BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable production of poultry meat

Volume 2: Breeding and nutrition

Edited by Professor Todd Applegate
University of Georgia, USA

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SCIENCE PUBLISHING

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Introduction

Poultry production faces a range of challenges. These are addressed in the three volumes of *Achieving sustainable production of poultry meat*. The three volumes are:

- Volume 1: Safety, quality and sustainability
- Volume 2: Breeding and nutrition
- Volume 3: Health and welfare

Volume 2 discusses recent developments in breeding and improving poultry nutrition.

Part 1 Genetics and breeding

The first group of chapters looks at developments in genetics and breeding. Production of poultry meat and eggs have long been key targets for improvement in poultry breeding programmes. Functional traits can be defined as the morphological, biochemical, physiological, immunological and behavioral attributes considered essential for the optimal functioning of the individual bird. Historically, functional traits of poultry have received less attention in breeding. However, over the past decade, the changes in rearing practices and increased awareness of poultry welfare has led to broadening of selection programs to include more functional traits in genetic improvement programs.

Chapter 1 discusses the key functional traits of reproductive capacity, skeletal integrity, cardiovascular fitness and disease resistance. It reviews how advances in molecular biology and sequencing of the chicken genome have made it possible to identify quantitative trait loci (QTLs) and gene variants associated with functional traits. These developments have increased the understanding of the genetic basis of these traits, their relationships with production traits, and their potential for incorporation into genetic improvement programs.

Building on Chapter 1, Chapter 2 discusses issues in balancing production and functional traits in breeding. Achievement of commercial genetic potential for growth and yield characteristics does not always result in the fittest individual, as indicated by the negative correlation between growth and reproductive performance. The challenge in breeding is for the animal is able to achieve its genetic potential for all aspects of growth. As Chapter 2 points out, for genetic homeostasis, a population must maintain enough genetic variation to moderately perform with regard to growth, reproduction and immune response. In addition, the population must maintain enough heterozygosity to buffer against environmental challenges.

Traits of economic importance such as growth, yield and feed conversion ratio will continue to be the primary focus of breeding. However, new challenges, many driven by the consumer, will test the ability of the commercial broiler and layer to maintain genetic homeostasis. Examples include the move to cage-free systems, where there is increased opportunity for more bird to bird interactions in establishing the pecking order. This will lead to a shift in resource allocation away from production traits as birds expend energy while protecting territory. The elimination of antibiotics in poultry production will present new challenges with disease organisms. The development of organic and free range

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markets creates yet another set of environmental shifts that will redirect resources from growth and yield related traits.

As Chapter 2 discusses, the industry has matured from single trait or simple index selection to the present day selection program that monitors more than fifty traits. It is a hallmark of the modern poultry industry to produce a product focused on improved health and well-being. Therefore, half of the fifty traits are directed toward fitness. The remaining traits are focused on economically producing a rapidly growing, high yielding, feed efficient product. Improved monitoring of these traits and how they can be balanced will allow for further refinement of breeding decisions.

Chapter 3 explores new developments in breeding to improve functional and other traits. Marker assisted selection (MAS) is a form of indirect selection that depends on the accuracy of measuring the marker and the genetic correlation between them. Chapter 3 describes the development of microsatellite markers and single nucleotide polymorphic (SNP) markers associated with high throughput automated technology, which has made MAS applicable to whole genome prediction of breeding values. The chapter explores how these techniques have been successfully implemented in commercial poultry breeding programmes. The development of technology for rapid genotyping of large numbers of DNA markers as SNPs cheaply and on large numbers of individual birds has made the application of MAS to commercial poultry breeding programmes both feasible and practical. The benefits are considerable in terms of improved accuracy of estimation of breeding values in combination with phenotypic measurements. Considerable benefits have been realised for traits with low heritability or measured in one sex such as egg production. These advances could also lead to a reduction in the generation interval in males of egg-laying strains, for example, where early selection decisions based on predicted merit before sexual maturity could be made.

The chapter also highlights how future technological developments may permit the use of whole genome sequencing rather than high density SNP chips for prediction of breeding values of selection candidates. As the chapter points out, genomic selection in poultry breeding programmes promises to increase the accuracy of selection, especially for traits that are expensive to measure (such as feed conversion ratio) or measured late in the life of an individual (such as female fertility). Additional benefits could include the incorporation of welfare traits with no loss of gains in production traits because of the greater accuracy of estimating breeding values.

