IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 15, Issue 3 Ser. II (March 2022), PP 47-53
www.iosrjournals.org

Process of Improving the Nutritional Value of Poultry Products

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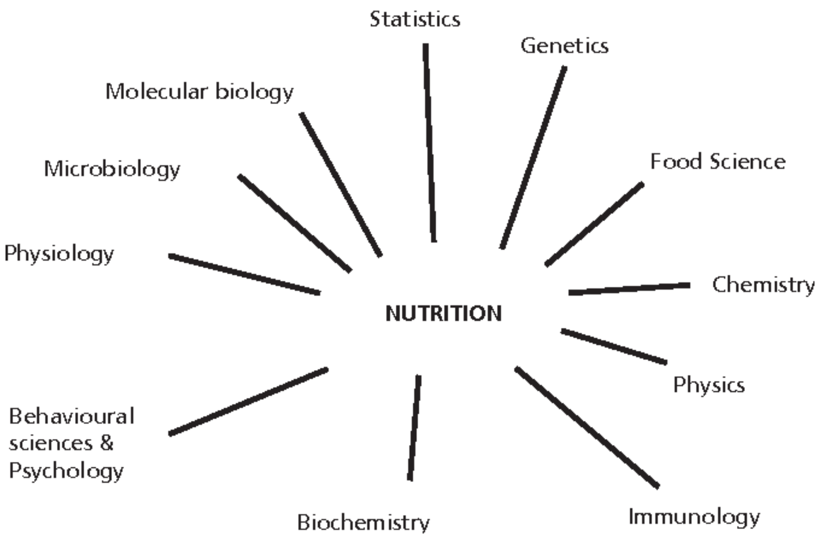
Abstract
It is considered to improve the nutrients of poultry in different ways. It is now not only possible to predict voluntary feed intake accurately, but broiler feeds and feeding schemes may now be better using the more advanced models. Development of such prediction models has stimulated useful and purposeful research targeted at filling the gaps in our knowledge of critical aspects of the theory incorporated into these models. In this paper it is discussed the controversy that exists in designing and interpreting response experiments, and highlight some of the most recent challenges related to the prediction of responses to nutrients by poultry. These latter include differences, brought about by selection for diverse goals, that have become apparent between modern broiler strains in their responses in feed intake and mortality, which are not independent of level of feeding or strain of broiler, as was previously believed. Uniformity, an important quality criterion in broiler processing, is also not independent of level of feeding, and the effect may now be predicted using stochastic models. An important aspect of response prediction is dealing with constraints to performance: whereas it is relatively straightforward to simulate the potential performance of a broiler, such performance is often constrained by the physical, social and infectious environment, among others, providing a challenge to attempting to predict actual performance. Some of these constraints to potential performance have not yet been adequately described.

Date of Submission: 08-03-2022 Date of Acceptance: 24-03-2022

I. Introduction

Predicting responses of poultry to nutrients has been the goal of nutritionists and imitation for a long time. The controlled feeding model of a growing pig was the first serious and successful attempt to integrate information about an animal, its feed and the environment in which it was kept, with a view to simulating its performance. This provided the impetus for the development of further models, of modifications to existing models and of research targeted at filling the gaps in our knowledge of critical aspects of the theory incorporated into these models.



Models incorporating this theory are thus more realistic and useful, providing the nutritionist with a tool for making decisions about the most appropriate course of action to take under different circumstances. Advances continue to be made, and it is now possible to optimize the feeds and feeding programs of broilers and pigs, through the integration of a feed formulation program, a model and an optimization routine. However, because models require a complete statement about each step in the chain of events, some interpolation must of necessity be used where appropriate data are missing. All models contain some such conjectures, so none can claim to be absolutely accurate. Also, as models become more sophisticated, the list of variables that may be predicted increases.

