RECENT DEVELOPMENTS IN POULTRY NUTRITION

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The basic concepts of non-ruminant nutrition can be well illustrated using poultry as the experimental animal.

Because chickens are readily available, inexpensive to purchase and to house in large numbers and because of their relative uniformity, many of the more important developments in the nutrition of simple-stomached animals have been made with poultry. For this reason, most of the examples given below relate to advances that have been made in the nutrition of poultry. The concepts discussed are, however, equally relevant to all types of non-ruminant animals.

Perhaps the most important advance in this field was the recognition by Fisher & Morris (1970) that nutritional requirements of farm livestock should be considered as variable rather than fixed quantities. Previously, and in many instances this practice still prevails, research workers would spend a great deal of time and money trying to define precisely the fixed requirements of animals for various nutrients under different environmental and genetic conditions. Fisher & Morris (1970) put into practice the concept of a response function: namely, a quantitative expression of the way in which animal performance reflects variations in dietary composition. Their pioneering work in this field should be regarded as one of the most important advances in our understanding of nutritional principles to have been made in the past decade.

The model proposed by Fisher & Morris is very simple in concept - the response for an individual bird being defined in terms of its body mass (maintenance requirement) and its potential level of output (either eggs or body tissue). This model is illustrated in Fig. 1. The population response curve is then obtained by averaging out the individual responses taking into account variations in maintenance requirement and the maximum potential level of output (Fig. 2). In the case of laying hens changes in body mass are ignored since in young laying pullets these are small and appear to be entirely due to fat deposition.

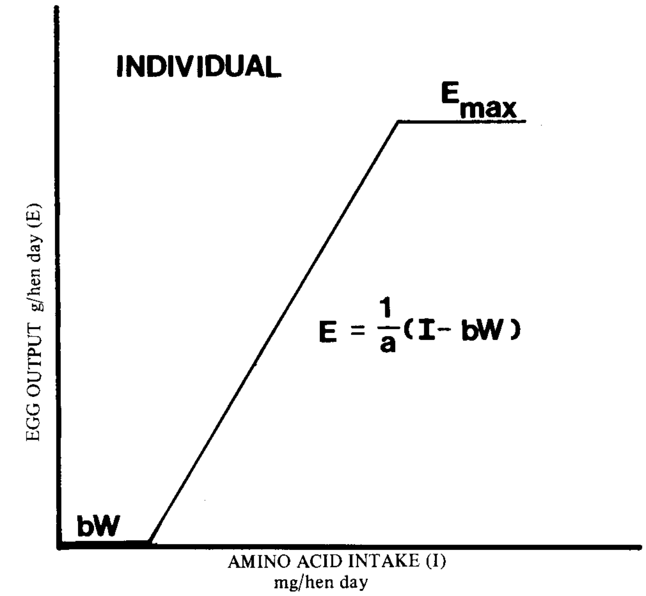

Fig. 1 Response of an individual to increasing dietary amino acid intake (Fisher, Morris & Jennings, 1973)

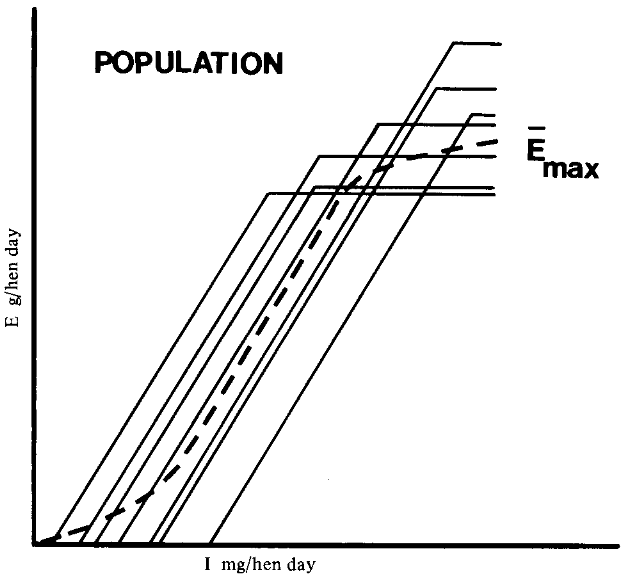

Fig. 2 Response of a population to increasing dietary amino acid intake (Fisher et al., 1973)

