AMINO ACID REQUIREMENTS OF BROILERS: RELATIONSHIPS WITH GROWTH AND MEAT QUALITY

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Summary

Over the last sixty years there has been a rapid reduction in market age for broilers. This has been a direct result from genetic selection (increase in muscle yield), improved diets, and better management of the resources available to the producers. A rapidly growing broiler needs to be supplied with sufficient nutrients to meet its requirements for maintenance and for the growth of all components of the bird, including feathers. The crude protein and amino acid status of a diet can influence the carcass composition of broilers, with increased carcass protein and reduced carcass fat accompanying increases in dietary protein or essential amino acid content. Rapid increases in growth rate have been associated with improved feed conversion efficiency, while amino acid requirements as a percentage of the diet have not changed substantially. Although nutritional requirements expressed as proportions of the diet may not change linearly with improvements in performance, a greater understanding of the requirements for specific factors such as requirements for optimum immune function or breast muscle deposition requires further research.

I. INTRODUCTION

Each year the world’s human population is predicted to increase by 70 – 80 million. The majority of this increase is from third world countries. With the economy of many third world countries improving, the demand for animal products and especially meat as a source of protein will increase. Chicken continues to be the least expensive meat in most of these countries. The broiler industry is ideally suited to meet this expected increase demand for animal protein with improved efficiency of production. The broiler industry in Australia and many parts of the world is relatively new compared with other livestock industries.

The broiler industry started on the east coast of the USA in 1920. By 1960, broiler meat made up 10% of the total meat consumption and increased by 5% annually to exceed the consumption of beef and pork in 1995 (Figure 1). By 2000, the total consumption of broiler and other poultry meats was 46.2% of total meat consumption (Kaku, 2001). Factors contributing to an increase in broiler production by 5% each year include genetic selection, dietary, environmental and managerial improvements, and economic factors. The broiler industry has developed into an robust business with several advantages over it competitors, these include the ease of establishing integrated operations with the adaptability for further processing and economically competitive price of poultry vs. red meats. In the USA in 2000, the price of broiler meat was cheaper than beef (32%) and pork (47%). The actual price of beef and pork has increased by 3.5 times compared to broiler meat which has increased by only 2.5 times since 1960 (Kaku, 2001). Consumers consider broiler meat healthy and inexpensive, which will only lead to further increases in demand (Ishibashi and Yonemoch, 2002).

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Figure 1: Consumption of broiler, beef and pork in the USA (data from Kaku, 2001)

II. INCREASE MUSCLE GROWTH

To meet the market demands poultry selection has concentrated on growth rate and muscle mass in broiler. In the last 30 years, the production time needed to raise a 1.3 kg chicken has been halved (Dransfield and Sosnick, 1999). To meet requirements and maintain protein deposition in broilers, nutritionist must look at the demands of the rapidly growing broiler and adapt the formulated diets to meet those demands. To do this, the nutritionists has to look at two major issues -- what is the potential growth rate of the selected broiler and what are the broilers nutrient requirements to meet those needs. A rapidly growing broiler needs to be supplied with nutrients in order to meet its requirements for maintenance and for the growth of all other components of the broiler, including feathers (Gous, 1998). A good definition of potential growth is given by Gous (1998), as the maximum possible growth rate that the genotype can achieve when given perfect nutritional and husbandry conditions.

Below the requirement, breast muscle development is sensitive to dietary lysine content in the diet. Many studies citing a positive correlation between dietary lysine level and breast muscle accretion have compared diets deficient in protein and/or lysine to diets adequate (Corzo et al., 2002; Tesseraud et al., 2003). The authors are unaware of any studies in which an increase in breast muscle or growth rate is associated with increases in dietary amino acids or protein at levels well beyond the NRC requirements.

Han and Baker (1991) determined requirements of 8 to 21 day old broilers to be not greater than 1.17% lysine for maximal weight gain. This was slightly higher than the National Research Council recommendations of 1.10% (NRC, 1994). Labadan et al. (2001) also determined that lysine requirements for broilers up to 2 weeks of age to be 1.32% compared to 1.10% recommended by the National Research Council (NRC, 1994). Muscle protein is high in lysine and the portion of breast muscle yield has increased (through genetic selection) compared to the total carcass meat in broiler. Breast muscle contributes about 30% of total carcass meat and accounts for 50% of total edible carcass protein (Summers et al., 1988); some researchers suggest that the lysine requirement has increased over time (Si et al., 2001). However, the lysine requirement for maximum breast muscle accretion was similar to the requirement for growth, but greater than for feed efficiency (Labadan et al., 2001).

