nutrient requirements of the animal and the content of those nutrients in the food. Because the animal is assumed to eat to satisfy its requirement for the first limiting feed resource, food intake would be expected to deviate from the desired intake when the food is unbalanced in some way or if the animal were placed in an unfavourable environment. In the case of a marginal deficiency of an essential nutrient, the animal may be capable of consuming sufficient of that imbalanced food to grow to its potential, but as the deficiency was made more severe, protein growth would fall below the potential. The inability of the animal to eat sufficient of such an imbalanced food could be due to the constraints of feed bulk, or the inability to lose to the environment the additional heat that would be produced if more food were consumed. Emmans and Fisher (1986) have given a comprehensive explanation of this theory of food intake. The most important consequence to the commercial broiler producer of providing broilers with a feed marginally deficient in an amino acid is that the bird will overconsume energy in an attempt to obtain sufficient of the limiting resource, and this energy will be deposited as lipid. It has been shown that broilers exhibit statistically significantly higher feed conversion efficiencies and lower lipid contents when higher concentrations of amino acids than are conventionally used in the broiler industry are included in the feed (Gous et al., 1990).

The broiler growth model has been developed over many years, and is backed up by a wealth of relevant scientific research to confirm the theory used to predict food intake and growth in broilers. Prediction of food intake is the most important feature of the model, and as this is done mechanistically, students will be able to learn the principles behind the model by designing feeding programmes and measuring their effect on the performance of given genotypes and sexes kept in differing environments, including the chemical and physical components of growth. A list of relevant references to the theory incorporated into the model is available to users of the program. Such a list is invaluable to nutrition students wishing to understand the principles behind the theory of food intake regulation incorporated into the model. This, too, is a process of continual improvement: by studying the relevant literature whilst using the model, students would continuously improve their understanding of the nutritional principles involved.

An advanced non-ruminant nutrition course, incorporating the principles outlined above, has been designed by staff in Animal and Poultry Science at the University of KwaZulu-Natal. This course begins by assisting the students to use the feed formulation programme to formulate feeds based on the NRC (1994) requirements for broilers, and the students are then required to simulate the growth of broilers using these feeds and the Broiler Growth Model. Using outputs from the Model as a guide, both the feeds and feeding programme may be altered, in an attempt to maximise or minimise a chosen objective function, such as margin/m²:annum, breast meat yield, or feed conversion ratio. Students work in groups, striving to do better than their peers, learning along the way the principles behind the Model. During this process the lecturer assists by explaining important aspects of nutrition theory, and providing relevant literature. Students enjoy the challenge, as they can predict instantly the response to the feeds and feeding programmes that they have designed, and monitor the progress made in their chosen objective function. The course outline, including relevant literature, is available to users of the program.
Some of the principles that may be investigated with the use of the program follow:

*Separate sex rearing.* The potential growth rates of male broilers differ substantially from their female counterparts, and consequently there should be an advantage in providing each sex with feeds tailor-made to meet their requirements, yet this is not universally applied in practice. The simulation model calculates the nutrient requirements for each sex, and appropriate feeds and feeding programmes may be designed and simulated, to determine whether there is a financial advantage in providing separate feeds for the two sexes. All that may be necessary would be to design a separate feeding programme for each sex using the same basic feeds. In addition, the appropriate environmental conditions for the two sexes may be obtained from the growth model.

*Evaluating new varieties of feed ingredients.* Assuming that there are no anti-nutritional factors present in the ingredient to be tested, and that an accurate description of the digestible protein, lipid and amino acids is available for the ingredient, the parameterisation function may be used once a feed containing this ingredient has been formulated. This will give relevant information about the monetary and biological value of this ingredient relative to others, what the limiting nutrients would be, and at what concentration the ingredient would appear in each formulation. This is an interesting and challenging exercise for a nutrition student.

*How does the Ideal Amino Acid Ratio change during growth?* The concept of an Ideal Amino Acid Ratio has generally been accepted by nutritionists, but it is important to realise, especially for broilers, that this ratio does not remain constant throughout growth. Differential rates of growth of feather and body protein, and the increasing requirement for maintenance during growth, means that the ratio is continually changing. The Model provides information on these ideal protein ratios for each day of the growing period, both in tabular form and with the aid of graphs, a useful way of illustrating the concept to students.

*What is the proportion of the total amino acid requirement that is required for maintenance during growth?* This is related to the point above. The Broiler Growth Model provides information on the relative rates of growth of body and feather protein, together with their requirements, and also for the increasing maintenance requirement.

*Relative rates of growth of body protein and lipid.* A common misconception is that protein growth occurs until a given stage of maturity and then lipid growth takes over. Because these two components of growth are allometrically related, growth occurs in both components until the bird or animal reaches somatic maturity, i.e. when the mature protein state is reached. Graphs of all the components of growth may be drawn to view the relative growth rates of these components. The effect on carcass fatness of offering a feed marginally deficient in one or more amino acids is also well illustrated in various ways in the Model.

*Ammonia emissions – predicting N excretion.* Of increasing relevance is the problem of N excretion by poultry. The excretion of N is a function of the amount of indigestible protein fed to the birds, as well as of the excess amino acids that are fed that cannot be incorporated into body or feather protein, and which are deaminated. The Model calculates these amounts, and illustrates the effect of poor quality proteins on the amounts of N excreted.

*Energy: protein ratios.* When feed is offered *ad libitum,* and where the dietary protein is fed below the requirement, energy is never limiting, but the limiting amino acid is utilised with maximum efficiency. However, at very high levels of protein, energy may well be limiting even when birds are fed *ad libitum,* and this results in a lower efficiency of utilisation of the protein. This concept is of particular relevance in starter feeds containing high levels of protein but low levels of ME, and the implications may be investigated using the formulation program and the Model. The problem cannot be alleviated by feeding additional protein, nor is increasing the ME content of the feed always an option, so alternative solutions must be sought.

*Replacing carbohydrate with oil in feeds to be used at high temperatures.* This concept is well documented as a means of reducing the heat increment of a feed, but when the heat increment is calculated (as the EE: ME ratio, which needs to increase to reduce heat increment) after replacing carbohydrate with oil, using conventional ingredients, the result is disappointing. Even when as much as 10% additional oil is added, the EE: ME ratio changes only marginally. This is because low quality carbohydrate sources are used in place of the high quality sources, to maintain the ME content of the feed due to the addition of oil, and as these poor quality carbohydrates have a high indigestible carbohydrate content, the faecal organic matter content of the feed is increased, which nullifies the
advantage gained from the addition of oil. Only when inert material is used would the heat increment be reduced, but this is usually impractical. These are important principles that a nutrition student would be unlikely to understand without attempting the exercise.

**What should be the objective function in broiler production?** Broiler producers have different objectives, depending on whether they are selling whole, processed, or further-processed broilers. Some producers hope to minimise feed conversion ratio, while others wish to maximise breast meat yield or margin/m² annum. Ultimately, the objective is probably to make as much money as possible whilst providing the customer with the desired product of the highest quality.

By simulating the growth of broilers under different circumstances these measures of performance and profitability may be compared, and the effect on these measures, of pursuing a specific goal, can be an interesting exercise, and one that will prepare a nutrition student with the background to argue for or against measures that are being pursued by a future employer. In this way, students are being prepared for the future in a constructive and an understanding environment.

**References**


