

# Total Nutrition

## Feeding Animals for Health and Growth

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**CONTEXT**

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## Preface

The successful raising of large numbers of animals for food and the production of large volumes of low cost food for the human population is an undoubted testimony to the value of basic and applied animal sciences. Moreover the intensive raising of animals for food is now being implemented on a worldwide basis in both the developed and developing countries.

This has produced the fortunate social situation, in the developed world, where an adequate and available supply of food of animal origin is taken for granted. It has also resulted in a society where ever-fewer people are actually concerned with, or have any knowledge of, the processes of providing food of animal origin. In addition the various food safety scares in the recent decades have focused consumer and political attention upon these processes of animal production. This has in turn led to stricter demands and controls by legislative authorities, consumer groups and retail organisations.

It is important that those engaged in raising of animals for food appreciate and respond to these various concerns. This was the impetus for my first book; *NUTRICINES Food Components in Health and Nutrition*. Here I attempted to show that there are many natural components of feed and food, the *nutricines*, that have valuable and beneficial effects in relating health to nutrition.

This second book, *TOTAL NUTRITION*, is an attempt to develop further the use of nutrients and *nutricines* in animal nutrition. The objective in *Total Nutrition* is to obtain the maximum value of various nutrients and *nutricines* at all stages of the animal production chain from feed raw materials to the nutrition of the mature animal. In *Total Nutrition* animal feeding must be done with feed components that are likely to be acceptable to the modern consumer. Judicious use of various nutrients and *nutricines* seems to offer a good practical solution to problems of health maintenance, good zootechnical performance, and reductions in adverse environmental impact of intensive animal production.

The book tries to follow a logical sequence. Problems of consumer perception and food safety are discussed in Chapter 1, followed by feed quality and hygiene in Chapter 2. Feed palatability and digestion and absorption of nutrients are discussed in Chapters 3 and 4 respectively. Animal health issues are the focus of Chapters 5, 6 and 7. Here the major topics are management of the gastrointestinal tract, the immune system and non-infectious diseases. Chapter 8 considers new ideas over the monitoring of animal performance and Chapter 9 addresses consumer demands, ethical and environmental issues.

Total Nutrition offers the exciting possibility of the further development of animal nutrition through improved use of a wide range of feed components, both nutrients and nutraceuticals. Feeding animals for health and nutrition must surely be a major objective for future progress in animal science.

Clifford A. Adams

# 1 Problems of Perception: Animal Production, Food Safety and Public Health

Animal husbandry, to produce meat, milk and eggs as food items, has been an occupation of the human race from time immemorial. Despite our modern sophistication and technological advances, feeding and raising of animals for food remains and always will remain one of the most fundamental aspects of human activity. Food of animal origin plays an important and indispensable role in human life. It is nutritionally of high value and on a social level it is highly desired.

The great social desire for food items of animal origin is vividly manifested in the developing world. It is well recognised that as countries develop economically their populations increase consumption of foods of animal origin. There seems to be a universal desire for large quantities of foods of animal origin as a part of the daily diet. The nature of these foods varies somewhat from country to country depending on religious and cultural differences. For example; cattle, pigs, horses, dogs, snakes and crocodiles are used as meat sources on a global basis but all these species are not eaten in all countries. Poultry meat, eggs and fish seem universally accepted.

It is also important to emphasize that meat, eggs and dairy products are excellent sources of protein for human nutrition and are very valuable food items. One hundred grams of lean meat provides up to half our daily protein requirement (Saucier, 1999). It is also a good source of vitamin B complex and of minerals, especially iron, which is readily bioavailable in meat. Eggs and dairy products are also widely recognised for their high nutritional value and easy digestibility.

Meat, milk and eggs are not only valuable foods in their own right, but they have also led to an enormous food manufacturing industry which is of great economic value. We have available today innumerable ready-prepared foods based on meat. Dairy products lend themselves to the production of hundreds of different foods, including cheeses, butter, cream, yoghurts, and ice creams. Eggs are used in a multitude of baking processes as well as in prepared foods.

