Brief Introduction to the NASEM (formerly known as NRC) 8th Revised Edition of the Nutrient Requirements of Dairy Cattle

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Introduction

After 20 years, a new “Dairy NRC” is about to be released albeit with new name. The 8th revised edition of the Nutrient Requirements of Dairy Cattle will now be designated as a product of the National Academies of Science, Engineering, and Medicine (NASEM) rather than the National Research Council (NRC). The Academies have always been the governing unit of the NRC. Although the name has changed, the procedures related to development of the revised edition remained the same. A committee of experts are chosen by the Academy that represents a broad range of expertise and geography, and the committee is vetted for potential conflicts of interest. The final committee was comprised of Rich Erdman (co-chair), Bill Weiss (co-chair), Mike Allen, Lou Armentano, Jim Drackley, Jeff Firkins, Mary Beth Hall, Ermias Kebreab, Paul Kononoff, Helene Lapierre, and Mike Vandehaar.

The main charge of the committee was “to (conduct) a comprehensive analysis of recent research on the feeding and nutrition of dairy cattle, including research on the amounts of amino acids (AA), lipids, fiber, carbohydrates, minerals, vitamins, and water needed by preweanling, growing, reproducing, and lactating dairy cattle. . . and to … evaluate new information to improve the accuracy of predicting animal performance from nutrient input and of predicting nutrient input when animal performance is known.” The committee was also charged with developing a computer model that reflected the discussion and equations in the text.

It is far beyond the scope of this paper to discuss everything that has been revised (the final book will likely exceed 500 pages). Rather this brief review will discuss some major revisions from NRC (2001) and their implications and will be limited to lactating cows even though the chapters on transition cows, calves and heifers have been modified extensively. The amount of text dedicated to different sections does not reflect the importance or magnitude of the changes made, but rather reflects this author’s areas of expertise. Details on equations and software will be available when the revision is published in December 2021.

Estimating Dry matter Intake

The dry matter intake (DMI) equation in NRC (2001) used only animal factors (milk production, body weight, and days in milk). Because milk yield is strongly related to DMI, the equation was fairly accurate on estimating DMI when production measures were known. The equation did not work as well when a diet was formulated without knowing actual production. The new NRC includes an improved animal factor only equation (based on more data and data from higher producing cows) and an animal and diet factor equation. Primary dietary factors that influence DMI are forage NDF (negatively related to DMI), in vitro NDF digestibility (positively related to DMI) and the primary source of fiber in the diet estimated using the ADF/NDF ratio (high ratio indicates a legume-based diet and a lower ratio indicates a grass-based diet). The new equations will be more accurate with today's higher producing cows and reflect the impact of diet on DMI. Users are cautioned that when using the diet factor equation, entered milk yields must be reasonable because milk yield is still the major driver of DMI. Equations to estimate DMI for dry and prefresh cows, calves and heifers were also updated and include dietary NDF (except for the calf equations).

Energy

The NRC (2001) was the first revision of the Dairy Requirements series that calculated energy values (i.e., net energy for lactation, NEL) from the nutrient composition of the feeds. Prior to that revision, NEL values of feeds were fixed. In the 2001 system, digestible energy (DE) was calculated for feeds by estimating the energy provided by digestible portions of NDF, CP, fatty acids (FA), and nonfiber carbohydrate (100 – NDF – CP – FA – ash). The DE of the diet was calculated as a weighted mean from feed values, and the diet DE was then discounted based on DM intake (DMI) and TDN concentration of the diet. TDN concentration was essentially a proxy for diet starch concentration. One issue that was identified regarding NRC (2001) was that energy balance (NEL supply minus NEL requirements for maintenance, milk, growth, and reproduction) was underestimated for high producing cows. Because it was a problem with high producing, high DMI cows, the source of the error was assumed to be an overestimation of lactation NEL requirements and/or an underestimation of NEL concentration of the diet likely caused by the discount factor.

Research published after NRC (2001) indicated that the greatest source of error was indeed the discount factor. Dry matter digestibility did not decrease as much with increasing DMI and diet TDN as the NRC 2001 equation calculated. One meta-analyses (de Souza et al., 2018) found the NRC (2001) discount was about 3 times greater per unit of DMI as a percentage of body weight) than suggested by current data (Figure 1). One reason for the error is that NRC (2001) used a cow fed at maintenance (approximately 7 kg of DM) as the base and discounted from there. Usually, the base was from nonlactating cows fed at restricted intakes. This resulted in substantial extrapolation and assumed linearity starting at a very low and restricted DMI. DeSouza et al. (2018) developed discount equation from digestibility data collected from lactating cows with DMI ranging from about 1.7 to 4.6% of BW. The average DMI of the dataset was about 3.5% of BW and that was set as the base in the new NRC; therefore, extrapolation is much less than with the old equation. Because increased dietary starch can depress NDF digestibility, its effect was also included (the base was set at 26% starch which was approximately the mean concentration in the dataset used. This approach is much more theoretically accurate than using TDN as done previously.

