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Updating the Cornell Net Carbohydrate and Protein System feed library and analyzing model sensitivity to feed inputs

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ABSTRACT

The Cornell Net Carbohydrate and Protein System (CNCPS) is a nutritional model that evaluates the environmental and nutritional resources available in an animal production system and enables the formulation of diets that closely match the predicted animal requirements. The model includes a library of approximately 800 different ingredients that provide the platform for describing the chemical composition of the diet to be formulated. Each feed in the feed library was evaluated against data from 2 commercial laboratories and updated when required to enable more precise predictions of dietary energy and protein supply. A multistep approach was developed to predict uncertain values using linear regression, matrix regression, and optimization. The approach provided an efficient and repeatable way of evaluating and refining the composition of a large number of different feeds against commercially generated data similar to that used by CNCPS users on a daily basis. The protein A fraction in the CNCPS, formerly classified as nonprotein nitrogen, was reclassified to ammonia for ease and availability of analysis and to provide a better prediction of the contribution of metabolizable protein from free AA and small peptides. Amino acid profiles were updated using contemporary data sets and now represent the profile of AA in the whole feed rather than the insoluble residue. Model sensitivity to variation in feed library inputs was investigated using Monte Carlo simulation. Results showed the prediction of metabolizable energy was most sensitive to variation in feed chemistry and fractionation, whereas predictions of metabolizable protein were most sensitive to variation in digestion rates. Regular laboratory analysis of samples taken on-farm remains the recommended approach to characterizing the chemical components of feeds in a ration. However, updates to the CNCPS feed library provide a database of ingredients that are consistent with current feed chemistry information and laboratory methods and can be used as a platform to formulate rations and improve the description of biology within the model.

Key words: feed composition, Cornell Net Carbohydrate and Protein System, modeling, methods, sensitivity

INTRODUCTION

Obtaining useful outputs from any biological model is very dependent on the quality of the information being used to perform a simulation (Haefner, 2005). The feed library in the Cornell Net Carbohydrate and Protein System (**CNCPS**) contains information not routinely available from commercial laboratories such as AA profiles, FA profiles, digestion rates (**kd**), and intestinal digestibilities (Tylutki et al., 2008). The feed library also provides commonly analyzed fractions that can be used as they are or updated by the user. Correct estimation of these chemical components is critical in enabling the CNCPS to best predict the ME, MP, and other specific nutrients available from a given ration (Offner and Sauvant, 2004; Lanzas et al., 2007a,b). Regular laboratory analysis of feeds will reduce the variation in model inputs to that derived from the sampling process, sample handling, preparation, and the variation of the assay itself (Hall and Mertens, 2012). However, in some situations, this is not possible and feed library values have to be relied on. In other situations, feed compositions are very consistent, meaning library values provide a reasonable estimation without laboratory analysis. The CNCPS feed library consists of approximately 800 ingredients, including forages, concentrates, vitamins, minerals, and commercial products, and serves as the reference database for describing the chemical composition of a diet. The origin of the feed library is from the work of Van Soest (1994, 2015), Sniffen et al. (1992), and related publications. The addition of AA to the feed library began

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with the publication of O'Connor et al. (1993). Many of the feed ingredients have been updated since that time, using data from more contemporary sources such as the National Research Council publications and other commercial feed additions through the CPM Dairy (University of Pennsylvania, Kennett Square, PA) effort, but not in a systematic or comprehensive manner. The objective of the current study was to evaluate and revise the CNCPS feed library to ensure that it is consistent with values being generated and used as inputs from commercial laboratories. A multistep approach was designed and used to combine current feed library information with new information and predict uncertain values. The intended methods for analyzing each major chemical component for use in the CNCPS are reported, as well as a sensitivity analysis of model outputs to variation in feed library inputs. An evaluation of model outputs and sensitivity relative to animal data is provided in a companion paper (Van Amburgh et al., 2015).

MATERIALS AND METHODS

Feed Chemistry

The chemical components considered in our study were those routinely analyzed by commercial laboratories and required by the CNCPS for evaluation and formulation of nutrient adequacy and supply. These include DM, CP, soluble protein (**SP**), ammonia, acid detergent-insoluble CP (**ADICP**), neutral detergent-insoluble CP (**NDICP**), acetic acid, propionic acid, butyric acid, lactic acid, other organic acids, water-soluble carbohydrates (**WSC**), starch, ADF, NDF, lignin, ash, ether extract (**EE**), and soluble fiber. Amino acids were also reviewed and updated. A list of the expected analytical procedures for measuring each chemical component and the units required by the CNCPS v6.5 are described in Table 1. Fractionation of chemical components from Table 1 into the pool structure of the CNCPS are described by Tylutki et al. (2008) and summarized in Table 2.

Calculation Procedure

To complete the analysis, data sets were provided by 2 commercial laboratories (Cumberland Valley Analytical Services Inc., Maugansville, MD, and Dairy One Cooperative Inc., Ithaca, NY). The compiled data set included 90 different ingredients and >100,000 individual samples. Additional means and standard deviations (**SD**) of individual feeds were sourced from the laboratory websites. The online resource for both laboratories includes >10 yr of data and an extensive collection of different ingredients. Each feed was evaluated for internal consistency and consistency against laboratory data. Internal consistency required each feed to adhere to the fractionation scheme summarized in Table 2. Briefly, equation [1] (Table 2) provides the relationship between carbohydrates (**CHO**), CP, EE, and ash. Carbohydrates are characterized as NDF, acetic, propionic, butyric, isobutyric, lactic, and other organic acids, WSC, starch, and soluble fiber. From equations [1], [4], and [5] in Table 2, equation [16] can be derived for the jth feed in the library:

$$100 = \text{CP}_j + \text{EE}_j + \text{ash}_j + \text{NDF}_j + \text{acetic}_j + \text{propionic}_j + \text{isobutyric}_j + \text{lactic}_j + + \text{other organic acids}_j + \text{WSC}_j + \text{starch}_j + \text{soluble fiber}_j. \quad [16]$$

Soluble fiber (CB2) is calculated in the CNCPS by difference (equation [5]). This means any error in the estimation of the CA1 (volatile fatty acids), CA2 (lactic acid), CA3 (other organic acids), CA4 (WSC)], or CB1 (starch) fractions will result in an over- or underestimation of soluble fiber. Also, error in the estimation of CP, EE, ash, or NDF will cause error in soluble fiber through the calculation of CHO (equation [1]) and the subsequent calculation of NFC (equation [4]). Other components, such as alcohols, are also included in soluble fiber within the current structure of the model. Overestimation of components in equation [16] can cause a situation where soluble fiber is forced to 0 and the sum of the equation is greater than 100% DM, which, theoretically, is chemically impossible. Feeds that did not adhere to the assumptions of equation [16] were updated. This rule can be problematic when the N content of protein deviates from 16%, in which a factor of 6.25 was used to convert the amount of N to an equivalent weight of protein (Van Soest, 1994). The mass of all proteins in the CNCPS are calculated as N × 6.25 despite the proper factor varying according to feed type (Van Soest, 1994). Therefore, for feeds high in NPN (urea, ammonium salts), equation 16 was allowed to exceed 100% DM. This is a legacy issue with the CNCPS and other formulation systems and would require considerable recoding to an N basis to overcome. However, future versions of the model will address this problem. Likewise, NDF in the data sets provided were not ash-corrected as recommended in Table 1, as these data were not available at time the analysis was conducted. The distributions of corn silage ash and NDF are in Figure 1. Both distributions are skewed to the left, which in the case of NDF, indicates ash contamination (Mertens, 2002). Over-estimation of NDF through