Part 2 Animal nutrition

The second group of chapters reviews key developments in understanding and optimising poultry nutrition. As Chapter 4 points out, feed is one of the most significant costs in animal production, and feed efficiency is therefore a very important genetic trait in livestock production. A clear link between breast muscle mitochondrial function within cells and feed efficiency has been reported in poultry. This chapter provides an overview of the mitochondrial processes which occur in muscle cells, presents the evidence that enhanced mitochondrial functions lead to high feed efficiency, and then considers the role of enhanced nucleotide metabolism and muscle cytoarchitecture in the feed efficiency of broilers. As it points out high feed efficiency is associated with factors such as enhanced mitochondrial energy (ATP) production and enhanced capability for synthesis and metabolism of purine

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and pyrimidine nucleotides. These insights provide new opportunities for breeding and other interventions to further improve feed efficiency,

Chapter 5 points out that selection for phenotypic feed efficiency has tremendously improved livestock productivity over the past 50 years. However, echoing themes in Part 1, the chapter points out that, associated with this success, there have been a number of undesirable changes in the regulation of energy homeostasis and water balance. Feed and water efficiency encompasses complex mechanisms regulating feed and water intake, energy expenditure, water retention and excretion, and intermediary metabolism related to nutrient and water utilization and partition. Knowledge of these should be used to guide more effective selection.

Chapter 5 focuses first on feed intake regulation, reviewing current understanding of both central feed intake regulation and peripheral and hormonal regulation. The chapter then turns to the issue of the regulation of water homeostasis. The chapter reviews research which may help in developing new strategies to improve both feed and water efficiency. New techniques involving genomics, epigenetics, proteomics, transcriptomics, mobilomics and metabolomics are helping to show the relationships between nutrients, water, genes and performance. These approaches have the potential to lead to more targeted management based on optimisation of nutrient and water intake fine-tuned with an animal's genetic profile. The identified molecular signatures could subsequently be used to improve water and feed efficiency via genetic selection, nutrition and livestock management.

As noted earlier, feed represents a major cost of poultry production. Broilers and layers are highly efficient in converting feed to muscle, but they still excrete significant amounts of unutilised nutrients. There remains therefore considerable room to improve the efficiency of conversion of feed to animal products. A good portion of this inefficiency results from incomplete digestion and/or utilisation of nutrients. Chapter 6 provides an authoritative overview of major advances in poultry feeding to overcome these challenges. Key topics discussed include advances in: understanding of nutrient metabolism and nutrient requirements; quantification of the availability of nutrients in raw materials; formulation of least-cost diets that bring nutrient requirements and nutrient supply together in an effective manner; the contribution of new feed additives; and progress in feed processing. The chapter provides a context for a number of following chapters which discuss specific aspects of nutrition. Advances include improvements in composition and ingredient quality, better feed formulation (covered in Chapter 12), the use of additives such as crystalline and synthetic amino acids (discussed in Chapter 7), feed enzymes (discussed in Chapter 8) and probiotics for better gut function and health (surveyed in Chapter 10), as well as improvements in modelling feed efficiency (reviewed in more detail in Chapter 11).

Dietary amino acids are central to optimizing growth performance, meat yield, and egg production of poultry. Chapter 7 reviews recent research on amino acid digestibility coefficients for feed ingredients, digestible amino acid requirements of poultry based on production efficiency, and the role of supplementation of crystalline and synthetic amino acids on nitrogen balance and ammonia output of poultry. The chapter discusses specific amino acids such as arginine, threonine, and branch chain amino acids. As the chapter points out, significant advances have been made in understanding factors influencing amino acid digestibility coefficients for poultry. However, amino acid requirements for immune function, disease/microbial load, and physiological needs may differ from growth performance and meat yield, providing a target for future research in the move to antibiotic-free poultry production.

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Chapter 8 reviews the current status of research on feed enzymes with an emphasis on identifying the key challenges researchers face in terms of enzyme development, mechanisms of action and enzyme efficacy. The key chapter discusses current drawbacks and opportunities in the application of phytase, carbohydrases, protease and their combinations in poultry nutrition. Sections cover the advances and continuing challenges in the application of particular enzymes. The chapter looks first at the use of phytase in poultry diets, reviewing research on efficacy, phosphorus content and environmental impacts. It then discusses non-starch polysaccharides (NSP) and NSP enzymes, including their physiological effects, and prebiotic potential. The chapter also discusses β-mannanase in poultry nutrition, starch digestion and supplemental α-amylase as well as microbial protease supplementation. The chapter shows the potential of enzymes in both improving feed efficiency and making poultry production more sustainable.