Poultry nutritionists are interested in responses to nutrients in economically important outputs such as body weight (or protein) gain, breast meat yield, egg output, feed intake and conversion efficiency, numbers of chicks produced per hen, etc. Because such responses are usually measured using groups of birds, they are invariably curvilinear, being the result of integrating the responses of individuals making up that population. Populations of birds therefore cannot have 'requirements' for nutrients: what nutritionists seek are the optimum economic dietary contents of each nutrient, and for this they need to know how populations respond to increasing dietary contents of the essential nutrients. Descriptions of such responses, whilst taking account of marginal costs and revenues, are therefore invaluable in determining how to maximize or minimize the objective function chosen for any given commercial operation. Clearly, being able to predict these nutrient responses may be seen as the foundation of a successful nutritionist.

The objective of this paper is to discuss some of the issues faced by those whose interest is to predict responses in poultry. Whereas the most satisfactory models are deductive in nature, they must nevertheless rely, to a greater or lesser extent, on the results of experiments to provide the numbers that will make the theory work. Yet controversy exists in the methodologies used to measure and interpret such nutrient responses, casting doubt on the accuracy of some of these numbers, the consequences of which are discussed here. It has become evident recently that some variables critically important in determining the profitability of an enterprise, such as mortality and uniformity, are not independent of level of feeding and strain of broiler, as was previously believed. Also, poultry breeding companies claim that they have been successful in improving breast meat yield, yet such improvements may be anomalies resulting from using a faster-growing, leaner bird and not because the relationship between breast meat yield and body protein weight has been altered by selection. These raise important issues about correctly describing the genotypes being simulated, and whether it is possible to use a deductive approach when describing mortality and uniformity in a broiler flock.

II. Prediction of Nutrients

Whereas it is relatively straightforward to simulate the potential performance of a broiler, such performance is often constrained by the environment and disease, among others, providing a challenge to imitation attempting to predict actual performance. Some of these constraints to potential performance have not yet been adequately described, providing yet another challenge to those wishing to predict nutrient responses in poultry. Measuring and interpreting responses Before nutrient responses can be predicted it is necessary to have some measurements on which theories may be based. Indeed, one of the most important reasons for conducting experiments, apart from testing a theory or comparing two theories, is to determine the numbers that will make a theory work, such as measuring the efficiency of utilization of the limiting amino acid for protein growth.

The measurement and interpretation of amino acid responses will be used as an example of the controversy that still exists in the methodologies used to measure and interpret nutrient responses. For example, the two general methods used to measure responses to individual amino acids are the graded supplementation technique, where a basal diet deficient in the test amino acid is progressively supplemented with increasing doses of the synthetic form of the test amino acid, and the summit dilution technique, in which a summit feed with excessive amounts of all amino acids but with the test amino acid first-limiting is progressively diluted with either a non-protein diluent or a dilution feed with the balance of amino acids reflecting those in the summit feed. Issues have been, and are still being raised regarding these techniques.

Accurately predicts responses in feed intake, live weight, protein and lipid gain obtained with the summit dilution technique, but seldom does so when the graded supplementation technique has been used. Because this model takes no account of amino acid imbalances, the responses being directly related to the content of the first-limiting amino acid in the feed, the lack of agreement between observed and predicted responses when using the latter technique provides circumstantial evidence that imbalances are indeed confounding the responses to some amino acids when this technique is used. If the response to nutrients is influenced differentially by the changing amino acid balance in the test feeds, when using the graded supplementation technique, the coefficients of response will be lower than they should be, resulting in an overestimate of the efficiency of utilization of the limiting nutrient.

If responses are influenced by both the level of limiting amino acid in the feed and changes in amino acid balance, then models of feed intake must be modified to take account of this confounding. The extent to which imbalances are created differs with the limiting amino acid, so it may be necessary to model this characteristic of feed at the biochemical rather than the whole animal level.

