FIFTH EDITION

LIVESTOCK FEEDS & FEEDING

RICHARD O. KELLEMS
D. C. CHURCH

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Preface

This book is intended to provide the reader with an understanding of the principles relating to livestock feeding. Numerous changes have occurred since its last publication with respect to scientific knowledge, world politics, international relations, food security, and many other areas. Many new world markets have opened. There is an increasing challenge to improve production efficiency so that livestock products can compete in these new marketing opportunities. Because the cost of feeding normally accounts for the largest single input in a production operation, there is a need for a better understanding of nutrition and feeding for those that are going to be involved in livestock production.

The book provides a brief historical perspective of the development of modern livestock production. The ability to provide a safe, nutritious food supply for the world's population has been the driving force behind the development of modern agriculture in the world, with the well-being of the animals and profitability being major considerations. Many advances in genetics, including the development of transgenic animals, and concern about the environment have impacted livestock producers. It is becoming increasingly important to have a better understanding of the effects that feeding and management of livestock have on livestock production systems and environment.

This book will provide the reader with a basic understanding of the nutrition, livestock production systems, and the utilization of feedstuffs. Species chapters will discuss the management and feeding practices that are unique to those species. Feedstuff characteristics and nutrient guidelines are given for various classes of the species in the Appendix Tables. It is our sincere hope that this book will enable the reader to gain knowledge of the principles and management practices used in livestock feeding.

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Brief Contents

Contents

CHAPTER 1

Livestock Feeding

Richard O. Kellems and D. C. Church

Dramatic changes in the feeding and production of livestock have occurred over the centuries. In the United States and other areas of the world, the inhabitants have shifted from a primarily nomadic existence to an agrarian and then to a primarily urban type of existence. The first inhabitants were normally nomadic hunters and gatherers, initially moving from area to area on foot; then they started to domesticate animals, such as horses, or build boats that allowed them more mobility so that they could collect food from a wider area. Then a shift occurred over time to a more agrarian type of living style, in which dependence on hunting lessened, and they started to produce crops that could be used as food and domestic animals to serve as a source of meat. As a result of these changes, people became less dependent on what they could hunt or gather for their food supply and more dependent on what they could produce. The primitive methods used required that they devote a major portion of their time to producing enough food to survive. As the population increased, the size of the communities increased, and people became less involved in food production and started to have other types of employment, so the proportion of the people involved in food production started to decline; today less than 2% of the population in the United States is involved in producing enough food for everyone else. Tremendous changes have occurred in how livestock are produced and fed as production systems have changed from subsistence to very specialized large-scale operations, such as found in the United States and other developed countries. Populations can still be found in these various stages of agricultural transition in different areas of the world today.

As these changes occurred, knowledge relating to how livestock should be fed has increased. Initially, individual producers most likely shared their experiences with one another, such as when a certain plant was grazed their animal grew well, or when another plant was consumed their animal became sick or died. These types of exchanges most likely caused people to feed their animals differently and improved animal performance. Most of the technical information relating to the feeding of livestock has been developed from countless experiments carried out worldwide, primarily during the past 150 years. Governments established public institutions (land grant universities in the United States and research centers in other parts of the world) to assist the agrarian sector to develop a knowledge base that would support the producers so that they could produce a safe and adequate food supply. Initially, very little research was conducted by privately sponsored institutions or individuals, but today more and more research is being conducted by private companies that are trying to develop products or systems that will increase production efficiency, which can then be marketed by these companies. In the United States and other developed countries, livestock production systems have been developed to a very high level. Even though the science of animal nutrition and feeding has been advanced significantly over time, our knowledge is still not complete and advances continue.