The "Reading model" developed by Fisher, Morris & Jennings (1973) to describe the response of laying hens to individual amino acids is defined as follows:

$$I = a\bar{E}_{max} + b\bar{W} +$$

$$x\left(\sqrt{a^2 \sigma^2_{\bar{E}} + b^2 \sigma^2_{\bar{W}} - 2abr\,\sigma_E \sigma_W}\right)$$

where x = the deviation from the mean of a standard normal distribution which is exceeded with probability *ak* in one tail, and is obtained from tables.

k = the cost per mg amino acid/value per g egg.

Of significance is the fact that the values of *a* and *b* in the above model are meaningful in that they represent the amount of ingested amino acid associated with a unit of egg production and a unit of maintenance respectively.

Amino Acid Nutrition

The values of *a* and *b* in the Reading model have been determined in the case of laying hens for methionine (Fisher & Morris, 1970), for lysine (Pilbrow & Morris, 1974), for tryptophan (Wethli & Morris, 1980) and for isoleucine (Griessel, 1981). These coefficients, shown in Table 1, are very similar to the concentrations of the respective amino acids in egg contents and body tissue, representing around 85 percent net efficiency of utilization of these amino acids for egg production and maintenance.

Table 1

Coefficients of response of laying hens and broilers to dietary amino acids (mg/day) and well-balanced protein mixtures (g/day)

Laying hens [1]	
Methionine requirement	= 4 E + 25 W
Lysine requirement	= 9,5 E + 90 W
Tryptophan requirement	= 2,25 E + 10,25 W
Isoleucine requirement	= 9,1 E + 48,7 W
Protein requirement	= 0,28 E + 0,16 W
where E	= Egg output (g/hen day)
W	= Body mass (kg)
Broilers [1]	
Methionine requirement	= 5,2 ΔW + 0,01 W
Lysine requirement	= 16,5 ΔW + 0,02 W
Protein Requirement	= 0,24 ΔW + 0,002 W
where ΔW	= Body mass gain (g/bird day)
W	= Body mass (g)

N.B. These coefficients apply to individuals *not* to flock means.

Data summarised from publications as indicated in text.

The response of broilers to lysine (Gous, 1980) and methionine (Maclachlan, 1981) have been measured using the dilution technique proposed by Fisher & Morris (1970), the respective coefficients being given in Table 1.

The Reading model not only describes the relationship between input and output, but allows for the estimation of the "optimum economic dose" of each nutrient under the prevailing economic conditions - the more variable the flock and the smaller the cost of input relative to the value of output, the higher is the amino acid intake that maximises profit. This concept is a vast improvement on the common method of using a fixed requirement irrespective of the costs of the nutrients and the value of the product.

There is a possibility that the above technique of determining optimum inputs of amino acids for animals might lead to the feeding of a diet imbalanced with respect to a certain amino acid simply because the cost of that amino acid might have been increased relative to the cost of the others. This would result in a poorly-balanced diet where all the other amino acids would be fed in excess of the animal's ability to utilize them, resulting in wastage.

The series of research projects currently being conducted at the University of Natal is based on the premise that ultimately the feed industry would benefit not only from response relationships relating to specific amino acids but also to well-balanced amino acid (protein) mixtures. Clark, (1981, unpublished) has derived equations for both broilers and laying hens describing the response in body mass gain and egg mass to the feeding of well-balanced protein mixtures (Table 1) from which the optimum daily intake of such mixtures can be ascertained. More accurate relationships between individual amino acids and dietary protein are being sought in order to improve our definition of a well-balanced protein mixture.