III. Response to the Limiting Nutrient

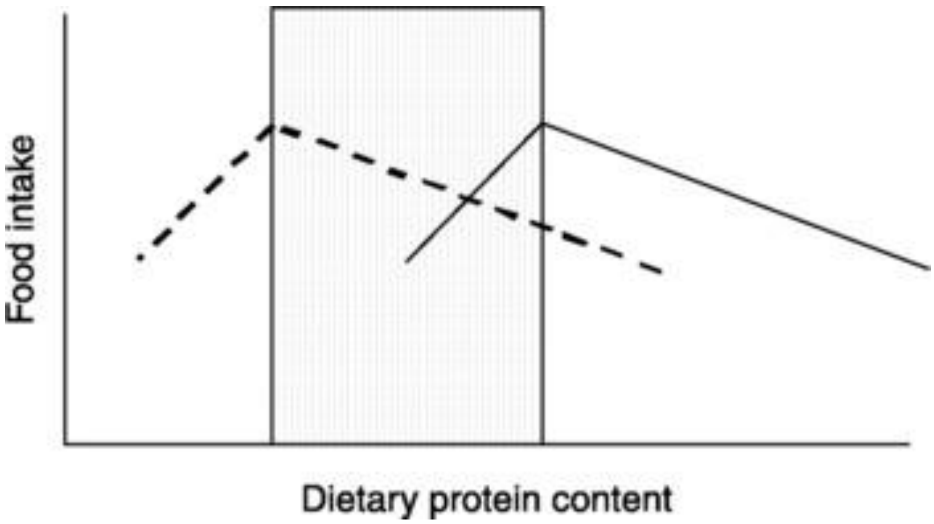
The response to the limiting nutrient, or to balanced protein, may be of considerable interest, but not as a means of defining a 'requirement'. Where marginal costs and revenues are included in the calculation, such responses may be used to determine the optimal economic intake of the nutrient by fitting the Reading Model to the data, and this may be of some value in laying hens whose requirements are relatively stable for long periods of time. However, in the case of growing birds the 'optimal economic intake' is meaningless, as, although it may apply to the period over which the trial was conducted, the requirements and hence responses of growing birds are changing continually over time. Such responses are therefore useful for testing theories of feed intake and growth, but are of little value in defining feeding programs for broilers.

In many instances the results of experiments have been used to define 'the requirement' for the class of poultry used in the trial. One should bear in mind that the results of any one experiment are rarely sufficiently robust that they can be universally applied in this way: strain, sex, stocking density, environmental conditions, feeding levels and programs, among others, all interact to define the response measured, and consequently the method of interpretation used to define the 'requirement', under the sub-set of conditions applied during the experiment, is of relatively minor importance. The value of such response experiments is therefore not that they enable one to define a requirement, but rather that they can be used for more fundamental purposes, such as to measure the efficiency of utilization of an amino acid. Because the measurement of response is central to its prediction, it is critical that each experiment is designed in such a way that the results can be used unambiguously when being incorporated into a model. Sensitivity analysis assists in identifying those aspects of a model that are particularly important, and the efficiency of utilization of amino acids is one such aspect that needs to be accurately estimated. Are the efficiencies the same for all amino acids? Do they differ for growth and reproductive processes? Because doubt has been expressed as to the accuracy of efficiencies measured using the graded supplementation technique, resources need to be applied to resolve this important issue.

Responses of interest many factors need to be considered when attempting to maximize profitability in an enterprise and all of these need to be predicted if a model is to be used to determine the conditions that will yield the desired outcome. Information required for optimization consists of feed costs at different levels of amino acid provision, a description of all the relevant animal responses, both fixed and variable costs affecting the production system, and details of revenue. The complexity of the information required would depend on the level of organization at which the optimization is to be made. If profit of the broiler grower is to be maximized at the farm gate, then responses in live ability, growth and feed conversion ratio will probably suffice. However, and more realistically, a wider view will be required, and the effect of broiler nutrition on slaughterhouse variables and further processing will need to be defined. Whereas such predictions have reached a high level of success, nevertheless some issues still remain unresolved and require further attention.