The improved discount equation should correct most of the underestimation of NEL balance in high intake cows by NRC (2001). However the NEL required for lactation also was likely overestimated slightly (Moraes et al., 2015) which contributed to the problem. This issue was addressed by increasing the metabolizable energy (ME) to NEL efficiency from 0.64 used in NRC (2001) to 0.66 as determined by Moraes et al (2018).

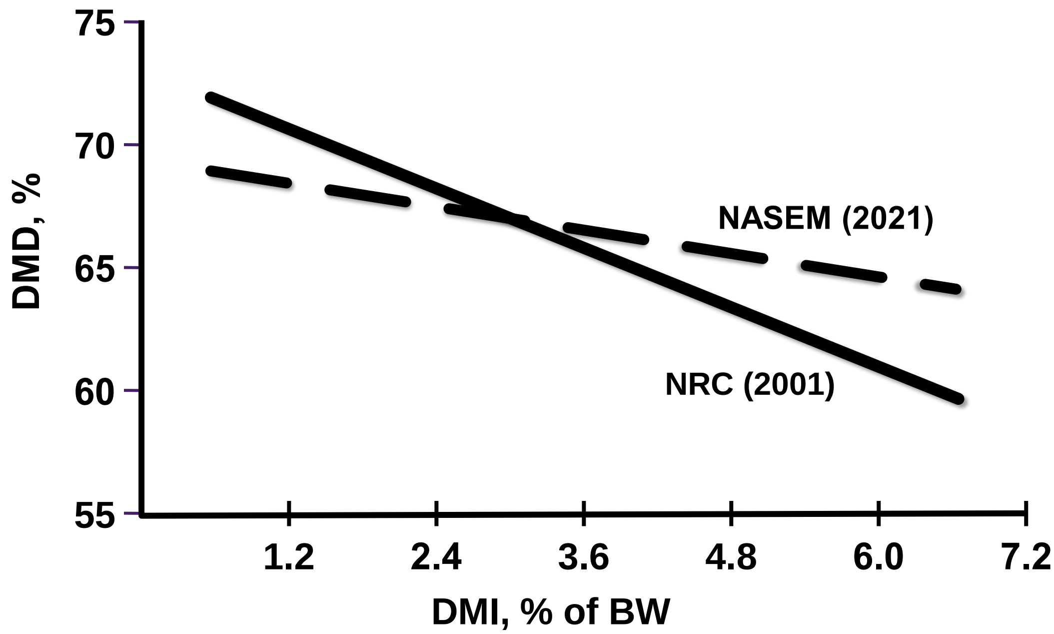

Figure 1. The effect of increasing dry matter intake (DMI) expressed as % of body weight (BW) on dry matter digestibility (DMD) using the NRC (2001) discount equation and the discount equation in the new NASEM (2021) model. For NRC (2001) diet TDN was set at 72% and for the NASEM line, dietary starch was set at 26%. Overall, the effect of DMI on digestibility (i.e., digestible energy) is about 3 times greater using NRC (2001) than in the updated NASEM book.

Other changes made to the energy prediction equation would be considered fine-tuning. The NFC fraction was replaced with starch and residual organic matter (ROM; i.e., NFC – starch) as outlined by Weiss and Tebbe (2018) and Tebbe et al. (2017). This allows better estimation of the energy provided by a variety of starch sources (e.g., different grind sizes of corn grain, high moisture vs dry corn, different maturities of corn silage). The true digestibility of ROM was set at 96% (Tebbe et al., 2018) and starch digestibility values are constants based on the feed (Table 1). Users can choose to use a lignin-based equation as in NRC (2001) or 48 h in vitro NDF digestibility. An equation is used to convert in vitro digestibility into estimated in vivo digestibility.

Table 1. Starch digestibility coefficients used in the new NRC for selected feeds (not all feeds are shown).

