

## SYMPOSIUM

# INVITED REVIEW: Nutrient requirements of ruminants: Derivation, validation, and application<sup>1</sup>

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### ABSTRACT

*In the United States, livestock nutrient requirements have been developed by volunteer committees of the Board on Agriculture and Natural Resources of the NRC. Estimates of requirements for ruminants are founded on an understanding of digestive physiology and metabolism and are typically determined by empirical approaches based on reviews of the literature and analysis of derived and experimental data sets. Systems for describing nutrient requirements of animals are intrinsically composed of 2 parts: (1) estimates of animal requirements for nutrients and (2) estimates of the ability of feedstuffs to meet those requirements. Ultimately, these systems contribute to animal health and well-being, but for application, they also should provide a means to predict animal performance and adjust feeding and management practices*

*to achieve economic goals. Changes in feed intake and nutrient requirements associated with sex, breed, physiological state, and the environment add to the complexity of establishing requirements. For ruminants, describing the concentration and availability of nutrients in the wide variety of feedstuffs used in practical diets is a significant challenge for NRC committees. Validation of nutrient-requirement equations is an increasingly important part of the NRC process, although the lack of independent data for validation is a problem. Development of computer models to facilitate application of nutrient-requirement systems also has become increasingly important. User-friendliness and functionality of models has improved over time, but more effort is needed to ensure that models allow for efficient, practical application of the systems. The recently established National Animal Nutrition Program (funded by USDA-National Institute of Food and Agriculture) should play an important role in interacting with NRC committees, particularly in providing support for feed-composition databases and development and evaluation of computer models. As a source of up-to-date reviews of the literature with respect to utilization of major nutrients, the 2013 ARPAS Symposium should help to define the nutri-*

*ent requirements of beef cattle and other ruminants.*

**Key words:** livestock, National Research Council, nutrient requirement, ruminant

### INTRODUCTION

Determining nutrient requirements of livestock species is a daunting task, with ruminants being a particularly noteworthy challenge. Compared with nonruminants, the complexity of the ruminant digestive system, as well as the incredibly large variety of feedstuffs that are used in practical ruminant-production systems, significantly complicates and expands the scope of processes typically used to determine nutrient requirements.

Understanding how ruminants ferment, digest, absorb, metabolize, and retain nutrients is vital to building comprehensive nutrient-requirements systems for these economically and ecologically important animals. The 2013 ARPAS Symposium “Applied nutrition of ruminants: Current status and future directions” was envisioned as a forum to provide up-to-date information on nutrient utilization by ruminants that could be used

<sup>1</sup>Presented at the American Registry of Professional Animal Scientists (ARPAS) Symposium: Applied Nutrition of Ruminants—Current Status and Future Directions, July 10, 3013, ADSA/ASAS Joint Annual Meeting, Indianapolis, Indiana.

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as a resource by NRC committees, scientists, practicing nutritionists, and students who work with ruminants. The comprehensive reviews on fermentation and digestive physiology (Krehbiel, 2014), carbohydrate and lipid nutrition (Hall and Eastridge, 2014), protein nutrition (Owens et al., 2014), and mineral and vitamin nutrition (Spears and Weiss, 2014) will be an important resource to the scientific and professional communities of animal nutritionists for years to come. The objective of this paper is to briefly describe the processes used to determine nutrient requirements of livestock, with a particular focus on ruminants.

## DETERMINING NUTRIENT REQUIREMENTS

### *Infrastructure and Mechanisms*

Since the 1940s, livestock nutrient requirements in the United States have been developed by committees working under the auspices of the NRC. The working arm of the National Academy of Science, the NRC is currently composed of 6 divisions, with the Division of Earth and Life Sciences housing the Board on Agriculture and Natural Resources, under which the livestock-nutrient-requirement committees operate. The NRC livestock-nutrient-requirement committees are chosen largely from the scientific community based on input from stakeholders. Committee members receive no payment for their work, but staff support for committee activities is provided by the NRC. In the last few years, funding for NRC livestock series has been derived, in part, from the sale of the nutrient-requirement publications, with additional funding typically coming from federal agencies (e.g., Food and Drug Administration) and various nonprofit groups (e.g., commodity boards and similar industry support groups).

The advantages associated with NRC leadership for development and updating nutrient-requirement publications are many. The stature

of the having an arm of the National Academy of Science being ultimately responsible for the content of the final reports is significant, as is the volunteer nature of committees. Although not a government agency, the independence of the NRC provides a high level of assurance that committee reports will be objective and credible. Finally, the NRC process ensures that reports will receive a comprehensive review by experts in the fields of study covered by the report.

Perhaps the most significant disadvantage of NRC oversight of the nutrient-requirement publications is the timeliness of producing and revising reports. A significant portion of the funds required to produce the report must be secured before work begins, which tends to lengthen the time between revisions. In addition, although not burdensome and in the long run positive for credibility, the rules and regulations pertaining to the work of NRC committees tend to slow the overall process. Significant progress has been made in recent years to decrease the time required in the NRC process, so the prospects for speedier work by present and future committees is good.

Another recent development that should have a positive effect on producing and updating livestock nutrient-requirement publications is the formation of the National Animal Nutrition Program (NANP). The program, funded by a grant from USDA-National Institute of Food and Agriculture through the National Research Support Program, will oversee committees whose role will be, in large part, to interact with NRC nutrient-requirement committees. The NANP is currently composed of a coordinating committee, a feed-composition committee, and a modeling and supporting technologies committee. Historically, acquiring reliable and comprehensive feed-composition data has been a struggle for NRC nutrient-requirement committees. In addition, finding third-party review and support for computer models associated with nutrient-requirement systems has been challenging. Thus, the NANP

should be a useful adjunct to the NRC process, particularly in providing support for feed-composition databases and development and evaluation of computer models. Details of the role that NANP should play in the process were presented at the 2013 ADSA/ASAS Joint Annual Meeting (Cromwell et al., 2013; Hanigan et al., 2013; Miller et al., 2013).

### *Basic Processes*

The essential elements and processes used in the developing nutrient requirements for ruminants are illustrated in Figure 1. There are fundamentally 2 main components to any system for determining nutrient requirements: (1) estimates of the animal requirements for nutrients and (2) estimates of the ability of feedstuffs to meet the requirements. For ruminants, the primary nutrients of interest are protein, energy (a property of nutrients but functionally treated like other nutrients in terms of requirements), vitamins, minerals, and water. Requirements for these nutrients at the tissue level vary with genetic and physiological factors such as sex, breed, growth, pregnancy, and lactation and also can be affected by environment (e.g., climatic factors and heat and cold stress) and management (e.g., housing, terrain, and so on). From the supply side, intakes of protein, carbohydrate fractions, and lipids (the dietary sources of energy), along with minerals, vitamins, and water, are affected by kinetics of digestion (e.g., rates of passage and digestion), interactions among nutrients (e.g., digestive interactions that result in associative effects and interactions among minerals), and the efficiency of digestion and absorption. Retention of absorbed nutrients is affected by metabolic efficiencies, with potential effects of nutrient deficiencies and excesses.

Validation of nutrient-requirement estimates is a vital penultimate step in the process. Equations, coefficients, and ultimate predictions of requirements must be tested to determine how well they fit observed data. In

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