BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

# Achieving sustainable production of milk

## Volume 3: Dairy herd management and welfare

Edited by Emeritus Professor John Webster
University of Bristol, UK

burleigh dodds
SCIENCE PUBLISHING

# Contents

## Part 2 Nutrition of dairy cattle

# Preface

'If you want to run a successful business, you have to look after your workers.' These words were spoken by the director of a conspicuously successful dairy enterprise while standing among his workers, handsome, healthy, robust Friesian cows at pasture in in the South West of England. The three volumes in this collection review the science that underpins the successful management of successful and sustainable dairy production. Volume 1 reviews research on milk composition, genetics and breeding. Volume 2 discusses safety, quality and sustainability. Volume 3 reviews our scientific understanding underpinning the nutrition, health and welfare of all cattle in the dairy herd. In essence, Volumes 1 and 2 are about milk, Volume 3 is about cows.

As I have written elsewhere (almost), 'Understanding the dairy cow is a matter of heart and mind. It is essential to examine her scientifically as a complex and elegant machine for the production of milk, the nearest thing in nature to a complete food. It is equally essential to recognize her as a sentient creature with rights to a reasonable standard of living and a gentle death. In both senses of the word, this understanding is not static. The more we study the workings of the dairy cow, the more efficiently we can exploit her capacity to provide milk from grasses, cereals and an enormous range of plant by-products that we cannot or choose not to eat ourselves. The more we study her nutrition, health, behaviour and environmental requirements the better we can ensure her welfare and sustained performance' (Webster 1993).

The selection of chapters and specific topics for this book has been based on the central principle that efficient, quality milk production depends on healthy, contented cows, which further implies that good welfare requires a sense of wellbeing that is both physical and mental. If we are to promote this sense of wellbeing, we need at the outset, a proper understanding of cow behaviour and the motivations that govern behaviour. We need then to address each of the key elements of welfare by ensuring the necessary provisions. These are perhaps, most clearly and succinctly expressed by the 'Five Freedoms and Provisions' of the UK Farm Animal Welfare Council (FAWC 1993).

1. *Freedom from thirst, hunger and malnutrition* – by ready access to fresh water and a diet to maintain full health and vigour.
2. *Freedom from discomfort* – by providing a suitable environment including shelter and a comfortable resting area.
3. *Freedom from pain, injury and disease* – by prevention or rapid diagnosis and treatment.
4. *Freedom to express normal behaviour* - by providing sufficient space, proper facilities and the company of the animal's own kind.
5. *Freedom from fear and distress* – by ensuring conditions that avoid mental suffering.

Part I – *Welfare of dairy cattle* reviews our understanding of cow behaviour and considers their welfare needs in terms of housing and management as adults in the dairy herd, during development as young calves and heifers and in the special circumstances of transport and slaughter. A critically important chapter also examines the consequences of genetic selection with special emphasis on traits relating to soundness and sustainability: fertility, disease resistance and environmental impact. This complements the section in Volume 1 that considers genetics primarily in the context of productivity.

The spectacular increase in milk production achieved through genetic selection has greatly increased demands on the modern intensively managed dairy cow. Indeed, it may reasonably be claimed that, in these circumstances, the capacity of the mammary gland to produce milk conspicuously exceeds the upstream capacity of the cow to provide it with nutrients. Part 2 – *Nutrition of dairy cattle* therefore places special emphasis on the new science that addresses the special problems associated with driving the digestive and metabolic processes at high speed. We review the Improved understanding of the nature of microbial digestion in the rumen that has led to the development of improved diets and feed additives designed to optimise nutrient supply and minimise the risk of disorders of digestion and metabolism. Special attention is given to management of high yielding cows in intensive systems to minimise two of the most important risks; rumen acidosis in lactating cows consuming large quantities of concentrate feed and the multiple physiological stresses associated with the transition period from late pregnancy to the onset of the next lactation.

Part 3 – *Health of dairy cattle* deals first and at greatest length with the big three causes of ill health, poor welfare and impaired performance in dairy cows: infertility, mastitis and lameness. All of these should rightly be considered as production diseases, since their prevalence is irrefutably linked to management practices. Chapters in this section explore how the management of these conditions can be (and has been) improved through a combination of treatments based on new science, better understanding of aetiology and improved management through education and the implementation of well-designed herd health programmes. Applications of new science to the control of infectious and parasitic diseases include genetic selection for specific and non-specific elements of immunity and alternatives to antibiotics.