Feed Intake

The process of feed intake and growth proposed was based on the premise that birds attempt to grow at their genetic potential, which would imply that they would attempt to eat as much of a given feed as would be necessary to grow at that rate. Factors that would prevent them from achieving this goal would be the bulkiness of the feed or the inability to lose sufficient heat to the environment in order to enable them to remain in thermal balance. Broilers have been shown to increase feed intake as the limiting nutrient in the feed is reduced, attempting thereby to obtain more of the limiting nutrient, until a dietary concentration is reached where performance is so constrained that feed intake falls. It is only on marginally deficient feeds that feed intake is predicted to increase. Where the limiting nutrient content is severely deficient, a decline in feed intake is expected to occur as a result of the severely constrained growth rates that occur on such feeds, which in turn result in a lower capacity for feed intake when measured over a fixed time period.



This general response in feed intake to decreasing contents of a limiting amino acid, namely, a linear increase followed by a decline in intake, is illustrated in Figure 3. If one assumes that the limiting nutrient content resulting in the lowest feed intake on the right of each graph reflects an adequate supply of that nutrient, and that strains may differ in the nutrient content assumed to be adequate, then it is possible to imagine a situation in which the range of nutrient contents chosen in a response trial will result in the feed intake increasing and decreasing in the two strains respectively. Whilst this may not be the reason for the difference in their responses in feed intake to a limiting nutrient, it does suggest that this may not necessarily be a classical genotype nutrient interaction. But because of the important implications of these differences when attempting to optimize the feeding of broilers, further investigations of the true cause of these differences are warranted The environment as a constraint to achieving the desired feed intake High temperatures are the most common reason for birds and animals not achieving their desired feed intake. It has been demonstrated that as the protein or amino acid content of a feed is reduced, pigs will increase intake in an attempt to meet their requirements for potential growth, the extent to which they are able to compensate for the deficiency being dependent on the amount of heat the pig can lose to the environment, which in turn is dependent on the environmental temperature. The results of these experiments are all accurately simulated using the pig growth model developed using the theory of growth. Whereas birds benefit in cold weather from the isolative properties of their feather cover, this thermal barrier constrains the amount of heat that may be lost to the environment in hot weather. As the potential growth rate of broilers is increased by genetic selection, their inability to lose sufficient heat to the environment is becoming a major constraint in commercial broiler operations worldwide. Accounting for all the factors that contribute to the environmental heat demand placed on the birds, such as temperature, humidity, wind speed and thermal radiation, and then accounting for the response of the bird to this ‘effective’ temperature, is a major challenge when modeling the response of broilers to nutrient supply.