Meat, milk and eggs and products derived from these animal foods are a part of the daily diet of many millions of individuals worldwide and this in turn requires the raising of many millions of animals for food use. Animal husbandry is truly a very large and global industry both in terms of volumes of materials used and in terms of numbers of animals raised.

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Over the last 25 years worldwide production of manufactured animal feeds has grown almost parallel with the increase in population of some 1.5% annually. In 2000 probably about 620 million tonnes will be produced and this will most likely increase to about 700 million tonnes by 2005. In 1999 Asia was the largest producing area with a volume of around 140 million tonnes and the European Union (EU) was second with a volume of 122 million tonnes (Schumacher, 2000). Animal husbandry is certainly an important economic component of the agricultural activities of most countries.

In the 20<sup>th</sup> Century the general expansion in scientific knowledge made major contributions to improved animal production systems. This has consequently led to the fortunate modern situation where food of animal origin is widely available in large volumes and at low cost. Certainly in the developed countries, adequate supplies of meat, milk and eggs are taken for granted. Yet all too often the tremendous scientific and technical advances which have supported this food supply are frequently overlooked.

The varied and extensive food supply now available in the developed world is also changing the concepts of human nutrition. Future developments in food science will focus on the components of foods, both the nutrients and nutrines (Adams, 1999), that have the potential to modulate functions in the body such as gene expression or immune status. There is an increasing awareness that many non-infectious diseases such as heart conditions, many cancers, diabetes and joint diseases may be subject to nutritional modulation. The objectives now are to use nutrition to promote well-being and good health and to reduce or avoid diseases (Schneeman, 2000). Modern animal husbandry must also respond to these changes in human nutrition and the concept of "TOTAL NUTRITION" is a useful strategy for animal production where attention is increasingly focused on raising animals with minimal medication and using nutrition to promote health as well as growth.

### **Consumer perceptions**

In the 21<sup>st</sup> century, animal production although highly productive, faces obstacles and difficulties, both real and perceived. Several factors have contributed to this situation. The widespread availability of food of animal origin, and the general prosperity of the population means that obtaining food is no longer a major concern for the majority of the people in the developed world. Fortunately there is a wide choice of food items available and it is relatively easy for consumers to switch from eating beef to pork or chicken for example if a food safety issue arises. This has been seen with various food safety scares such as salmonella in poultry and BSE in cattle. In both cases massive

reductions in purchases by the consumers occurred. It is very difficult for the animal production industry to predict where the next issue will arise.

Increased urbanization and concomitantly a reduced proportion of the population engaged in agriculture means that fewer people are conversant with or knowledgeable about the processes of food production from animal husbandry. Consequently the consumer is in many cases completely in the hands of the mass media for information and knowledge on aspects of food production and food safety. Over recent years the animal production industry also has perhaps not been sufficiently committed to public education on issues of food production and food safety. These socio-economic factors together with various unfortunate food safety scares have focused enormous critical attention on the animal husbandry industry worldwide.

In recent years a succession of major issues have occurred that have undoubtedly moulded public perception. These food scares commenced with the *Salmonella* problems in poultry of the 1970s. This was shortly followed by the appearance of BSE (Bovine Spongiform Encephalopathy) in cattle in the 1980s and its' resurgence in Continental Europe in 2000. There have been increasing concerns expressed by various health professionals about the development of bacteria resistant to antibiotics. The Dioxin crisis in feed fats in 1999 and the introduction of genetically modified crops (GMOs) further increased public concern over various aspects of food safety

Also in the 1980s, animal welfare issues gained widespread publicity. A whole plethora of animal welfare issues have been debated including live animal transport, tail docking in piglets, sow stalls and tethers, beak trimming in poultry, feed restrictions in poultry breeders, battery cage production of eggs, and leg weakness in several species.

These issues have all been given major publicity by the media and unfortunately much of this has generated a negative perception of the animal production industry, especially in the European Union. Consequently both the general public and government officials now direct increased attention to methods of food production and to food safety and this has had a significant impact upon all phases of animal production. It has resulted in greatly increased new legislation concerning animal welfare and nutrition.

In 2000 the European Commission published a white paper setting out the future direction of food production in the EU. This document specifically states that animal feed must be treated under the same conditions as food. This will require much more transparency in systems of animal nutrition and production. It will also require considerations of animal health and welfare as well as productivity.