As the population and standard of living continue to increase throughout the world, the demand for animal products will continue to increase. The challenge to livestock producers and nutritionists is to increase the efficiency of conversion of feedstuffs into animal products, which includes the use of more alternative feedstuffs, such as straws and agricultural by-products, so that an adequate supply of animal products can be provided. During the past decades we have seen dramatic improvement in crop production, even though the amount of land being farmed has changed very little (Table 1–1). Similar increases in production of animal products have also occurred during the same period of time. Food and feed production vary each year depending on the following: government regulatory practices; price being received for the products and projected future price; environmental conditions, particularly weather; and the cost of various inputs, such as fertilizer, equipment, labor, and availability of money. The challenge is to understand how we can utilize available natural resources more efficiently to ensure that an adequate food supply can be provided for the world's population.

This book will provide the reader with a basic understanding of the feeding and nutritional practices associated with modern livestock production, specifically by providing the reader with a basic understanding of how nutrients are digested and utilized, the function of various nutrients, an understanding of the nutritional value of various feedstuffs, how processing affects nutrient utilization, specific nutrient requirements for various livestock species, practical feeding practices used for various species of livestock, and a basic understanding of how rations are formulated.

TABLE 1–1 World Coarse Grain (in Million Metric Tons)

	Coarse Grains[a]	
	Tons per Hectare	*Total*
1966/67	1.61	508.9
1976/77	2.02	692.0
1986/87	2.45	822.4
1994/95	2.76	858.4
1998/99	2.86	894.4

Source: *Grain World Market and Trade Report,* USDA. Oct 1999 (1).
[a]Coarse grain consists of corn, sorghum, barley, and oats.

BASIS FOR SUCCESSFUL FEEDING OF LIVESTOCK

The fundamental principles relating to the economical feeding of livestock were outlined by Professor W. O. Atwater (2) in 1878:

> The right feeding of stock, then, is not merely a matter of so much hay and grain and roots, but rather of so much water, starch, gluten, etc., of which they are composed. To use fodder economically, we must so mix and deal it out that the ration shall contain just the amounts of the various nutrients needed for maintenance and for the particular form of production that is required. . . . [W]e must consider: What is the chemical composition of our fodder materials? How many pounds of . . . [nutrient] . . . are contained in a hundred pounds of hay, clover, potatoes, meal, etc.? Of these various ingredients of food, what proportion of each [is] digestible and consequently nutritious? What part does each of these food ingredients play in the animal economy? . . . How much of each do different animals, such as oxen and cows, need for maintenance of life and production of meat, milk, etc.? And finally, how may different kinds of fodder be mixed and fed so that the digestible material shall be most fully digested and utilized, and the least quantity wasted?

This statement by Atwater, which was published more than 100 years ago, is in most respects still applicable to the concepts used in feeding livestock today. In addition to the factors outlined by Atwater, more recent advances in our nutritional knowledge have occurred. Understanding of the interactions between nutrient utilization and various other factors, such as disease, parasites, and toxic substances in feed, has been elucidated. For example, we now know that it is cost effective to eliminate internal parasites in order to increase performance and maximize the efficiency of nutrient utilization. Management practices such as increasing frequency of feeding have been shown to be profitable in some situations and can be used to maximize nutrient intake and thus increase performance. Many feedstuffs currently fed to livestock contain antiquality factors, such as the trypsin inhibitor found in soybeans, which, if fed to poultry without being inactivated, will impair performance; but certain amounts can be fed to cattle without

having an adverse effect. Our understanding has increased as to how to inactivate these antiquality factors and to what species of livestock they can be fed without observing detrimental effects. The nutrient requirements of our various livestock species continue to change as genetic advances are made. The nutrient requirements for a dairy cow producing 45 kilograms (kg) of milk per day are different than those for a cow producing 10 kg of milk per day. The same is true for a broiler that takes only 7 weeks to reach market size versus one that takes 12 weeks to reach the same size. With the rapid advances in biotechnology currently being made, the use of new products, such as bovine somatotropin (Bst), will change how nutrients are utilized by the animal and thus their nutrient requirements. So the feeding of livestock is a very dynamic and ever-changing discipline and has become more of a science and less of an art as our knowledge relating to nutrition continues to increase.