Care must be taken when discussing changes in lysine requirements as a function of growth rate. Although broiler growth rate has increased dramatically in the past 60 years (NRC 1944; 1954; 1977; 1984; 1994), the actual lysine requirement, expressed in percentage
of the diet, has changed very little over the years. The lysine recommendation given by the National Research Council was 0.902, 0.9, 0.85 to 1.2 and 0.85 to 1.1% of the diet for the years 1944, 1954, 1984 and 1994, respectively. The ranges given for 1984 and 1994 reflect the effect of age on lysine requirement as the bird ages; lysine requirements decrease with age. Earlier versions of the NRC recommendations for poultry did not take into account the changing requirements of birds as they approached a target body weight. During the last 60 years, the growth rate of birds has increased dramatically. In 1944, a typical Rhode Island Red cockerel or pullet would reach 1.6 kg at 14 to 17 weeks, or 16 to 19 weeks, respectively. In 1944, cockerels would be expected to reach 2.27 kg in 17 to 22 weeks of age; females would reach this weight in 25 to 30 weeks (NRC, 1944). In 1954, “heavy breed” male chickens required 11, and females 14, weeks to reach 1.6 kg (ages to heavier weights were not given in the 1954 NRC). A contemporary publication suggests that New Hampshire males and females would reach 2.3 kg at 21 and 31 weeks, respectively (Titus, 1955). Although different strains of chicken were reported in each of these publications, the standard for meat-type chicken production was moving towards an increased growth rate. In 1977, broiler chickens would be expected to reach 2 kg in 8 weeks (NRC, 1977). In 1984, that body weight was reached prior to 7 weeks of age (NRC, 1984), and by 1994 a 2 kg body weight would be expected in male broilers at approximately 6 weeks. Growth rates have continued to increase since that time. Concurrent with the improvement in growth rate has been a dramatic improvement in feed efficiency. In 1944, meat-type chickens required approximately 4.1 kg of feed for each kg of gain (NRC, 1944), whereas feed conversion efficiency had decreased to 1.8 kg of feed per kg of gain by 1994 (NRC, 1994). Much of the improvement in efficiency can be attributed to the decrease in maintenance requirements due to a shorter time to a particular weight. As mentioned previously, the requirements for lysine as a percent of the diet, and presumably other amino acids, have changed very little since 1944. Expressed in terms of total lysine required to reach a particular body weight therefore, have decreased.

III. MEAT QUALITY AND INCREASED MUSCLE GROWTH

Genetic selection for growth has resulted in producing a larger broiler with a greater percent of muscle mass. Dransfield and Sosnick, (1999) found in rapidly growing broilers there is an increase appearance of morphological abnormalities, induce larger fibre diameters and a higher proportion of glycolytic fibres, and a lower proteolytic potential in the muscles. After death, there is a faster development of rigor mortis resulting in paler colour and reduced water holding capacity and poorer quality of further processed products. Little work has been done investigating the relationship between growth rate and meat quality. Presumably, these factors would decrease the consumer acceptance of such meat from rapidly growing broilers.

IV. GROWTH AND IMMUNITY OF THE BROILER CHICKENS

It has been recognised for many years that nutrient deficiency are associated with an impaired immune response and with increased susceptibility to infectious disease. In turn, infection can affect the status of several nutrients, thus setting up a vicious cycle of under nutrition, compromised immune function and infection. This recent research called “immunonutrition” has focused on looking at nutrition, infection and immunity and how they related (Grimm and Calder, 2002). Additionally, amino acid nutrition likely has more nuanced effects on immune function than has been reported for simple deficiencies. This is an exciting area of research, and one that is poised to become more important to the poultry industry as the use of growth-promoting antibiotics is changing around the world. Amino
acids such as glutamine, arginine, cysteine and taurine have been identified as important immune-modulation substrates (Suchner et al., 2000). The relationship between growth and immune response in broilers has been studied while modifying dietary arginine in the diet. Both Webel et al. (1998) and Kidd et al. (2001) studied the effect of dietary arginine and determined that as long as arginine levels are kept near the National Research Council (1994) recommendations for age, the arginine at those levels should support the immune system functions in healthy chicks.