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Events in the end of the 20<sup>th</sup> Century also encouraged the major retail groups to become much more actively involved in checking and controlling the production of the food products they buy. The major supermarket groups realized that by taking the lead on such issues as animal welfare and food safety the strength and image of their brands would be enhanced. In the UK in particular the supermarkets have become very involved in all stages of animal production. This includes selection of feed ingredients such as antibiotic growth promoters, colorants for egg yolks, meat and bone meal and animal fats. They make decisions on aspects of welfare such as maximum stocking density and transport of live animals. These measures have encouraged the use of more extensive systems such as free-range egg production.

The events in recent years have certainly changed the balance of power between producers of food and the consumer with the supermarkets following a much more proactive policy towards the supplier. In reality the supermarkets can now impose regulations on feed manufacturers and animal producers which are more stringent than those required by governments. This is now presented as a response to consumer concerns over food safety and quality.

There are however dangers here as pressure groups representing a minority interest can now sharply focus media attention on a topic to force changes in animal production which are not necessarily supported by scientific evidence. One recent example of this is the exclusion of the red carotenoid, canthaxanthin, from layer feed in the UK even though this is accepted by legislative and scientific authorities as posing no risk to human or animal health. Another potentially more damaging example is the attempts by various environmental pressure groups to prevent the distribution of the genetically modified "golden rice" (Potrykus, 2001). This modified rice is a major scientific breakthrough in crop production as it adds an essential dietary component to one of the most important staple foods of the poor and developing world. This genetically modified rice strain contains genes to produce  $\beta$ -carotene which is a precursor of vitamin A. In many poorly developed countries there is a lack of vitamin A in the diet which leads to blindness in children. Golden rice could be of great benefit here.

There clearly are many consumer concerns over food safety and this has focused attention upon methods of animal feed manufacture and upon systems of raising animals for food. One manifestation of this concern is the significant and growing interest in "organic food" production where crops and animals are produced without the use of pesticides, chemical fertilisers or antibiotics. Detailed comparisons of the nutritional quality of foods produced under organic versus

## Chapter 1

conventional systems are not easy to make. Foods of plant origin produced under organic systems may have a higher content of some nutrients but there seems little difference in overall nutrient content (Brandt and Molgaard, 2001) and much more work will be needed here.

The quantity of organic food production will inevitably be limited by the exigencies of the production system and organic food will always be significantly more expensive than the products from intensive agriculture. Organic farming leads to reductions in crop yields of 30-50% and is not a feasible global option for meeting the food requirements of the world's population (Avery, 1999). Whilst organic foods can supply a niche market for people prepared and able to pay higher prices it can never deliver the large quantity of low cost foods that a modern society needs. Furthermore organic food is no more immune from contamination by pathogenic micro-organisms than food produced under intensive systems.

A whole plethora of events have generated serious problems of consumer perception of modern agriculture (Fraser, 2001). Some of these perceptions are valid and there is certainly an obligation upon the animal production industry to respond to these legitimate concerns. Other perceptions are not scientifically founded and these need to be combated by careful and reasoned arguments. It will be important for the industry to be more transparent and to develop production systems more in tune with consumer requirements. This is where a concept of Total Nutrition may offer some assistance with a focus on using nutrition to support health as well as growth of food-producing animals.

### Food safety

Because of the many adverse consumer perceptions about food the European Union has made food safety a top priority (Vanbelle, 2000). The central element of the EU approach to food safety is that it must be based on a global integrated system throughout the food chain from farm to fork across all sectors of the feed, animal production and food manufacturing industries. This means that feed manufacturers, farmers and food manufacturers all have the primary responsibility for food safety.

It is also important to establish precisely what are the main threats to food safety and human health. These are listed in Table 1 and clearly micro-organisms, both bacteria and moulds represent a continuing threat to food safety. These have the potential to be lethal for the human or animal population and must always be controlled. Other aspects such as drug residues and pesticide residues are not usually life-threatening but rather undesirable. Use of food additives is often

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considered a health risk or food safety issue but judicious application of preservatives and antioxidants also has many positive health benefits as discussed in chapters 2, 5 and 7.