Dietary Metabolizable Energy

There have been two major developments in the field of energy metabolism in the last five years, one dealing with the rapid determination of the metabolizable energy concentration of ingredients and mixed feeds; the other being in our understanding of the response of broilers to dietary energy concentrations.

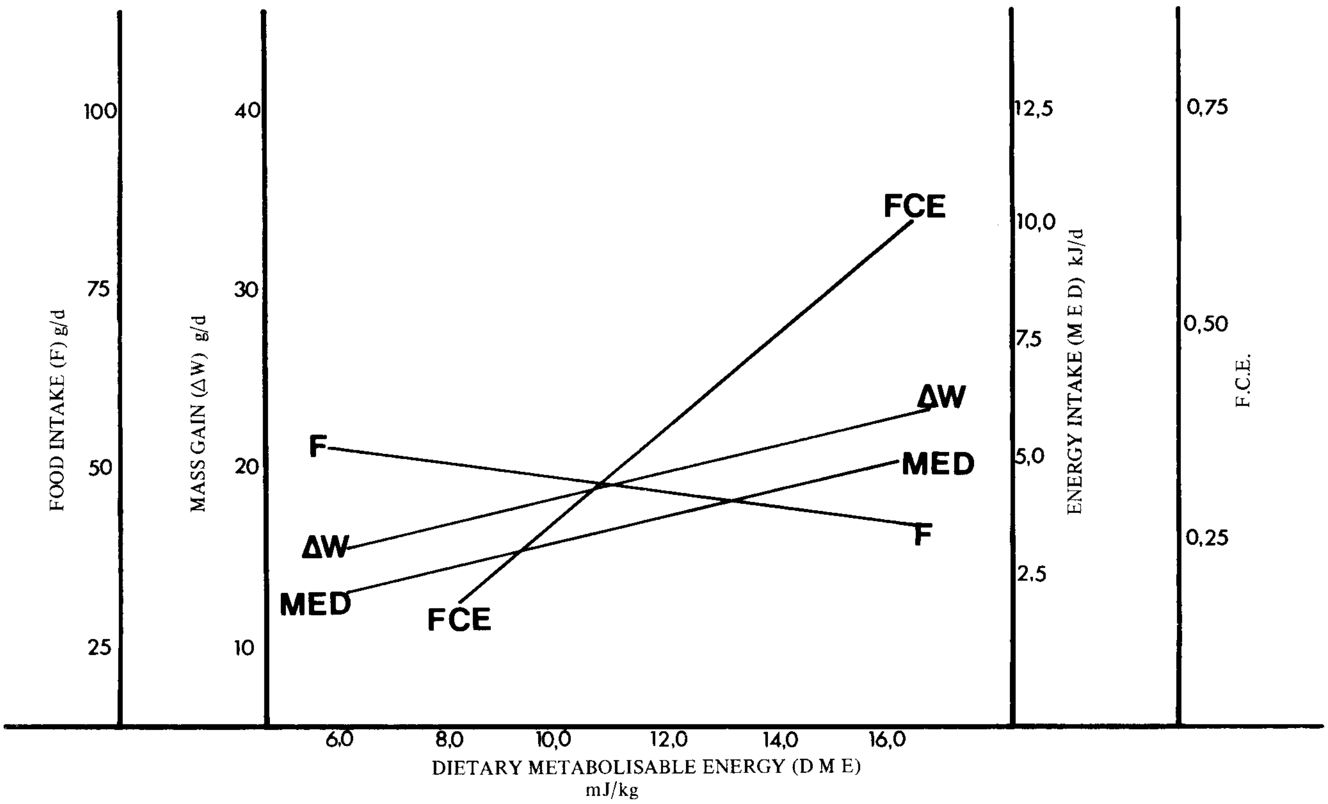

Fig. 3 Response of broiler chickens to increasing concentrations of dietary metabolizable energy (Fisher & Wilson, 1974a)