Chapter 9 discusses key advances in understanding the role of phytate in phosphorus and calcium nutrition of poultry. Poultry depend upon a continuous supply of phosphates for the formation of bones as well as other physiological functions. In plant seeds, phytic acid (InsP6) is the primary storage form of phosphorus (P), and it is usually present in salt form (phytate). The move to minimize the use of feed phosphates makes it imperative to better understand the interacting factors related to InsP6 breakdown in the digestive tract. As the chapter points out, the potential to utilize InsP6-P is very high in broiler chickens. However, degradation of InsP6 in the gastrointestinal tract is variable and affected by supplements of calcium, P, and other dietary factors. The chapter discusses ways of adjusting feed ingredients and supplements of P, calcium, and phytase to optimize feed formulation.

Optimising gut function and immunity is an important goal for poultry producers to improve bird productivity, health and food safety. Probiotics and prebiotics are attractive approaches to use in the pursuit of optimal gut health, especially with the ongoing need to reduce the use of in-feed antimicrobial growth promoters. Chapter 10 reviews research to address the three main obstacles to the use of probiotics in particular: concerns about effectiveness and reproducibility of action; concerns about lack of knowledge regarding mechanisms of action; and making an informed choice about which product to use from amongst the many that are available. As Chapter 10 points out, recent research has increased our knowledge of the effects of both probiotic and prebiotic treatment, their possible modes of action, and the strengths and limitations of their use. The chapter summarises studies on why some products may give variable outcomes and what may be done to further validate the performance of existing products. It also explores ways of developing a new generation of more reliable and effective probiotics and prebiotics.

Animal nutritionists face various problems when formulating feeds for poultry. Advances in simulation modelling have made it possible to look into all aspects of production when formulating feeds for animals. Chapter 11 looks at the use of simulation models to optimize poultry nutrition. It discusses modelling methods, their strengths and weaknesses. The chapter then reviews ways of predicting responses of poultry to nutrients and predicting food intake. The chapter also describes the methods used to predict potential laying performance of hens and the environmental factors that affect feed intake. Finally, this chapter shows how models can be used to optimize feeding programmes.

Systematic evaluation of each stage of the feed manufacturing has the potential to identify opportunities for improvement in manufacturing efficiency and reduced nutrient variation in finished feed. This will ultimately result in lower cost sustainable poultry production. Chapter 12 examines the role of automation technology in composing and

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delivering feed, and addresses the issues of batching, mixing and pelleting feed as well as means of assessing feed quality. It discusses such issues as particle size reduction in feed, improving feed pelleting as well as post-pellet liquid application.

Soybean and canola meal are the conventional ingredients used to provide protein in poultry feed. However, they are relatively expensive and must be imported to many poultry producing areas. Developing alternative protein sources for poultry nutrition will reduce the pressure on these key protein sources, as well as promoting the development and sustainability of the poultry industry. Chapter 13 first reviews the supply of conventional protein sources for poultry, and then considers the range of alternative protein sources which might be developed. These alternative sources include grain by-products, oil seed and fruit by-products, grain legumes or pulses, algae and duckweed. The chapter considers how birds respond to diets containing alternative protein sources and current constraints on the use of these sources. Finally, it provides recommendations for improving the nutritive value of these alternative sources of nutrition.

Contaminants in poultry feed may result in deteriorated feed quality, reduced performance and increased incidence of disease in poultry as well as potential safety issues. Chapter 14 focuses on those contaminants considered to pose the most significant risk to poultry and human health: mycotoxins, dioxins, and bacterial pathogens. It discusses both the risks from these contaminants as well as research on current best practice to control feed contamination, including good manufacturing practices (GMPs) and Hazard Analysis and Critical Control Point (HACCP) systems in feed sourcing and manufacturing. It also discusses particular techniques for managing contaminants. As an example it discusses the use of binding agents to control of mycotoxins, limitations in their efficacy and novel techniques such as the use of microorganisms and their enzymes to detoxify specific non-absorbable mycotoxins. The chapter also discusses control of pathogens using natural feed additives such as prebiotics, probiotics as well as phytogenic feed additives. As the chapter points out, genomics, transcriptomics, and proteomics are now transforming our approaches to the detection, prevention, and treatment of biological feed contaminants. These advances are also allowing the development of control measures and treatments that are more specific in terms of their targets.

As pointed out in Chapter 5, enhanced feed efficiency and increased growth rates have led to a reduced ability in poultry to balance energy expenditure and maintain body water balance under variable environmental conditions. Chapter 15 focuses on the effect of combinations of environmental conditions (temperature, ventilation, relative humidity) on the thermal status and performance parameters of broilers, turkeys and laying hens. It discusses body temperature control by endothermic birds, including neuronal and endocrine regulation. It then reviews what we know about different strategies used by birds to cope with changes in temperature, including physiological and cellular responses to changes in the environment. Finally, it highlights the role of epigenetic temperature adaptation during embryogenesis as a tool to improve poultry tolerance to heat.

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