**Table 1**  
Threats to  
food safety

Threat	Example
Naturally occurring bacteria	<i>Listeria</i> in fruits and vegetables
Bacteria from intestines of animals contaminating food	<i>Salmonella</i> and <i>Campylobacter</i> in meat
Naturally occurring toxic substances	Algal toxins in shellfish, mycotoxins on fruits and cereals
Residues from medical treatment of animals	Antibiotics
Environmental contaminants	Dioxins, heavy metals
Pesticide residues	In fruits and vegetables
Food additives	Flavours, colours, preservatives

The safety of foods derived from animal production can be influenced in many ways, including the presence of chemical residues, such as pesticides and antibiotics. Perhaps the most important food safety factor is the possible contamination by pathogenic bacteria species such as; *Bacillus*, *Campylobacter*, *Clostridia*, *E. coli*, *Listeria*, *Salmonella*, *Shigehella*, *Staphylococcus* and *Yersinia* (Jackson, 1990). Bacteria are in a constant state of evolution with infinite capacities to respond to our efforts to control them. Consequently food safety is and always will be a perennial problem and will most likely never be completely solved. This does not imply however that strenuous efforts should not be made to improve food safety. Indeed current events require nutritionists, feed manufactures and animal producers to develop new and novel strategies in response to these concerns.

The food safety scares and issues of antibiotics and animal welfare have generated a whole plethora of new demands and of potential solutions (Knudsen, 2001). There is an increasing tendency to require the raising of food animals without recourse to antibiotics and other drugs. There is a certain body of public opinion that equates everything natural with high levels of safety and quality and much discussion of sustainable agriculture. This attitude overlooks the fact that many compounds of natural origin are toxic and that extremely large quantities of food of animal origin are required to feed the human population. Furthermore in many cases arguments promoting sustainable agriculture are programmes to promote sustainable poverty. Nevertheless practices of modern animal husbandry and animal nutrition have a very high profile and are inevitably visibly linked to food safety. There are now new criteria for safety when it comes to the feeding, healthcare and general

treatment of livestock, and these must be taken into consideration in future programmes of animal production. There is an increasing onus on the animal production industry to convince sceptical consumers and regulatory officials that food products of animal origin are produced in the best possible way and that food safety is a major issue.

## Antibiotics

One well-publicised major concern of recent years has been the use of antibiotics as growth promoters in monogastric animals and the generation of resistant strains of bacteria. This practice has certainly been very poorly perceived by the consumer and there is a lot of consumer pressure not to use antibiotics in raising of animals for food.

The growth promoting effects of subtherapeutic levels of antibiotics in animal feeds was discovered in the late 1940s and has subsequently become an important part of modern animal nutrition. This widespread application of antibiotic growth promoters has also been supported by a great deal of scientific research. A comprehensive literature review indicated that in 12, 153 reported trials the addition of antibiotic growth promoters to feeds increased animal performance 72% of the time (Rosen, 1995). With such a large body of supporting data it is hardly surprising that antibiotic growth promoters became standard ingredients in pig and poultry feeds over the last 50 years.

However, concerns about the use of antibiotics in animal production, and the appearance of bacterial resistance were also expressed quite some time ago and is certainly not a new phenomenon (Anderson, 1965). The emergence of ampicillin-resistant *S. typhimurium* strains was traced to the use of this antibiotic to treat or prevent infections in calves. This raised concerns in 1965 that resistant strains of *S. typhimurium* found in calves could transfer resistance to other bacteria such as *E. coli* and subsequently to other human pathogens.

Since that time several other examples of the generation of bacterial resistance to antibiotics have been reported (Witte, 2000). Special attention was paid to avoparcin, virginamycin and tylosin because of possible cross-resistance against therapeutic antibiotics used in human medicine. Perhaps the most serious situation was the isolation of glycopeptide-resistant *Enterococcus faecium* in the intestinal flora of animals and humans (Wegener *et al.*, 1999). The antibiotic, avoparcin is also a glycopeptide and consequently animal husbandry came under suspicion as a reservoir of resistant bacteria. Some strains of *Salmonella typhimurium* DT104 have been shown to have resistance against several antibiotics including ampicillin, chloramphenicol, streptomycin, sulfamethoxazole, and tetracycline. (Bower and

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Daeschel, 1999). This multi-resistant strain can thrive in an animal being fed sub-therapeutic doses of antibiotic when competing bacteria from the normal flora are suppressed. The resulting reservoir of infectious organisms can persist and be transmitted to other animals and eventually enter the food chain.