Feed	Starch digestibility
Default	0.91
Corn grain, dry, fine grind (<1250 μm)[2]	0.92
Corn grain, dry, medium grind (1500 um to 3250 μm)	0.89
Corn grain, dry, coarse grind (>3500 μm)	0.77
Corn grain, high-moisture, fine grind (<2000 μm)	0.96
Corn grain, high-moisture, coarse grind (>2500 μm)	0.90
Corn grain, steam flaked	0.94
Sorghum grain, dry, ground	0.83
Sorghum grain, steam flaked	0.94
Corn silage <30% DM	0.91
Corn silage 32 – 37% DM	0.89
Corn silage >40% DM	0.85
Barley, ground	0.91
Wheat	0.93

Another change was to the true digestibility coefficient used for FA. In NRC (2001) the true digestibility of FA was assumed to be 100% at maintenance DMI (92% for a typical lactating cow). This was based on very limited data because at that time, FA was not commonly measured. Over the past 2 decades a substantial database of FA digestibility was developed and allowed better estimation of the true digestibility of FA. Two meta-analyses have been conducted (Weiss and Tebbe, 2018, Daley et al., 2020) and both derived essentially the same true digestibility value (73%) with no metabolic fecal FA (i.e., intercept was not different from 0). In the new NRC, digestible FA are calculated as 0.73* FA (% of DM). This is substantially lower than the 0.92*FA (% of DM) used in NRC (2001) but the difference is not as great as it appears because in NRC (2001), FA contributed to metabolic fecal energy but not in NRC (2021). However, the DE concentration of feeds with appreciable concentrations of FA will be lower in the new NRC than in NRC (2001).

In NRC (2001), metabolizable energy (ME) was calculated directly from DE using an equation that was developed several decades ago. That equation did not correctly account for the effect of protein or fat on ME. The new NRC will estimate methane using a published equation based on DMI and dietary concentrations of FA (negative effect on methane) and digestible NDF (positive effect on methane). Urinary energy is estimated by estimating urinary N excretion (g/d) and multiplying that value by 0.0143 Mcal/g (Morris et al., 2021). Both methane and urinary energy are calculated for a diet, not a feed. Therefore, feeds will not have ME or NEL values. The change in the method to calculate ME will result in higher ME values for diets with high FA concentrations and lower ME values for higher fiber diets and diets with excess CP. In the previous NRC, NEL was approximately .64*ME. Based on a re-analysis of Beltsville calorimetry data, Moraes et al. (2018) determined that 0.66 was more accurate and that value is used to convert diet ME into NEL concentrations of diets.

Energy requirements were also evaluated and modified as necessary. The greatest change was in the maintenance requirement. Several papers published over the past 15 years determined that the standard equation for maintenance (which has been used for more than 30 years) underestimated the maintenance requirement of modern dairy cows. Using an average from several newer studies, the maintenance requirement was increased from 0.08*MBW to 0.10*MBW (where MBW is metabolic body weight in kilograms). This change is a 25% increase in maintenance or about 2.5 Mcal of NEL/day for a 650 kg cow). The equation to calculate gestation energy requirements changed to better model fetal growth but the change did not appreciably alter gestation NEL requirements. Lactation energy requirements changed slightly because the efficiency coefficient (0.66) changed from 0.64. Equations to estimate NEL requirements for grazing cows were updated based on newer data and generally activity requirements will be less when calculated using the new NRC than when using NRC (2001).

Protein and Amino Acids

This section underwent the greatest change as compared to NRC (2001) and the complexity of the model precludes a detailed discussion in this paper. Microbial protein is estimated based on estimated rumen digested starch and fiber (these are estimated based on diet composition, not digestion rates). Rumen undegradable protein is based on the A, B, C fraction scheme described in NRC (2001); however rather than estimating rate of passage based mostly on intake as done in NRC (2001), constant rates of passage are used (one for concentrates and one for forages). Significant improvements were made in the estimates for the digestibility of the rumen undegraded protein because the data base was much larger allowing greater screening for spurious values. Supplies of metabolizable protein (MP) and metabolizable AA are the sum of digestible microbial AA or true protein and digestible rumen undegraded AA or true protein. In NRC (2001) endogenous protein was included in MP supply; however, this was an error because endogenous protein does not cause a net increase in MP supply. Therefore, endogenous protein is considered a requirement rather than a supply function in the new NRC.