Breast meat yield

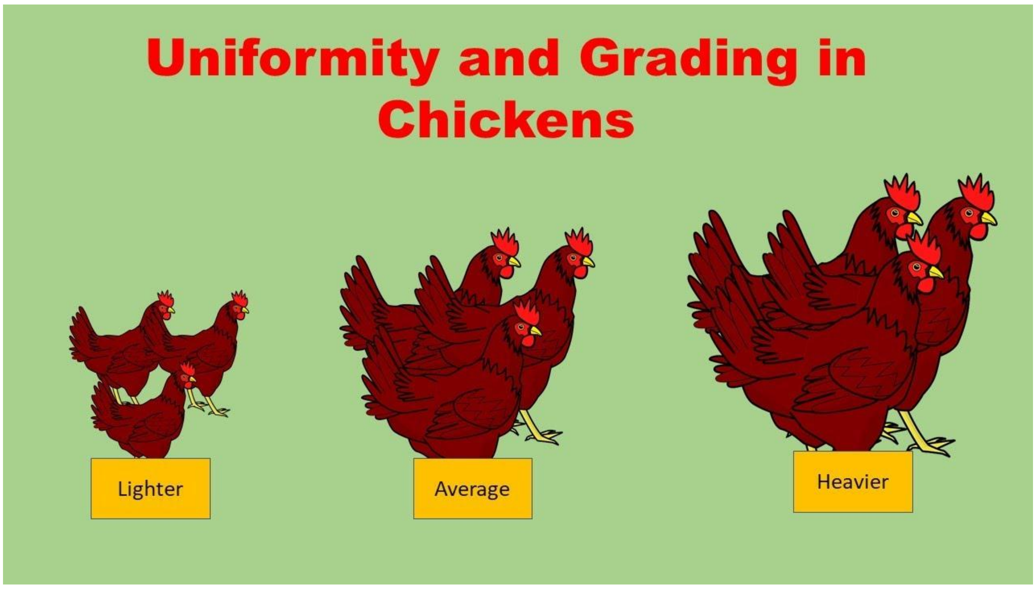
Emphasis has therefore been placed by geneticists on improving breast meat yield, and highly sophisticated equipment has been developed to improve the speed and accuracy with which broiler carcasses are cut up into the required portions. Clearly, models need to be able to predict the weights of the various physical parts of a broiler at different stages of growth so that this information can be used by nutritionists and economists to determine the optimum slaughter weight of broilers when they are to be sold in this way. Whilst it is well documented that breast meat yield is related to the protein or amino acid content of the feed has shown that such responses are strain-dependent.

They found that the response in breast meat yield continued to increase in the low feed intake strain referred to above over the range of dietary protein contents used. A challenge for the future is to determine whether geneticists have been successful in increasing breast meat yield at a given body protein weight, or whether the improvements that have been noted in breast meat yield in some broiler strains are not simply due to the birds being harvested at a higher protein weight or a lower fatness. Again, the differences in response between strains need to be accurately predicted if optimal feeding programs are to be implemented.

Flock uniformity

An increasingly important characteristic of broiler production is the uniformity of body weight and conformation of birds when harvested, since consumers have become more sophisticated, demanding highly uniform whole birds and portions. There is evidence that uniformity decreases

as the feed becomes marginally deficient in protein and this may be simulated using a population model in which the performance of each individual in the population is simulated and the responses averaged. The probable cause of decreased uniformity on feeds marginally deficient in an essential nutrient is the variation in the ability of, broilers to over consume energy when faced with a deficiency. This characteristic will enable the successful birds to show little reduction in growth, whereas the feed intake of others, without the capacity to deposit as much lipid, could be severely constrained, resulting in poor growth. Furthermore, the exercise suggests that



at both high and low (limiting) concentrations of dietary protein uniformity increases, the requirements of all individuals in the one case being met, and in the other, all individuals are similarly constrained. So it is only on marginally deficient feeds that uniformity is compromised, a situation that is likely to occur frequently in commercial broiler operations. Thus, uniformity in a population of birds, caused by feeds varying in essential nutrient content, may be simulated mechanistically.

Mortality

Mortality is not always reported in response experiments, and where it is the results are often equivocal, with little or no effect being noted in response to the limiting nutrient. This has led to suggestions that growth rate should sometimes be slowed down in fast-growing strains through the use of lighting programs, the use of mash rather than pellets, and even feed restriction. Circumstantial evidence suggests that these interventions are not necessary with all fast-growing broiler strains, implying a strain nutrition interaction. It is difficult to see how mortality might be accounted for mechanistically in models, as these observations lack a deductive explanation, and can thus only be accounted for empirically. However, it is clear that responses will need to be strain-specific if these are to be of value when predicting performance with a view to optimizing poultry feeds. Social and infectious environments The basis on which the amino acid requirements for growing and reproducing animals should be calculated is to start with the genetic potential of the animals and to determine what the nutrient requirements would be in order for them to achieve this potential. If no environmental factors constrain performance then this is a sensible method of determining requirements, as the potential performance will be achieved and there will be minimal wastage of valuable nutrients. However, if the animals are subjected to stresses, such as high temperatures, high stocking density, disease and low level infection, potential performance will be reduced.