We have it on reliable authority that new wine should not be put into old bottles. It may be equally unwise to invite an old scientist to review and edit new research. If this had been a book on the applications of molecular genetics, I would have been quite lost. However, it is all about living dairy cows: organisms that are highly complex but which have remained fundamentally the same for a long time. Over the last 50 years I have witnessed big shifts in fashion in dairy science. For many years, the emphasis was on increased milk production. Breeding for increased production *per se* has been very successful, though at significant cost in terms of infertility and productive life span. Attempts to increase performance through hormonal and other forms of biochemical manipulation have had little impact, partly through failure to anticipate public opinion and partly through failure to understand homeostasis. Research directed towards improved nutrition and digestive health has been, and continues to be, of enormous benefit to the health of dairy industry and the cows themselves. The reason for this is almost too obvious to mention. Whereas the metabolism of an individual animal operates within strictly controlled limits, the potential for manipulating feeds and feed mixtures to optimise nutrient supply while ensuring healthy digestion is almost limitless.

The campaign for good health can never be entirely won. The most newsworthy problems arise from the appearance of new or re-emergent epidemics such as Foot and Mouth disease, but over time these do not begin to compare with the big three: infertility, mastitis and lameness. Here we have needed the best of science simply to hold the line in the face of increasing challenges arising from the environment and management. Most recently, scientists have been presented with new problems associated with the impact of dairy production systems on the sustainability of the living environment, in particular those associated with high output of carbon (especially methane) and nitrogenous compounds.

They receive proper attention here. However, in our enthusiasm for this new science, we should never overlook the fact that these are two of the key elements of life. The poison is only in the dose.

John Webster

## References

Farm Animal Welfare Council. 1993. Second Report on Priorities for Research and Development in Farm Animal Welfare, MAFF, Tolworth UK.

Webster John. 1993. *Understanding the Dairy Cow*, 2nd ed. Blackwell Scientific Publications, Oxford UK.

# Introduction

Cow's milk is one of the world's most important agricultural food products. Its importance in the diet is widely acknowledged as a source of calcium, protein, vitamins and minerals. It is an essential ingredient in a wide range of foods. Demand is increasing, particularly in developing countries as a result of growing populations, increasing urbanisation and income levels as well as changes in diet.

In meeting demand, more intensive dairying systems in developed countries face a range of challenges such as maintaining high standards of safety in the face of the continuing threat from zoonoses and contaminants entering the food chain, whilst continuing to improve nutritional and sensory quality. At the same time farms need to become more efficient and sustainable by using fewer inputs and reducing greenhouse gas emissions. It is essential that farming must also meet higher standards of animal health and welfare. Smallholder systems in developing countries face problems such as poor nutrition for cattle, low productivity and vulnerability to disease which impact on safety, quality, sustainability and animal welfare.

Drawing on a range of international expertise, the three volumes of *Achieving sustainable production of milk* review key research addressing these challenges. Volumes 1 and 2 review research on the quality and safety of milk, genetics and sustainability. This volume reviews the current state of our scientific understanding of the nutrition, health and welfare of cattle in the dairy herd.

## Part 1 Welfare of dairy cattle

In recent years we have developed the necessary tools to gain a much deeper understanding of cow behaviour in intensive management systems. This improved understanding can facilitate the design of new, sustainable management systems which promote cattle welfare. Chapter 1 summarises current research on cattle preferences and behaviour. It considers the importance of understanding the perceptual world of cows, and then how the preferences and emotions of cows are revealed through their social, nutritional and reproductive behaviour, their movements (locomotion and resting) as well as their responses during transport and slaughter. Research to identify cows' emotional responses to increasingly artificial environments facilitates the identification of systems that are more conducive to high levels of welfare.

Building on Chapter 1, Chapter 2 provides an overview of key issues in the welfare of dairy cattle, providing a context for the following chapters in Part 1. These issues include: housing (with potential problems of confinement and restricted movement, for example), the consequences of a unilateral focus on milk yield in areas such as breeding (with implications for health), poor handling of cattle (for example in transport and slaughter), as well as disrupted social structures (for example in the treatment of heifers and calves). It reviews controversies about reconciling what we know about the natural social behaviour of cattle with the demands of more intensive production systems, and suggests priorities for future research.

In modern dairy farming, lactating cows and un-weaned calves are often housed indoors, in a restricted space, at high density, and/or separate from other animals. Such

housing conditions affect the welfare of the animals by creating risks of illness and injuries and placing restrictions on behaviour. Picking up from Chapter 2, Chapter 3 examines the physical and social aspects of dairy cattle housing. It focuses on the different housing systems available for lactating cows, and the advantages and disadvantages of these alternatives. Topics discussed include stall design, flooring and stocking densities in relation to social competition and dominance within herds. The chapter then reviews the issue of housing for un-weaned calves. It discusses how housing affects weight gain, health and aspects of behaviour such as locomotion and rest, as well as the implications of housing un-weaned calves individually, in groups or with their mothers.