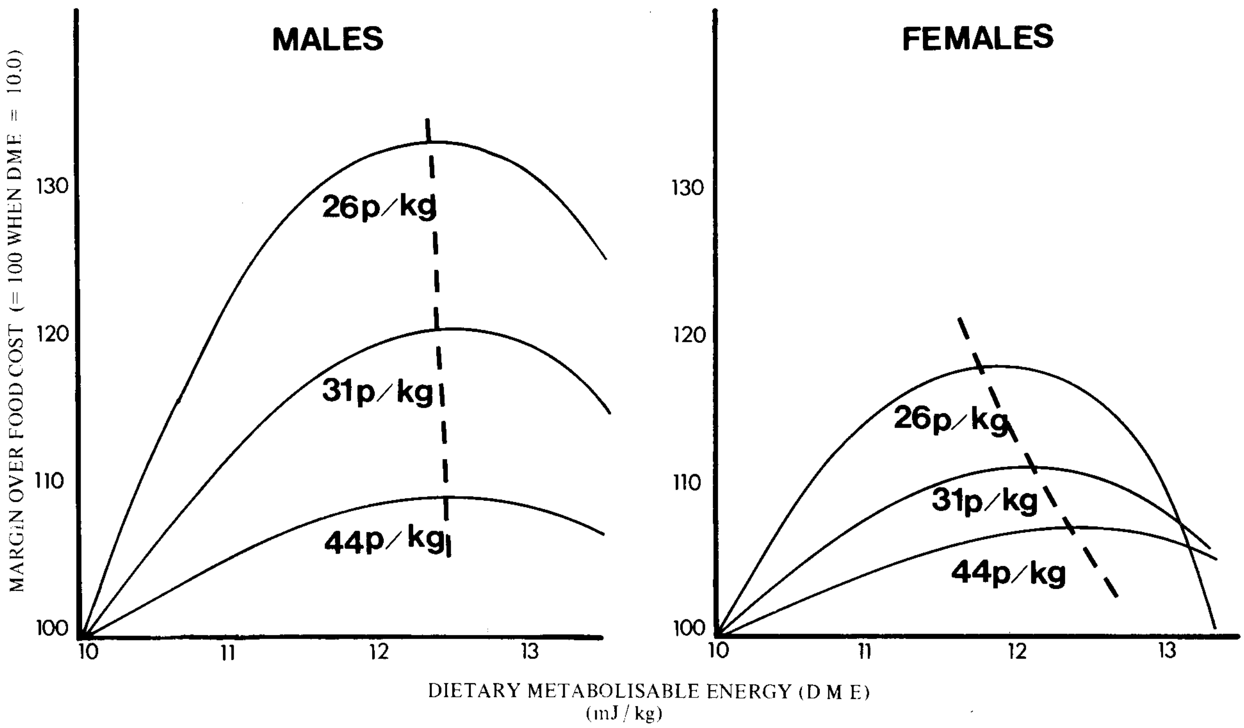

Fig. 4 Optimum energy levels for male and female broilers at different prices for broiler meat (1973 prices). Margin over food cost expressed as a percentage of those obtained when DME = 10 mJ/kg (Fisher & Wilson, 1974b)

Sibbald (1976) reawakened our interest in the determination of ME by publishing a new, rapid technique which appeared at first sight to be foolproof and a vast improvement over the classical technique of ME determination.

The method involves force feeding adult roosters a quantity of feed after a 24-h fasting period and subsequently collecting the faeces produced for the next 24 hours. Gross energy determinations of the feed and faeces and measurements of the quantities fed and voided are used to determine the ME of the ingredient fed. A correction is made for metabolic faecal energy (FE_m) and endogenous urinary energy (UE_e) excretion resulting in a "true" metabolizable energy (TME) value as opposed to the "apparent" ME (AME) value which results when no correction for ($FE_m + UE_e$) is made.

Intensive investigations have been, and indeed are still being made, mainly by Sibbald himself, on this technique and a number of modifications to the original method have been made.

These investigations have included:

1. the ideal amount to be fed - it would appear that an amount equal to one percent of the body mass of the bird is adequate, although accuracy increases with the amount fed until the birds either regurgitate or become crop-bound.