As a result of genetic advances in livestock, the conversion of feed nutrients into animal products continues to improve. Table 1–2 shows the improvements that have been made in efficiency in feed conversion in poultry; these are a result of a better understanding of nutrition and improvements in growth rates resulting from genetic advances. Fewer cows are now required to produce more milk, which increases efficiency of production (Table 1–2). High-producing animals require less feed per unit of gain, primarily because less of the nutrients that are being consumed are being used for maintenance and because they require less time to reach their desired market size. Since the primary dietary constituent used for maintenance is energy and the primary constituent found in animal products is protein, dietary protein levels will need to be increased as the genetic productive potential of livestock increases, as will the dietary concentration of other nutrients. Thus nutrient requirements are continually changing as genetic progress is being made.

Feed Consumption Effect on Dietary Nutrient Density

Feed consumption has a dramatic effect on dietary nutrient specifications. Feed consumption can be affected by a number of different factors, such as environmental temperature, humidity, and stress. Adjustments need to be made to feeding programs as a result of changes in consumption. If for some reason an animal consumes 10% less feed than projected, then, in order to achieve the projected level of performance, it will be necessary to increase the nutrient density of the diet to compensate for the reduction in consumption. For instance, if the diet was formulated to contain 10% crude protein, then if feed were reduced by 10% the diet would have to contain 11.1% [10%/0.9 (decimal equivalency of 90%) = 11.1% CP] in order to have the same intake of crude protein.

Another change that has occurred is that the nutrient content of feedstuffs is changing as production practices and genetics changes are made in these crops. As the yield of a crop increases, often the trace mineral content decreases; so to satisfy the requirement of the animal, these minerals need to be fortified at a higher level. The nutrient content of alfalfa grown in an area where only three crops are produced may differ from alfalfa grown in an area where seven or eight crops are

TABLE 1–2 Changes in Pounds of Feed Required Per Pound of Gain in Poultry and Milk Production Per Cow and Total Milk Production in the United States

	Feed Required per Pound of Gain For Poultry	*Milk Production (lb/cow/yr)*	*Total Milk Production per Year (million lb)*
1965	3.3	8,522	127,000
1976	3.2	10,354	115,458
1986	3.0	13,031	143,667
1994	2.8	15,704	150,704
1999	2.6	17,771	162,711

Source: USDA. *Agricultural Statistics*, 2000 (3).

harvested. Climatic conditions can affect the nutrient characteristics of a crop, especially those produced by dryland operations. Watering and fertilization practices can alter the nutrient characteristics of a crop. Farming practices often affect the nutrient content of feedstuffs, such as the excessive application of manure or fertilizer to land, which often increases the nitrate content of the crop being harvested, which could be toxic to the livestock being fed.

Recent genetic improvements of many of the crops used in feeding livestock have increased the digestibility and reduced the amount of antiquality factors associated with these crops. For example, the genetic improvements made in alfalfa have dramatically increased its crude protein content, decreased acid detergent fiber (cellulose and lignin), and, as a result of these changes, increased the digestibility of the energy-yielding components of alfalfa. Plant breeders have reduced the antiquality factors in several crops that are extensively used as feeds for livestock. Rapeseed is one example of a crop that has had the antiquality factor (goitrogenic compounds) reduced by plant breeders; these changes have been so dramatic that the name of the resultant crop has been changed to canola. Canola is primarily produced as an oil source, but the residue remaining after the oil is extracted is marketed as canola meal. The above-mentioned changes can be monitored using laboratory procedures, but continued updating of these changes in the nutritional characteristics of various feeds is required of the livestock producer in order to effectively optimize the use of these feedstuffs in various feeding programs.

