NITROGEN AND ENERGY NUTRITION OF RUMINANTS

Ray L. Shirley

ANIMAL FEEDING AND NUTRITION

A Series of Monographs

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NITROGEN AND ENERGY NUTRITION OF RUMINANTS

ANIMAL FEEDING AND NUTRITION

A Series of Monographs and Treatises

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Foreword

This is the eighth in a series of books in animal feeding and nutrition. The books in this series are designed to keep the reader abreast of the rapid developments in this field that have occurred in recent years. As the volume of scientific literature expands, interpretation becomes more complex, and a continuing need exists for summation and for up-to-date books.

Nitrogen and Energy Nutrition of Ruminants is written by Dr. Ray L. Shirley, a distinguished scientist who is recognized worldwide for his outstanding work in animal nutrition and who has done an excellent job in assembling a large volume of information on the subject. He has brought together both basic and applied research information and indicated how it can be used in ruminant nutrition. The book is written to fit the needs of a course in nitrogen and energy nutrition of ruminants, but can also be used as a reference for other courses in nutrition and by college and university students and teachers. It is a valuable source of information for county agents, farm advisors, teachers of vocational agriculture, consultants, veterinarians, and livestock producers, and it will also be helpful to feed manufacturers, dealers, and others concerned with producing the many different supplements, feeds, and other ingredients used in ruminant feeding and nutrition.

Increasing attention is being paid to the seriousness of the world's food problem. Many third world countries have increased food production, but this increase is not keeping pace with rapid population growth. Over one billion people now suffer from chronic malnutrition. Every $2\frac{1}{2}$–3 years, the world's population increases by 220–240 million people, and about 87% of this population growth is taking place in countries which are the least able to feed themselves.

Many scientists feel there is a need to double animal protein production in the next 20 years in order to improve the protein status of the world's rapidly growing population. In addition to excellent quality protein, animals provide many important vitamins and minerals. The developing countries of the world have about 60% of the world's animals but produce only 19% of the world's meat, milk, and eggs. Better feeding and nutrition would increase their production of animal foods. One important problem is the development of feeding programs which provide the energy and nitrogen needed in animal diets. This book provides information on a wide range of feed resources, including range, grasslands, plant and animal by-products, cellulosic wastes, crop residues, roots, nuts, as well as other vegetable crops, fruit crops, and animal wastes, for animals that otherwise would contribute little in feeding mankind. This book can therefore be very helpful in increasing animal food products for human consumption throughout the world.

Tony J. Cunha

Preface

This book was written as an expansion of notes utilized by the author in a course on nitrogen and energy nutrition of ruminants taught at the University of Florida. No available book has provided sufficient coverage of the many new developments and insights on nitrogen and energy nutrition for the course, and one summarizing the more recent publications in the field is especially needed for teachers, as well as for extension people, consultants, and producers of cattle and sheep.

This volume covers research on various nitrogen and energy feedstuffs and defines terminology commonly utilized in nitrogen and energy nutrition. The utilization of nitrogen and energy in oilseed meals, fish meals, cereal grains, distillers' residues, molasses, silages, grasses, hays, crop residues, animal waste, and nonprotein nitrogen sources is discussed. Details are given on development and utilization of net energy systems, systems for balancing total nitrogen, and nonprotein nitrogen with total digestible nutrients (TDN) or energy components of ruminant diets. Discussions are presented on metabolism, feedlot, milking, and grazing trials. Growth stimulants, processing of feedstuffs, type of animal, and environmental and management factors that affect feed intake, growth, feed efficiency, and quality of product are reviewed.

Emphasis is given to the contributions of ruminal microbes in upgrading forage and nonprotein nitrogen sources to higher-quality bacterial protein, as well as their ability to downgrade high-quality protein and waste nitrogen when protein is fed in excess of microbial needs. Research is presented on means to increase bypassing of the rumen to prevent nitrogen wastage when ruminants are fed concentrate diets. Contributions of ruminal microbes in utilizing cellulosic materials as lignocellulose and hemicellulose as well as starch and other carbohydrates are discussed.

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Ray L. Shirley

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Introduction

Nitrogen and energy are closely associated dietary factors in the nutrition of ruminants. Ruminal microbes require nitrogen for cellular protein synthesis and multiplication, since they utilize energy from lignocellulose and other cellulosic cell wall constituents as well as from starch and simpler metabolites. Certain phases of nitrogen and energy nutrition can be separated from other nutrients such as minerals and vitamins, but the many interrelationships between nitrogen and energy appear to warrant a book dealing primarily with these two dietary factors. Nitrogen and energy feedstuffs greatly exceed the other dietary factors, both in quantity and in cost, in commercial operations with ruminants.