2. total collection period has been found to be most important, as some feedstuffs move through the gut more slowly than others (examples being fishmeal, bloodmeal and lucerne meal), resulting in inflated ME values if a 24- h collection period is used. A 48- hour collection period is thus recommended for all ingredients assayed (Kessler & Thomas, 1980).

3. The amount of metabolic faecal energy and endogenous urinary energy voided, a critical value in the determination of TME, is independent of body mass or age, of season or of environmental temperature. Instead of measuring this variate prior to, or during, each test, perhaps a constant value based on a large number of observations should be used. J.J. Du Preez (Personal communication) has shown that the endogenous energy excretion is overestimated when measured in the manner proposed by Sibbald (1976) because the fasted birds lack energy during this period and hence utilize protein reserves with a concomitant increase in uric acid excretion. Estimation of endogenous energy excretion should thus be made on birds that are in a positive energy balance.

   Also, Okumura, Isshiki & Nakahiro (1981) have shown that the proportions of protein and energy in preliminary diets actually affect the urinary nitrogen excretion during the test period. This might have a significant effect on comparitive TME values between laboratories.

4. Should a nitrogen-correction be made? Some workers believe that such a correction is essential while others do not. There is evidence to indicate that the additivity of TME values is improved when a nitrogen correction is made. Further evidence of such improvements are needed.

5. There appears to be no reason why only adult roosters should be used for such an assay, as the TME values are similar when using different sexes, breeds, strains and ages of birds.

6. Investigations are continuing on the value of using birds whose caeca have been removed.

   A modification of Sibbald's technique that should be carefully noted and assessed is that proposed by Farell (1980), in which birds are trained to consume their daily requirement of food in a one-hour feeding period. This overcomes the need to force-feed the birds and also ensures a more reasonable daily intake of food. Because food intake is greater than when using Sibbald's method, there is little or no need to correct for ($FE_m + UE_e$), so the ME values obtained are more directly comparable with the ME values that are universally acceptable at present.

One result of Sibbald's method that was not originally foreseen, is that a reasonably accurate estimate of amino acid availability in the feedstuffs can be obtained, and there is naturally a great deal of interest being shown in this field at present (Sibbald, 1979). On the subject of the response of broilers to dietary energy concentrations, Fisher & Wilson (1974) published a summary of a large number of experiments on this subject, the results of which were expressed in graphic form (Fig. 3). The economic implications of this study are tremendous, allowing feed formulators to determine the optimum energy concentrations of diets for male and female broilers both in the starter and the finisher periods, taking into account such factors as transport and other surcharges; optimum dressed carcass mass; turnover rate etc. As an example of the output obtained from such an exercise, the optimum energy concentration for males and for female broilers is illustrated at different prices for broiler meat (Fig. 4). Because males tend to overconsume energy as the dietary energy concentration increases they are capable of growing at a faster rate at high energy concentrations, so irrespective of the price of broiler meat the optimum energy concentration remains virtually the same. Female broilers, on the other hand, seem to control their energy intake more accurately than do males, so they do not benefit to the same extent by being fed high energy diets. Therefore, the optimum dietary energy concentration for females varies quite markedly as the price of the product changes.

Such information is invaluable especially in an integrated broiler operation and it is surprising that so little use is made of these functions in the broiler industry in South Africa. For the sake of our diminishing economy as a whole, these important advances in the field of nutritional economics should not be ignored.

Mineral Metatolism

Perhaps the most important economic advance in this field in recent years has been the finding that we have been feeding laying hens too much phosphorus. In the past, laying diets have contained between 0,45 and 0,55 percent available phosphorus, whereas results indicate that as little as 250 - 300 mg per hen day is adequate and indeed, that shell quality is improved at these low levels. A reduction of 0,1 percent available phosphorus constitutes a considerable saving in the cost of laying diets, and together with the improvement in the quality of egg shells at these lower levels would indicate that such a reduction is economically justifiable. Adverse reports that indicate a higher mortality among birds fed low levels of phosphorus especially in hot weather can be explained by the fact that food intake and consequently phosphorus intake is reduced in hot weather.