Atwater pointed out that an animal has a requirement for a specified amount of specific nutrients. Common practice is to list the nutrient requirements for an animal expressed as a concentration in the diet, rather than as an amount of a particular nutrient. For example, the crude protein requirement for a beef steer that is being finished in a feedlot could be indicated to be 11%, but a more precise method of describing the requirement is to specify how many kilograms or grams of crude protein or grams of specific amino acids are required each day to achieve a certain performance level, thus allowing for differences in feed consumption to be taken into account. If a steer consumes 10 kg of a ration containing 11% crude protein, it would consume 1.1 kg of crude protein per day. If you wanted the same level of intake of crude protein by another group of steers that were only consuming 9 kg of ration, the crude protein content of the ration would need to be increased to 12.2% ($10 \times 0.11 = 1.1$ kg CP/9 kg $\times$ 100 = 12.2% CP). Since the intake can vary among groups of animals, it is becoming more common to specify nutrient requirements as an amount instead of as a proportion (%) of the ration.

Many processing (pelleting, grinding, chopping, etc.) and management practices (feeding frequency, lighting regimes, etc.) are being implemented that alter feed consumption and change the concentration of specific nutrients in the diet. An individual involved in feeding livestock in a modern operation must have an understanding of the effect feed processing and management practices have on livestock performance. For example, if a roughage crop is chopped or ground and pelleted and fed to livestock, nutrient consumption is increased in some situations dramatically, which means that more forage could be fed instead of grains, and performance could be maintained. Utilization of the nutrient components found in cereal grains is increased dramatically by rolling and grinding. Many antiquality factors can be inactivated by using various processing methods so that other nutrient components of these products can be more efficiently utilized. Processing techniques have been developed that have changed the physical characteristics of products so that the desired consumption of various nutrients can be achieved, such as salt blocks, molasses blocks, protein blocks, and liquid supplements, or where the physical form restricts consumption when livestock have free access (range, grazing situations, etc.) to these products.

Those involved in formulating rations need to have an understanding of the harmful substances found in various feedstuffs. For example, cottonseed meal derived from certain varieties of cotton can have a relatively high amount of gossypol associated with it. Gossypol is relatively toxic to monogastric animals (calves, swine, poultry); thus, normally, cottonseed meal is restricted or not used in the rations for these animals. If the person formulating rations for feedlot cattle had a choice between rapeseed or canola meal (same family as rapeseed) that had the same nutrient contents, then he or she would need to know that the rapeseed meal contains higher levels of glucosinolates, which have a negative impact on performance; thus the canola would be the preferred supplemental protein to use.

When formulating or evaluating feed tags, it is useful to have general knowledge of the nutrient contents and feeding characteristics of various feedstuffs. For example, if corn that is low in the amino acid lysine

is the primary ingredient in a pig starter ration, then a protein supplement like soybean meal, which is high in lysine, or a synthetic lysine source would need to be added if the lysine requirement of the animal is to be met. Often the dietary calcium level is increased in a ration when most of the calcium is being derived from alfalfa, since the calcium in alfalfa has a lower biological availability.

Understanding how agricultural by-products, derived from the production of other food products for human consumption, can be effectively utilized in feeding livestock is becoming more critical, because the lands used for agricultural production are not increasing and in some areas of the world are declining. So it is becoming more and more important to utilize all the resources generated by photosynthesis more effectively. In countries like the United States where cereal grains are reasonably priced, these grains will continue to be the foundation of our livestock feeding operations; but in other countries where cereal grains cannot be economically used to feed livestock, by-products will need to be used.

It is certainly necessary to have some knowledge of supplemental feedstuffs—those that are used in relatively small amounts for specific reasons or to make up for inadequacies associated with the other ingredients that are being used. Synthetic sources of amino acids and vitamins are examples of these types of products. It is also necessary to have a knowledge of the different nonnutritive additives that are in common usage—medicants, antibiotics, hormones, and others.

Last, but certainly not least, the cost of different sources of nutrients must be given due consideration. Feed is the major cost associated with the production of all livestock and often accounts for between 50% and 75% of total costs; thus it becomes easy to see how the cost of the individual feedstuffs and rations may determine whether an operation will stay in business or go bankrupt.

The previous sections have highlighted some of the factors that affect the feeding of livestock and for which a beginning student needs to gain some appreciation. These factors and concepts will be discussed in other chapters in more detail so that gradual understanding can be developed.

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