Understanding of the nitrogen and energy nutrition of ruminants has been enhanced by investigations in many phases of basic chemistry, physics, microbiology, physiology, endocrinology, genetics, and environment, as well as general animal husbandry. Basic chemistry concepts apply to all nutrition, and concepts of physics apply especially to energy units and body functions. The many bacterial and protozoal species of the rumen allow ruminants to utilize grasses, roughages, and many waste products that have a high content of lignocellulose, hemicellulose, and other cell wall constituents that nonruminants cannot utilize. Meeting the dietary nitrogen requirements of the microbes results in a significant increase in their capacity to derive energy from such refractory dietary ingredients.

The term *dietary nitrogen* instead of *dietary protein* is commonly used with ruminants. This is because ruminal microbes can utilize nonprotein nitrogen (NPN) sources such as urea, biuret, and ammonium salts, as well as plant and animal proteins. Nonruminants have very limited, if any, capacity to utilize NPN. Some ruminal microbes prefer ammonia to amino acids for synthesis of bacterial cell proteins. The rumen's microbial population can function at above the maintenance level of the host with only NPN in the diet if sufficient dietary energy is provided. If enough nitrogen from either protein or NPN sources is present, ruminants can obtain energy from grasses and other roughages for maintenance plus the production of meat, milk, and wool.

Ruminal microbes degrade dietary protein to amino acids, and then to ammonia and various non-nitrogen-containing fragments. The microbes then resynthesize microbial protein from these substances. The process results in an upgrading of forage protein to microbial protein that has higher levels of essential amino acids and greater biological value than plant proteins. However, with the high-concentrate diets fed ruminants for increased meat and milk production, the capacity of ruminal microbes to degrade dietary protein may exceed their capacity to resynthesize ammonia into microbial protein, and ammonia nitrogen may be lost through urinary urea excretion. To alleviate this loss of nitrogen and obtain maximum growth or production by ruminants, many studies have been made on factors that allow the dietary protein to bypass the rumen when it exceeds the requirements of the microbes.

Normal bypassing of the rumen by dietary protein with high-concentrate diets is generally highest with grains, lowest with forages, and intermediate with oilseed meals. Heating of protein or treatment of proteinaceous materials with formaldehyde or tannic acid will increase bypassing and decrease the loss of dietary nitrogen due to excessive deamination in the rumen. Residues from alcohol fermentation of grain and fish meals are sources of protein that are resistant to degradation in the rumen.

Recent development of the Urea Fermentation Potential (UFP) system at Iowa State University, Ames and the total digestible nutrients (TDN)–crude protein system at the University of Wisconsin, Madison, as well as the crude protein and metabolizable energy requirement tables of the National Research Council (NRC) bulletins, emphasize the importance of properly balancing dietary nitrogen and energy for various classes of ruminants and various levels of production. Understanding these systems is essential to the economical utilization of urea as a source of dietary nitrogen.

Utilization of crop residues, alcohol and methane fermentation residues from grains, wood by-products, and animal wastes should provide energy and nitrogen sources for ruminants that are economical for certain levels of production. A proper balance of available nitrogen and energy will enhance the nutritional value of such feedstuffs. Treatment of lignocellulosic materials with alkali has been demonstrated to increase greatly the store of carbohydrates available for ruminal microbes.

The development of large feedlots has necessitated studies on the more precise energy requirements for various weights and types of cattle. The California Net Energy System, which recognizes the net energy for maintenance (NE_m) and net energy for gain (NE_g) requirements of various weights of cattle and rates of gain, has provided a guideline for optimum feeding programs for feedlot cattle. By utilizing the UFP system or the TDN–crude protein system for dietary urea when applicable, dietary nitrogen should be provided efficiently. For example, an understanding of the protein and energy requirements of lactating cows has greatly enhanced dairy milk production, as well as meeting the dietary requirements of lactating beef cattle and sheep.

Maximum production of meat and milk by ruminants has been increased greatly by research on dietary requirements for common salt, phosphorus, calcium, cobalt, copper, iron, sulfur, iodine, and other minerals. Ruminant production has been enhanced by monensin, lasalocid, Ralgro, Synovex, melangestrol acetate (MGA), and other growth factors. Antibiotics and various chemicals that control disease and parasites are also essential to the efficient utilization of nitrogen and energy in ruminant diets.

Good breeding and selection of animals, and proper supplies of supplemental minerals, nitrogen, and energy feeds to ruminants on pasture during drought and nongrowing seasons, result in more healthy and productive livestock. Of course, management of ruminants exposed to extreme cold, heat, wind, rain, mud, and other stress factors is essential to prevent maintenance requirements of nutrients from becoming excessive. Finally, healthy, productive ruminants need a well-balanced diet that promotes sufficient feed intake to realize the potential of the animals and the goals of the producer.