As long as intake of available phosphorus remains within the range 250-300 mg per bird day there will be no adverse effects from the feeding of low phosphorus diets to laying hens.

A second aspect of mineral metabolism that has been neglected in the past, but which has a significant effect on growth of broilers, is the balance between cations and anions in the feed. Sauveur (1980) has produced a useful parameter whereby the relationship between electrolytes can be expressed - he has shown that performance is related to (Na + K – Cl) and that maximal growth in broilers was obtained with this parameter varying from 250 to 300 m.e.q./kg of food (Fig. 5). It is perhaps time that we took note of such work to ascertain whether the occasional drop in growth rate experienced in broilers is not perhaps due to an imbalance of electrolytes.

Other problems associated with electrolyte imbalances include diarrhoea, tibial dyschondroplasia, poor quality egg shells and visceral gout (Sauveur, 1980).

Vitamin Nutrition

Nutrient responses discussed above refer not only to amino acids but to all other nutrients including vitamins. Whitehead (1978) determined the response of broilers to biotin, the response being a typical curvilinear and asymptotic model (Fig. 6). His trial was conducted over an eight-week period so the maintenance requirement during that time would have varied considerably, preventing the fitting of a Reading model to his data.

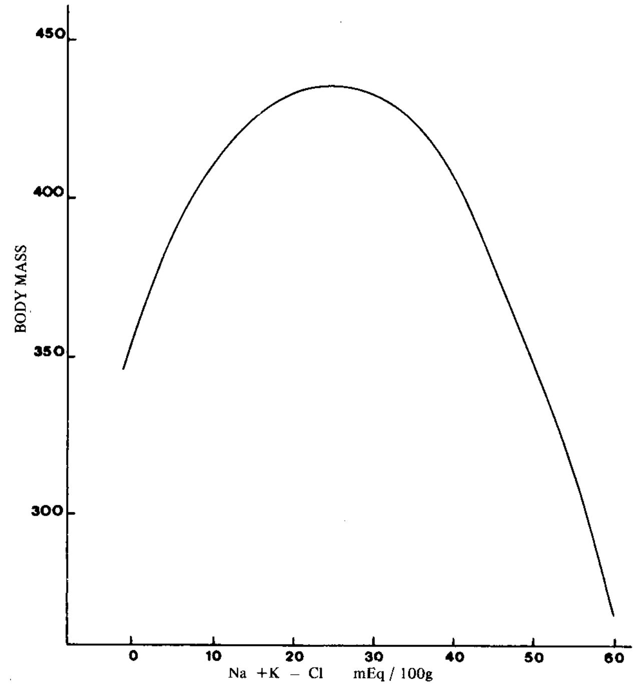

Fig. 5 *The effect of (Na + K – Cl) concentration on 4-week body mass of broiler chickens (Sauveur, 1980)*

Biotin has been found to be relatively unavailable in wheat-based diets (Frigg, 1976) and the deficiency of this vitamin in such diets has been found to be the cause of the conditions known as fatty liver and kidney syndrome (FLKS) (Payne, Gilchrist, Pearson & Hemsley, 1974) and flip-over syndrome (commonly referred to as heart attacks in broilers) (Hulan, Proudfoot & Macrae, 1980). It is unclear to what extent biotin is limiting in diets based on maize and fishmeal but it is certain that further research is required in this area.