It is highly likely that most of the antibiotic resistance problems in human medicine stem from overuse or inadequate control in medical practice for humans. Nevertheless there is concern that enteric bacteria such as *E.coli*, *Salmonella*, and *Campylobacter* with antibiotic resistance can transfer from animals via the food chain or by direct contact. This could establish a population of resistant genes in both animals and humans (Barton, 2000).

Antibiotics can be used in three ways in animal production: therapeutic to treat sick animals, prophylactic to prevent infection in animals and as growth promoters to improve feed utilization and productivity. Use of antibiotics in therapeutic treatment to cure sick animals is usually under the control of veterinarians and is also a welfare issue. Use of antibiotics as prophylactics or for growth promotion is much more of an economic tool to obtain more efficient production and it is in these areas that alternative systems of animal production must be applied.

Widespread publication of instances of bacterial resistance together with other food safety issues culminated in banning of many antibiotics from use in animal nutrition in the EU. In general there is now great opposition to the use of antibiotic growth promoters in animal production by consumers and retail organisations.

Opposition to the use of antibiotic growth promoters in animal production however is not new and started in Sweden in 1985 when a new feed law was promulgated. Under those regulations, antibiotic and chemotherapeutic substances were allowed in feeds only on prescription by a veterinarian. This was slightly amended in 1993 when the use of zinc oxide was approved at 2000 ppm in pig starter feeds for two weeks after weaning.

A culmination of all these various trends and concerns was that in 1999 a whole range of pharmaceutical products were prohibited for use in animal nutrition in the EU (Table 2). The only antibiotic growth promoters still permitted are; avilamycin, flavomycin, salinomycin and monensin.

Consumers are concerned about the wholesomeness and safety of food and therefore the animal feed and production industries must be able to convince consumers that they are producing food of animal origin that is both safe and of good nutritional quality. This also means

food products or animal origin that have no residues of antibiotics and with only minimum levels of bacteria that have acquired antibiotic resistance.

**Table 2**  
Recent history of  
antibiotic growth  
promoters in the EU

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April 1997	Avoparcin prohibited for use in animal nutrition.
July 1999	Virginiamycin, spiramycin, tylosin phosphate and zinc bacitracin prohibited from use in animal nutrition.
September 1999	Carbadox and olaquinox prohibited from use in animal nutrition.
October 1999	Dinitolmide, ipronidazol and arpinocide prohibited for use as coccidiostats.

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## Intensive animal production

We must inevitably rely upon intensive modern systems of animal production for the large bulk of our food supplies. Nevertheless there are many radical changes occurring in modern animal husbandry and the situation is by no means static. The animal production industry is now rapidly evolving into an integrated food industry for the 21<sup>st</sup> Century. It is widely recognised that there is a continuous chain from primary animal feed raw materials to health through nutrition of the human population. It will always be necessary to achieve a satisfactory balance between maximising production volumes, minimising costs and ensuring food safety and customer satisfaction. For many years animal nutrition and animal feed production were hidden links in the overall food chain. Nowadays the animal production industry must be visible, and seen to be engaged in providing consumers with, safe, healthy, abundant and affordable food.

Modern systems of animal production have been extremely successful in delivering large volumes of low cost food to the human population. This requires genetic strains or lines of animals which have the potential for rapid growth and high production rates of the food item of interest, whether it be milk, eggs or meat. Decades of research into animal nutrition, genetics and husbandry permit us to control with great precision the development of our food animals. Factors such as reproductive rates, health status, growth rates, percentage of body fat, shelf life of meat, colour of meat and eggs are all subject to nutritional control.

The demands of a modern society for food of animal origin also requires the raising of large numbers of animals in relatively small areas. This combination of high productivity of animals and large