As identified in Chapter 2, narrow breeding goals focussed on milk production traits have been detrimental to the reproductive performance and health of dairy cattle. There is therefore a need to develop breeding strategies which allow production and non-production traits to be balanced against each other. Chapter 4 discusses the principles behind multi-trait selection. It reviews practices of selecting for milk production, energy balance and fertility, and then consider ways of incorporating newer breeding objectives such as health traits, feed efficiency and reduction of methane emissions, as well improving heat tolerance in cattle in the face of a changing climate. The chapter concludes by discussing the use of modern genomic selection and gene editing techniques. As the chapter points out, while genomic selection has been implemented for many traits (such as fertility and longevity), there are still obstacles to overcome in applying it to other traits of interest, associated with the heritability of the trait, the number of animals in reference populations and the cost of phenotyping. These provide priorities for future research.

Each year, some cows are culled from dairy herds. Most of these cows are culled due to sickness or lameness, meaning that they are likely to experience pain and distress during marketing, transport and slaughter. Chapter 5 reviews strategies for ensuring the welfare of these cows both before and during transport as well as slaughter. The chapter summarises the legislation and codes of practice surrounding the transport and slaughter of cows, considers important pre-transport conditions which can affect the welfare of cows during transport and at the slaughterhouse. It also discusses causes and signs of distress as well as strategies to avoid welfare problems.

National survey results suggest that approximately 1 out of every 10 dairy heifers in the United States die before weaning. Such statistics highlight the potential for improvements in the rearing of young dairy calves. Chapter 6 reviews strategies for managing calving, improving calf vitality and successful colostrum feeding. It also assesses prevention of neonatal disease, alleviation of pain during common procedures and provision of optimal housing. Finally, it discusses execution of accelerated feeding programs, stress-free weaning, and maintenance of efficient rearing by optimal nutrition and housing of post-weaned dairy heifers. In each case, the chapter both identifies key advances in improving calf health and welfare, as well as remaining hurdles to achieving meaningful improvements in the success of heifer rearing programs, particularly as they relate to calf welfare.

## Part 2 Nutrition of dairy cattle

Nutrition is a key element in the efficiency and sustainability of milk production as well as in cow health and welfare. This is the subject of the chapters in Part 2. Ruminants are characterized by their capacity for pre-gastric anaerobic fermentation in the rumen

(foregut), which harbors a variety of microbes including bacteria, archaea, protozoa and fungi. The complex association of different microbes acts synergistically for the conversion of cellulosic feed into volatile fatty acids (VFAs) and proteins that fulfill the nutrient requirements of the animals. Chapter 7 summarizes current knowledge about rumen microbial diversity, ecology, function, and relationships with host phenotypes. It also reviews research on factors influencing composition of rumen microbiota and how this understanding can be used to alter microbiota to improve rumen function. As it points out, advanced sequencing-based technologies have led to the detailed identification of rumen microbiota/microbiotome at both taxonomic and functional levels, providing new insights into the role of the rumen in ruminant production and health.

A range of biochemical and physiological factors affects feed efficiency in dairy cattle. Chapter 8 provides an overview of the physiology and biochemistry of the cow, and then focuses on what we know about the biology of lactation, with particular emphasis on the effects of genetic variation on nutrient intake metabolism. The chapter shows the role of biochemical metabolic models in exploring the effect of genetic selection or genetic variance on feed efficiencies. The chapter also includes a case study looking at the mechanisms and effects of simple genetic variations which have been shown to have a significant impact on feed efficiency.

The models described in Chapter 8 play a role in accurate assessment of the nutritional value of feeds, which is essential in the formulation of diets and evaluation of different feeds. Chapter 9 discusses different methods of estimating digestibility, energy and protein value of dairy cattle feed formulations. Topics include evaluation of feed energy value and methods to predict digestibility and its effect on energy value. The chapter then assesses discounts of digestibility and associative effects and ways of calculating metabolisable energy (ME) and net energy concentration (NE). The chapter also reviews ways of evaluating protein value, including estimation of microbial protein and rumen undegraded protein (RUP). The chapter summarises the advantages and weaknesses of static empirical models and dynamic mechanistic models, emphasizing the need to evaluate models using large datasets from productions studies to improve the accuracy of predictions of nutrient efficiency.