Recent studies in our laboratory have focused on the effects of growth rate of broiler chickens on inflammatory responses. The inflammatory response is of particular interest to broiler producers, as inflammation results in the diversion of nutrients away from growth and towards the non-specific mechanisms designed to ward off pathogens (Korver and Klasing, 1997, Korver et al., 1997). In commercial situations, even low-level activation of the inflammatory response may result in decreased growth rate and efficiency. In our studies, modern broiler chickens were compared to two random-bred broiler lines maintained at the University of Alberta; a 1977 broiler line and a 1957 broiler line. Within each strain, birds were either allowed ad libitum feed consumption, or were pair-fed to the level of feed intake of the 1957 strain to eliminate the effect of feed intake on immune function. Within each strain and dietary treatment, half of the birds were subjected to an experimental cellulitis challenge by subcutaneous injection of a field isolate of E. coli from cellulitis lesions. As expected, the modern broilers grew faster and were more efficient than the either of the random-bred lines, in both the ad libitum and pair-fed treatments. Interestingly, the cellulitis challenge resulted in greater growth depression in the random-bred lines than the modern line. Associated with this response was a greater responsiveness of T cells in vitro from the modern birds to a uniform level of interleukin-1, indicating that modern broilers regulate their immune system differently than older, unselected lines of birds. Further research in this area is ongoing in our laboratory. An increased awareness of the mechanisms regulating immune response in broilers will become more and more important as production aids such as prophylactic antibiotics are removed from poultry feeds around the world.

V. USING THE INDICATOR AMINO ACID OXIDATION METHOD TO DETERMINE BROILER REQUIREMENTS

Traditional methods to determine amino acid requirements in broilers are based on using growth as an indicator of change in the diet. The concentration of amino acid in the diet producing the maximum growth response (or breast muscle deposition, or feed conversion efficiency) is regarded as being the requirement for the test amino acid. The determined requirement is then expressed as a fixed concentration in the diet (g/kg) (Gous, 1998).

The indicator amino acid oxidation (IAAO) technique for determining amino acids (AA) requirements has been developed and validated in pigs (Kim and Bayley 1983a; 1983b; Ball and Bayley 1984; Ball et al., 1986; Ball and Bayley, 1986; Bertolo et al., 1986; House et al., 1998; Shoveller et al., 2003), humans (Zello et al., 1993; Di Buono et al., 2001; Kriengsinyos et al., 2002) and chickens (Tabiri et al., 2002a; 2002b; Coleman et al., 2003). To better understand the IAAO technique there are several good reviews based on human studies that describe the benefits and disadvantages of the IAAO method (Pencharz and Ball, 2003; Brunton et al., 1998). The technique is based on the concept that a deficiency of one indispensable AA will restrict protein synthesis. Therefore, all other indispensable AA will be in relative excess and will be oxidised. As the dietary intake of the AA\textsubscript{test} increases, the oxidation of all other indispensable AA decreases, corresponding to the increase in protein synthesis. If the intake of AA\textsubscript{test} increases beyond the requirement, no further change in
indicator oxidation will occur (Pencharz and Ball, 2003; Brunton et al., 1998). The point at which the oxidation of the indicator AA reaches a plateau is taken as the requirement provided no other nutrient is limiting. The indicator AA must have an oxidative pathway distinct from and unrelated to the AAtest (Pencharz and Ball, 2003; Brunton et al., 1998), so that a change in dietary AAtest will not affect the pool size of the indicator AA. Phenylalanine and lysine have been shown to be suitable indicator AA for IAAO studies in humans (Bross et al., 1998). The oxidation pattern of L-[1-14C]phenylalanine as the indicator amino acid after changes in the dietary levels of lysine has been demonstrated in broiler breeder pullets (Coleman et al., 2003).

The IAAO method is ideally suited for use in poultry. Although the requirements of many amino acids for broilers are well established, this technique can be used to determine the requirements of individual birds, such that an estimate of population variability can be established. Requirements of birds under specific conditions such as inflammatory stress can be rapidly determined. There are numerous other uses for this technique as well, including determination of metabolic availability of amino acids in feedstuffs.

VI. CONCLUSION

Broiler chicken production and consumption is increasing around the world; chicken meat is an efficient, high quality source of protein that is relatively simple to produce, even with limited inputs. The increase in demand for poultry products, and the economics driving increased efficiency have led to dramatic improvements in growth rate, breast muscle deposition and feed conversion efficiency of broiler meat. Many of the improvements have been the result of genetic selection; however the nutrition of the bird must be suitable to support such rapid and efficient growth.

Amino acid requirements of meat-type chickens have been published since at least the 1940s. In that time, the amounts of various amino acids as a proportion of the diet have not changed dramatically. The efficiency of use of those amino acids has increased dramatically, largely as a function of a decrease in age to a particular body weight. Little work has been published regarding the effect of rapid growth rate of modern broilers on meat quality and consumer acceptance.

The future of amino acid research may well be in the subtle topics of nutrition-immune function interactions, and relationships between environment and amino acid metabolism. Both of these areas may be important keys in maintaining high levels of production in the absence of growth-promoting antibiotics. New techniques such as the indicator amino acid oxidation technique can play a role in elucidating these relationships.

REFERENCES

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