It would be sensible to adjust the nutrient content of the feed supplied to the animals during the time of stress. There is ample evidence that the potential performance of animals is reduced when under stress. Examples abound of poorer growth rates at high temperatures, at high stocking densities and when the animals are suffering from an infection. However, little evidence exists of how the animals should be fed under such circumstances. The solution to this dilemma may be approached in two ways: the first is that, because the feed intake of the animals will be reduced as a result of the stress, the concentration of nutrients in the feed should be kept the same or even increased under such situations. The second theory proposes that because the potential of the animals will be compromised by the stress there is no reason to supply food with the same nutrient content as would be supplied if they were growing at their potential.

The optimum feed composition was shown to be no different for broilers kept at high stocking densities as for those allowed ample space to grow. But where a slower-growing genotype was used, the optimum composition of feeds differed markedly from that for a fast-growing genotype, yet it was no different for the stocking densities. Therefore the optimum nutrient composition in feeds for broilers kept at high stocking densities, or under other conditions of stress that reduce feed intake, does not relate to the apparent reduced potential of the bird, as shown by the difference in optimum feed composition when a slow-growing genotype is used; instead, because the efficiency of utilization of dietary nutrients is not altered, the optimum dietary composition remains the same. However, not all stressors reduce feed intake alone: certain diseases, such as those associated with the digestive and absorptive processes, may cause a reduction in utilization efficiency and this would be worth exploring further. This more sophisticated approach to the problem of predicting the effects of an infection on performance models the rate of reduction in feed intake as a disease challenge progresses through the animal, enabling actual feed intake to be predicted from the relative feed intake and animal state. The pattern of relative feed intake during the course of an infection would clearly differ also with the type of infection and with the tissues or organs targeted.

IV. Discussion

The theory used to predict feed intake has had major advantages for imitation, as it has been successfully applied in simulating the effect of, among others, changes in dietary amino acid and protein content, environmental temperature, infection and social stress. It has led to feed intake being an output from models instead of being an input, which has enabled models to be used to optimize feeds and feeding programs, a process not possible unless feed intake is accurately predicted. It has spawned many useful scientific studies that have corroborated the theory, and it has led to a simplified method of accounting for the heat produced by an animal when consuming a given feed, known as the effective energy system. And because the effective energy value of a feed is a function of both the feed and the animal being fed, what would be the advantage of describing feeds in these terms if a model were not available to determine the value of this feed to the animal itself? Those early models stimulated useful and purposeful research targeted at filling the gaps in our knowledge of critical aspects of the theory incorporated into these models, this being useful in it in improving the scientific value of research. In spite of the progress made in the past decades, there are still many challenges that lie ahead for those wishing to predict responses to nutrients in poultry. Many of these have been raised through the development of existing models. Yet the principles are the same as those for predicting feed intake in broilers, the main difference being in the definition of potential performance. But a model has now been developed that adequately describes the ovulatory cycle of a laying hen, from which laying performance and egg composition throughout the laying cycle. What remains is to model the effect of inadequate nutrient intake on egg production. Similarly, the performance of broiler breeder hens, in response to daily nutrient allocations, needs to be adequately. There remain opportunities for imitation to address these and other challenges in the future.

Such as the model to predict age at first egg of laying pullets for any specified pattern of photoperiod used during the rearing period, whilst many others are simply equations representing the result of a single experiment, with little or no predictive value outside of the experiment itself. It is the latter that have justifiably caused this skepticism. One of the challenges faced by those predicting responses to nutrients is to convince the poultry industry that good models have the potential to be of immense benefit to nutritionists, geneticists and other decision-makers in the industry.

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Dr. HASHEM AHMED HASHEM AHMED, et. al. "Process of Improving the Nutritional Value of Poultry Products." *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 15(03), 2022, pp. 47-53.