Managing dairy herd nutrition must not only meet the nutrient requirements of the animals but also contribute to the overall sustainability of dairy farm operations. As Chapter 10 points out, research to reduce enteric methane emission through feeding strategies is an important element in improving the efficiency of conversion of feed to milk, particularly with the use of a wider range of by-products such as distiller's grain in dairy rations. Chapter 10 discusses the use and importance of phosphorus and nitrogen in cow nutrition, their broader environmental impact, and a range of sustainable solutions to reducing that impact. The chapter also explores the overall carbon footprint associated with dairy farming. It includes a case study of using nutrient management to reduce enteric methane emissions in intensive dairy production systems in California and Wisconsin.

Chapter 11 reviews pasture-based systems for dairy production. When properly managed, grass-legume mixes can provide well balanced nutrition able to sustain good levels of milk production in dairy cattle so that cows need only be fed non-pasture feeds when there is insufficient pasture. To achieve good nutrition management in grazing systems, it is essential to identify genuine feed deficits to optimise pasture use and minimise reliance on supplementary feeds. As Chapter 11 points out, getting this balance right can have more impact on costs than deciding on the type of supplement to be fed. The chapter reviews the factors which must be taken into account when deciding

whether and how to supplement pasture with additional feed, as well as choosing the right supplementary feed to use.

The production of animal feed requires a significant use of resources which reduces the sustainability of dairy farming operations. When choosing feed sources and feeding methods, it is therefore essential to consider context-specific trade-off analyses, and to take into account the relationships between use of natural resources, feed products and the livestock in question. Chapter 12 reviews key elements in trade-off analysis in making better use of existing feed resources and producing more feed biomass of higher fodder quality. It looks at current and future levels of animal sourced food (ASF) production, the relationship between feed ration composition and milk productivity, and methods of ration balancing in intensive and extensive dairy systems.

The manipulation of ruminal fermentation to maximize the efficiency of feed utilization and increase ruminant productivity is of great commercial interest. Building on Chapter 7, Chapter 13 reviews the ways of manipulating rumen fermentation in dairy cattle. It considers a wide variety of approaches, looking in each case at potential benefits and limitations. Approaches include the use of dietary buffers, antibiotics and fat supplements as well as immunological control of the rumen microbial population. It also discusses the use of plant extracts to manipulate rumen fermentation, boost production and decrease emissions. Finally, it summarises research on direct fed microbials, probiotics and exogenous fibrolytic enzymes.

## Part 3 Health of dairy cattle

The final group of chapters looks at key aspects of the health of dairy cattle. Picking up on the discussion of nutrition in Part 2. Chapter 14 starts by considering one of the main disorders of digestion and metabolism in dairy cattle: subacute rumen acidosis (SARA). Given the high milk yields required of current dairy cattle, feeding energy dense diets is necessary to meet nutrient requirements. Typically, this entails the use of diets that are highly fermentable. However, excessive fermentation in the rumen decreases ruminal pH and leads to the onset of ruminal acidosis. The chapter explores current research on the nature, causes and prevention of SARA. As the chapter points out, management strategies that ensure adequate and consistent dry matter intake (DMI), while balancing fermentability of the diet, are most likely to ensure high milk yield while mitigating undue risk for SARA.

An essential event in dairying is the birth of a calf and the transition of the mother cow from gestation and into lactation. While the transition can proceed without incident, it is also a period of substantial risk for many cows. As Chapter 15 points out, most of the clinical disease events in a diary cow's life occur during the transition period. It is believed that almost all cows experience some immune dysfunction during the peripartum period, and that this combined with nutritional and other issues leads to a variety of metabolic and infectious disease events. Chapter 15 addresses the best way to monitor the health and management of cows during the transition period. It discusses a number of factors which can affect herd transition health, including the intrinsic characteristics of the cows, limitations and challenges associated with the housing and environment in which cows are placed, and the role of husbandry. The chapter concludes with a case study on the use of transition cow risk assessment (TCRA) techniques in a dairy operation.

Reproduction and fertility are central components to successful dairy enterprises and the appropriate management and understanding of the physiological events needed for fertility is crucial to sustainable dairy farming. Chapter 16 discusses the physiology of the main impediments to fertility as well as the management issues that need to be addressed in order to ensure good fertility of dairy cows. It deals with parturition and uterine health, the importance of the post-partum environment and the role of oestrus, as well as methods of establishing pregnancy and the effect of heat stress on cows' fertility. The chapter also examines fertility of heifers and the impact of genetics on fertility.