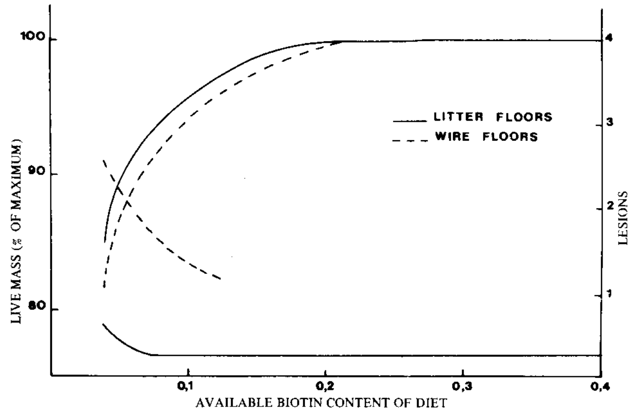

Fig. 6 *Live mass and severity of foot lesions of broiler housed on litter and wire floors fed diets containing graded levels of biotin (Whitehead & Bannister, 1978)*

Choice Feeding

Individual birds vary widely in performance and in food intake and this contributes to a variation in nutrient requirement when this is expressed as a proportion of the feed. In meeting the requirements of the more demanding birds the majority of the flock would be oversupplied with the limiting nutrients, resulting in a low (40 percent) gross efficiency of converting the limiting amino acid in the feed into egg amino acid (Fisher, 1976).

One way in which this inefficiency could be overcome would be to improve the persistency of laying hens, thereby reducing the number of pause days when no eggs are being laid. An alternative suggestion has been proposed by Emmans (1979): if hens could choose between laying feed and whole grain they might more precisely meet their nutrient requirements.

Experiments in which the hens were free to choose between a complete feed and whole grain; or between a "balancer" (a feed made by removing some of the cereal from a normal, complete balanced feed) and whole grain, have yielded promising results (Emmans, 1979; Cowan & Michie, 1979). Hens can under certain conditions select an economically efficient diet, but in many instances tend to consume more food when given a choice than when presented with a complete feed.

Dietary self-selection, in an experiment by Leeson & Summers (1979), led to the suggestion that laying-type pullets could be reared more economically if the level of dietary protein was increased during this period rather than the common practice of reducing the protein content as the birds become older. Pullets were found to eat 100 g less protein and 83, 68 kJ less energy on this step-up protein diet compared with the conventional method, and to lay at a higher rate throughout the laying period. However, this technique does not work successfully with broiler breeder pullets (Leeson & Summers, 1981), resulting in significantly heavier birds at sexual maturity than birds fed a conventional broiler breeder replacement diet.

Choice feeding therefore may not only help to solve the problem of overfeeding nutrients to the majority of birds in a flock but may also provide further insight into feeding behaviour which could ultimately be of benefit in our understanding of non-ruminant nutrition. Further research is undoubtedly warranted on this subject.

Future Research Priorities

In spite of the progress made in the nutrition of non-ruminants there are a number of problems that have not been solved where further research is needed.

One of the major problems facing the broiler industry at present is the excessive deposition of fat in the carcasses of broilers. Much of this problem is undoubtedly of genetic origin but a significant reduction in carcass fat could be brought about by tailoring daily nutrient intakes to the requirements of the birds. This could be accomplished by rearing sexes separately and by using amino acid and energy response curves, as outlined above, to determine more precisely the optimum intake of nutrients at each stage of the growing period.

Although most vitamins and trace elements are relatively inexpensive, certain nutrients such as biotin and choline chloride are not. In the light of recent reports on the relative unavailability of biotin in wheat-based diets the tendency might be to increase the biotin content of all diets irrespective of the level of biotin already present in the diet. Responses to these and other nutrients need to be developed in order to determine the optimum economic dose of each of these nutrients.

More research needs to be directed at evaluating new protein and energy sources. Ingredients such as high lysine maize, single cell protein and spent grain could be invaluabole to the feed industry, and if such ingredients are produced in large quantities in the future it is essential that their advantages and limitations are known.

In the future there must be an increase in the use of computer modelling to more accurately determine the most economical levels of nutrients to be included in diets. This will ultimately lead to an improvement in the efficiency of feed formulation with a consequent better utilization of raw ingredients used by the feed industry in this Country.

Conclusion

The most interesting and useful research in the past decade has been that directed towards defining the response of animals to various nutrients. This will lead ultimately to a more economic approach to non-ruminant nutrition resulting in less wastage of limiting nutrients and more efficient usage of feed ingredients available to the feed industry.

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