**Improvements in Balancing for Energy for Dairy Cattle**

*Paul J. Kononoff*
*Department of Animal Science*
*University of Nebraska-Lincoln, Lincoln, NE*



## Introduction

In 1863, the National Academy of Sciences was established by U.S. Congress. The aim was to bring together experts to provide scientific and technical advice to the nation. In response to the challenges brought to the Nation by World War II, The Board on Agriculture which is an arm of the National Academy of Sciences formed committees to contribute material that would provide feeding standards for livestock. In 1944, the 1st Edition "Dairy NRC" was published as Recommended Nutrient Allowances for Dairy Cattle. This publication was made up of 21 pages and contained 75 references and 4 tables. This, along with subsequent editions, became trusted resources for the feed industry (Erdman, 2017) In September 2015, a new committee was established and brought together to update and compile the most recent version (8$^{th}$ Edition) of this report (NASEM, 2021a). The following individuals served as members of this committee; Richard Erdman (University of Maryland), William Weiss (The Ohio State University), Michael Allen (Michigan State University), Lou Armentano (University of Wisconsin–Madison), James Drackley (University of Illinois at Urbana-Champaign), Jeffrey Firkins (The Ohio State University), Mary Beth Hall (Agricultural Research Service, U.S. Department of Agriculture), Mark Hanigan, Virginia Tech), Ermias Kebreab (University of California, Davis), Paul Kononoff (University of Nebraska–Lincoln), Helene Lapierre (Agriculture and Agri-Food Canada), and Michael Vandehaar (Michigan State University). The resulting report was published by the National Academy of Sciences, Engineering and Medicine (NASEM) and released in December of 2021. Many of the highlights of the publication were previewed to the public at the 40$^{th}$ American Dairy Science Association Discover Conference on Food Animal Agriculture in the Fall of 2021 (Itasca, IL). The publication itself includes 21 Chapters which were made up of a total of 482 pages, 75 tables, 25 figures. The committee's statement of task is also included in the publication (Page 475), and in brief was to prepare a report that was based upon peer-reviewed scientific literature related to the nutritional requirements of dairy cattle. The publication itself can now be purchased at the following website: https://www.nap.edu/catalog/25806/nutrient-requirements-of-dairy-cattle-eighth-revised-edition. The NASEM nutrition computer model can also be downloaded from this website free of charge. The objective of this presentation is to summarize the components of the publication that described energy requirements of dairy cattle with much of it enclosed in Chapter 3. Additionally gaps in knowledge and future needs will be addressed.

## NASEM and Energy

There is a high degree of similarity between the NRC (2001) and the NASEM (2021) net energy of lactation (NEL) supply models. In the newer model, estimates of digestible energy (DE) includes starch, rather than non-fiber carbohydrate, as an input. The addition was made possible because of the frequent measure of starch reported in the published literature but also reflects real-world application as it is responsible for contributing a large proportion of energy and is frequently assayed on many feeds. There are two equations which may be used to estimate NDF digestibility. The first is a lignin-based equation used in the 2001 publication (Eq. 3-3a; Page 24) and the second is a user input value which is based in observed 48 h in vitro digestibility assay (Eq. 3-3b; Page 24). In a typical lactating cow, the true digestibility of fatty acids is reduced from 0.92 to 0.73; a change supported by numerous and extensive recently published studies. Compared to the NRC (2001) model, the discount effects of the increasing feed intake on digestibility have been tempered and only applied to NDF (Eq. 3-5a; Page 25) and starch digestibility (Eq. 3-5b; Page 26) and not the total diet. In estimating metabolizable energy (ME), losses of energy in methane (Eq. 3-9; Page 28) and urine (Eq. 3-10a and 3-10b; Page 28) are now calculated. The new publication also lists energetic parameters summaries from the literature as well as assumed by the 2001 and 2021 publications (Table 3-2; Page 29). Of note is the increase of NEL for maintenance from 0.08 to 0.10 Mcal /kg $^{0.75}$ BW/d and conversion efficiency of ME/NEL from 0.64 to 0.66. Overall, energy requirements are about 8 % higher for lactating cows consuming a typical corn and soybean-based diet. The chapter closes with an extensive discussion on factors affecting feed efficiency and correctly outlines an equation of how to estimate it by accounting for changes in body energy stored (Eq. 3-21; Page 36) (Weiss, 2021a; b).

**New Understanding of Energy Need and Use**

In the future research should explore factors that affect digestibility and energy availability from feedstuffs. In diets fed to lactating cows a large proportion of energy is derived from NDF, yet this analyte varies not only in digestible but by composition and in turn this affects the amount of energy that is supplied to the cow. For example, lignin contained in fiber is known to be indigestible and although containing energy it is not available to the cow. The energy contained in lignin is reported to be approximately 6.0 Mcal/kg (Voitkevich et al., 2012) and across a variety of feedstuffs we recently observed the GE concentration of the NDF fraction to vary but average 4.03 Mcal/kg (Stypinski et al., 2023) yet the dairy NASEM assumes it to be 4.20 Mcal/kg (NASEM, 2021b). Chemically speaking, increasing the concentration of lignin within the NDF fraction should result in an increase in the GE, but it should also limit the digestibility of the NDF and in turn digestible energy (DE). Future research should seek to more accurately describe not only digestibility of NDF, but also the concentration of energy in this fraction. It is also generally believed that there is a high degree of variation of intake in the dairy cow population but how this affects nutrient requirements of maintenance and use of metabolizable energy for milk synthesis is not fully understood (Bauman et al., 1985). Interestingly since 1970 the cows ability to digest feed appears to have been reduced 2-3% and this may be an indirect result of selecting for cows with greater intake potential and milk production (Potts et al., 2017). Whatever the case, the modern dairy cow likely not only consumes more feed but is more efficient with the nutrients she receives. Overall, the NEL system is widely considered to at least theoretically, to be the most comprehensive system. The goal of this system is to accurately represent the biology of the cow and to predict the impact of formulation decisions on her performance. Yet it could be argued that by simply assuming a fixed efficiency by which ME is used for milk synthesis that the NEL system could still be improved. For example we know that the type of volatile fatty acid metabolized by the cow can affect efficiency of nutrient use (Holter et al., 1970). Efficiency can also be affected by feed ingredient choices such as fat (Andrew et al., 1991; Morris et al., 2020) yet this knowledge is not currently represented in nutrition models.

**Milk Protein and Energy Supply**

The new NASEM protein model was probably the most anticipated update and underwent the greatest of modifications. Although this presentation does not focus on protein per se, it is worth our while to discuss how aspects of energy are described to affect protein metabolism and milk protein production. First, microbial nitrogen flow out of the rumen is estimated by an equation which is based upon ruminal energy supply, namely digestible NDF and starch (Eq. 6-3; Page 74). The chapter also includes an equation to predict milk protein yield from the supply of essential amino acids as well as energy (Eq. 6-6; Page 81). This change is logical because energy can affect milk protein synthesis (DePeters and Cant, 1992; Morris and Kononoff, 2021).

**Summary of NASEM Nutrient Requirements**

Although seeming omitted from the 2001 publication, tucked in the back of the new NASEM publication (Pages 470-473) are concise and well organized and informative listings of Nutrient Requirement Tables (Table 21-1; Page 471 for Holsteins and Table 21-2; Page 472 for Jersey's) which are intended to be used as a general guide to compare expected nutrient concentrations of diets fed to meet minimum requirements of dairy cattle at varying stages of maturity, lactation stages, growth rates, milk production, and milk composition.



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