Mastitis is one of the most economically important diseases in dairy production. Associated costs include treatment, culling, decreased milk production and quality. Cow welfare is also compromised. Chapter 17 reviews the indicators of mastitis and the contagious and environmental pathogens which cause it, including *Escherichia coli*, *Klebsiella*, streptococci, Prototheca, Coagulase-negative staphylococci and other pathogens. It then discusses how mastitis can be managed and controlled on dairy farms, including good farming practices to management the cattle environment (such as appropriate bedding to minimize contamination and spread of disease). There is a particular focus on the use dry cow therapy and the appropriate use of antibiotics.

Lameness in dairy cows is a major economic and welfare problem worldwide. Despite its importance, there are still significant gaps in research, particularly in disease pathogenesis, treatment and herd interventions. However, appropriate surveillance can make a substantial difference to ensuring prompt and effective treatment. Key methods include quantifying lameness levels, analysing recorded lesions causing lameness, evaluating risk factors and prioritising interventions. Chapter 18 reviews what we know about lesion aetiology and categories of risk for the main causes of lameness in dairy cows. It also assesses the evidence underpinning what makes effective control programmes for the prevention and management of lameness in dairy cows.

Chapter 19 describes developments in infectious disease control in the dairy cattle industry. A risk analysis approach is presented as a framework for managing infectious disease at both global and farm level. The chapter introduces the principles of risk assessment and management, discusses hazard and risk identification as well as risk assessment and evaluation. It then considers methods of risk management and risk communication. The chapter highlights the importance of issues such disease detection, the use of diagnostic tests and their appropriate interpretation. The range of impacts of infectious disease on the dairy industry is described as well as ways to evaluate the risks they present. The chapter also discusses key challenges in successful implementation and effective communication of risk management on dairy farms.

Parasitic helminth infections are one of the most important causes of production loss in livestock worldwide. Grazing dairy cattle are exposed to various worm species, all of which can impact health, welfare and productivity to varying degrees. For several decades, helminth control relied primarily on the frequent use of broad spectrum anthelmintics. However, the use of such treatments needs to be moderated in order to avoid selection pressure for anthelmintic resistance. Chapter 20 describes the likely helminth threats to grazing dairy cattle, with particular emphasis on the issue of anthelmintic resistance. It then offers a review of progress in developing evidence-based control programmes to reduce selection pressure for anthelmintic resistance. Finally, it reviews progress in the development of anti-helminth vaccines. Such vaccines are a long way off commercial availability, but recent progress suggests that these could form part of a sustainable solution to helminth control on dairy farms.

There is considerable variation in resistance to disease in livestock that enables the effective selection of healthier and more productive animals in breeding. Chapter 21 reviews what we know about the sources of variation in resistance to disease in cattle. It then considers three strategies for selecting for resistance. The first approach is by selecting for resistance to particular diseases. A second technique is selecting for animals with strong innate and or adaptive immune responses to achieve a broad-based disease resistance. A final approach is selecting for animals that perform well in an environment in which disease is endemic. The chapter illustrates these differing approaches with three case studies looking at improving resistance to cattle tick infestation, mastitis and bovine respiratory disease (BRD). The chapter also reviews additive and non-additive genetic variation, as well as new technologies such as high density SNP chips and techniques like genome-wide association studies (GWAS).

As well as having an obligation to safeguard animal health and welfare, veterinarians and dairy producers also have responsibilities to protect human health from the risk of antimicrobial resistance and the food chain from medicine residues. Chapter 22 describes typical regulatory controls for veterinary medicines and current antimicrobial use in dairy production. Echoing themes in Chapters 18, 20 and 23, it argues for the need for change in the way we view and use medicines. The chapter proposes how medicine prescribing practices might be changed in the dairy industry. As an example, integrating a detailed review of actual medicine use on-farm into health planning is an effective way of reducing the numbers of animals treated, as well as ensuring that when treatments are required they are applied appropriately. This approach can greatly enhance the farmer-veterinarian working relationship, whilst making preventive medicine a reality. It enhances animal health while reducing both medicine costs and the risk of antimicrobial resistance. Using this kind of approach, the chapter also shows how key antimicrobials could be phased out over a relatively short period of time, whilst simultaneously improving animal health, welfare and milk production.

The importance of ensuring animal welfare and food security, of combating antimicrobial resistance (AMR), and of increasing food production, all contribute to the need for preventative medicine. Herd health management (HHM) involves the delivery of a more co-ordinated approach where management interventions are prioritized and the veterinary surgeon acts as a central hub for the farm team. Chapter 23 reviews the principles and development of HHM. It then discusses the key steps in effective implementation, starting with data collection and measurement. It then summaries monitoring techniques before looking at management, including planning, training and support HHM for schemes. Finally, the chapter looks at the benefits of HHM in improving animal health whilst reducing costs and reliance on antibiotics.

# Index