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Evaluation of the National Research Council (2001) dairy model and derivation of new prediction equations. 1. Digestibility of fiber, fat, protein, and nonfiber carbohydrate[1]

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ABSTRACT

Evaluation of ration balancing systems such as the National Research Council (NRC) *Nutrient Requirements* series is important for improving predictions of animal nutrient requirements and advancing feeding strategies. This work used a literature data set (n = 550) to evaluate predictions of total-tract digested neutral detergent fiber (NDF), fatty acid (FA), crude protein (CP), and nonfiber carbohydrate (NFC) estimated by the NRC (2001) dairy model. Mean biases suggested that the NRC (2001) lactating cow model overestimated true FA and CP digestibility by 26 and 7%, respectively, and under-predicted NDF digestibility by 16%. All NRC (2001) estimates had notable mean and slope biases and large root mean squared prediction error (RMSPE), and concordance (CCC) ranged from poor to good. Predicting NDF digestibility with independent equations for legumes, corn silage, other forages, and nonforage feeds improved CCC (0.85 vs. 0.76) compared with the re-derived NRC (2001) equation form (NRC equation with parameter estimates re-derived against this data set). Separate FA digestion coefficients were derived for different fat supplements (animal fats, oils, and other fat types) and for the basal diet. This equation returned improved (from 0.76 to 0.94) CCC compared with the re-derived NRC (2001) equation form. Unique CP digestibility equations were derived for forages, animal protein feeds, plant protein feeds, and other feeds, which improved CCC compared with the re-derived NRC (2001) equation form (0.74 to 0.85). New NFC digestibility coefficients were derived for grain-specific starch digestibilities, with residual organic matter assumed to be 98% digestible. A Monte Carlo cross-validation was performed to evaluate repeatability of model fit. In this procedure, data were randomly subsetted 500 times into derivation (60%) and evaluation (40%) data sets, and equations were derived using the derivation data and then evaluated against the independent evaluation data. Models derived with random study effects demonstrated poor repeatability of fit in independent evaluation. Similar equations derived without random study effects showed improved fit against independent data and little evidence of biased parameter estimates associated with failure to include study effects. The equations derived in this analysis provide interesting insight into how NDF, starch, FA, and CP digestibilities are affected by intake, feed type, and diet composition.

Key words: National Research Council (2001) dairy model, total-tract digestibility, model evaluation

INTRODUCTION

Ration evaluation programs and the equations that comprise them such as those proposed by the National

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Research Council (**NRC**) are an essential component of animal nutrition research, education, and extension in the United States and throughout the world, where these ration evaluation systems are employed. To ensure that these ration balancing systems meet their objectives, it is necessary to evaluate them extensively against published data. Although the NRC (2001) dairy model was quantitatively evaluated before publication, the extent of the evaluations was limited and largely restricted to protein supply and milk yield (NRC, 2001; St-Pierre, 2003).

The energy and protein fractionation schemes used within the NRC (2001) dairy model are process-based, but the processes are described primarily by empirical equations that predict energy and N fluxes through the dairy cow. The energy fractionation scheme relies heavily on the estimation of nutrient digestibility within different feed classifications (NRC, 2001). Errors for predicting TDN and digestible energy (**DE**) within the NRC (2001) model might be a result of either poorly characterized feed composition or poorly parameterized equations for determining nutrient digestibilities. The relative contributions of these sources of error is currently unknown, and future efforts in model refinement might be misdirected without assessment of these error sources.

The objectives of this work were to use a literature data set of apparent total-tract digestibility of NDF, fatty acids (**FA**), CP, OM, and starch to evaluate the nutrient digestibility estimates provided by the NRC (2001) dairy model and to derive new equations, when necessary. The NRC (2001) predictions of true total-tract digestibilities were evaluated by adjusting apparent FA and N digestibilities to a true basis based on estimated endogenous contributions. We hypothesized (1) that NRC (2001) digestible nutrient predictions would have poor fit when compared with measured data, and (2) that model accuracy and precision would be improved by deriving new equation forms. The effects of these adjustments on RUP and RDP estimates and predicted milk yield are detailed in a companion paper (White et al., 2017).

MATERIALS AND METHODS

The analysis conducted in this study is described here as a series of steps, including (1) data collection; (2) correcting mis-specified ingredients; (3) evaluating the NRC (2001) model; (4) deriving new models; and (5) cross-validating new models. The objective of this work is not to define the superiority of new equations compared with the NRC (2001) model. Direct comparison of these models is essentially infeasible because the new equations were derived and evaluated against the same data set. The primary purpose of deriving new equations was to identify which variables helped to reduce mean and slope biases and improve fit against independent data when predicting nutrient digestibility.

Data Collection

Data were collected from the original set of papers used to evaluate the NRC (2001) dairy model. This collection of papers was updated with more recent work published between the early 2000s until mid-2015. Data from lactating and nonlactating cattle were used, and an exhaustive listing of studies in the data set is presented in Supplemental File S1 (https://doi.org/10.3168/jds.2015-10800). Studies were included in the data set if they presented a numerical measurement of duodenal or omasal N flows or apparent total-tract digestibility measurements. Studies were excluded if they failed to report feed ingredients used and their inclusion rates. The final data set contained usable data from 550 treatment means from 147 studies. The number of treatments used for model derivation was nutrient specific because not all studies reported all response variables (some studies only reported total-tract digestibility of NDF and starch but not CP and FA). The summary statistics for the resulting data set are included in Table 1, and a copy of the data can be downloaded from the National Animal Nutrition Program (2015) website.

Because measured digestibility data from total-tract digestibility experiments were the only data used, the equations in this study reflect prediction of digested material, rather than potentially digestible material. Throughout the paper, the terms "digested" and "digestibility" are used to refer to the actually digested material or reported apparent total-tract digestibility.

Evaluating and Correcting Ingredient Biases

Most studies reported the inclusion rates of the ingredients used in diets (Table 1); however, few studies reported nutrient composition of all ingredients. When ingredient nutrient composition data were available, they were used to calculate dietary nutrient provision. When ingredient-level data were not available, data were populated from the NRC (2001) feed table. In most cases, FA, NDF, ADF, DM, and CP of diets were reported. When the measured dietary nutrient compositions were compared with the predicted dietary nutrient compositions (calculated from ingredient inclusion levels and tabular feed composition), mean and slope