For lactating cows, maintenance requirements are mostly based on both net protein and amino acids. The requirement for metabolic fecal protein was changed markedly and is now a function of dietary fiber. The calculation for endogenous urinary CP was also changed. In addition, rather than using a classic requirement model for milk protein (e.g., to produce 1200 g of milk protein you need X grams of MP or specific AA) a response model is used (based on AA and energy supplied by the diet, the cow should be able to produce X grams of milk protein). The response function for milk protein yield is based on DE supply (the DE is from components other than CP) and supply of lysine, methionine, leucine, isoleucine, histidine, and total essential AA. The equation to estimate milk protein yield illustrates that an almost infinite array of AA profiles can result in similar milk protein yields. Efficiency of converting metabolizable AA to milk protein is not fixed as it was for MP in NRC (2001). The function includes a quadratic term for total essential AA which means efficiency decreases as supply of essential AA increases.

Minerals

The same basic approach to establish mineral requirements used in NRC (2001) was used in the new NRC. However, a term used to describe human nutrient requirements was introduced to reflect the uncertainty associated with requirement calculations for many minerals. If the committee deemed that the data was not adequate to establish a requirement for an essential mineral, the term ‘adequate intake’ or AI was used. Basically, when that term is used, it means the committee thinks that if most cows eat this amount of mineral she will function normally. Requirements were calculated for all macrominerals and for copper and zinc. Adequate intake was used for cobalt, manganese, iron, iodine, and selenium.

Overall changes in dietary requirements or AI were small for most minerals although equations may have changed appreciably. For example, the maintenance requirement for absorbed Ca increased substantially; however, this was countered by a substantial increase in the absorption coefficients (AC) for Ca. For some electrolytes, endogenous fecal excretion increased while endogenous urinary excretion decreased (or vice versa) resulting in little overall change in requirements. These changes may not alter diet formulation, but they better reflect routes of excretion and more accurately reflect absorption. Phosphorus requirement (both absorbed or dietary) did not change greatly but the new NRC calculates the AC for P from the chemical form (inorganic or organic) of P within the feedstuff. This should improve overall accuracy. Magnesium requirements increased slightly but AC were changed substantially. The AC for Mg supplements were reduced by more than 50% while the AC for basal feeds increased about 50%. These changes were based on a large database that was not available in 2001. In addition, the new NRC includes an equation to adjust the AC based on dietary potassium.

Most trace mineral requirements or AI did not change greatly or at all and only Cu and Mn will be discussed. The requirement and AC for Cu underwent rigorous evaluation because of increased concerns about high liver Cu and Cu toxicity in dairy cows. For the average lactating cow, the dietary Cu requirement in NRC (2001) appears to be correct; however, partitioning of requirements between maintenance and lactation were incorrect.

Based on new data, the maintenance requirement for Cu is about twice as high as in NRC (2001) which means dietary requirements for dry cows and low producing cows will increase. However, the lactation requirement (per kilogram of milk) was more than 3 times too high. Therefore, Cu requirements for higher producing cows will be slightly less than in NRC (2001). The AI for Mn was also evaluated rigorously because an experiment with pregnant beef heifers fed diets that met NRC (2001) requirements resulted in calves born expressing clinical Mn deficiency (Hansen et al., 2006). Based on very limited data (Weiss and Socha, 2005), the maintenance AI for Mn was increased about 30% and the AC was reduced by about 40%. The net result was dietary AI for Mn about doubled for dry and lactating cows.

Vitamins

The new NRC established AI for vitamins A, D and E and in most situations, values were the same as in NRC (2001). The new NRC maintained the base requirement for vitamin A of 110 IU/kg of BW but included an additional requirement of 1000 IU/kg of milk greater than 35 kg/d (based on the retinol concentration in milk). Therefore, for a 650 kg cow producing 35 kg of milk, the vitamin A AI is 71,500 IU/d but for the same cow producing 40 kg of milk/d, the AI is 76,500. The vitamin D AI for lactating cows was increased from 30 IU/kg to 40 IU/kg of body weight. For other animals the 30 IU/kg body weight AI was maintained. The change for lactating cows was based on maintaining blood plasma concentrations of 25-OH vitamin D at 30 ng/ml. The AI for vitamin E was not changed for dry and lactating cows (1.6 and 0.8 IU/kg body weight). An increased AI was set for late gestation cows (i.e., prefresh) at 3 IU/kg of body weight or about 2000 IU/d.

Conclusions

The 8th revised edition of the NASEM (formerly NRC) Nutrient Requirements of Dairy Cattle reflects the current state of knowledge for applied dairy nutrition. All facets of nutrition for calves, heifers, dry cows, and lactating cows were reviewed and changes in requirements were made when appropriate. The book also contains up to dates reviews on numerous topics relevant to feeding dairy cattle. This article is only a brief introduction to the changes made since NRC (2001) but attempted to highlight important (but definitely not all) changes made. People desiring more details will need to purchase the book (I do not receive any royalties from book sales).

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