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The Cornell Net Carbohydrate and Protein System: Updates to the model and evaluation of version 6.5

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ABSTRACT

New laboratory and animal sampling methods and data have been generated over the last 10 yr that had the potential to improve the predictions for energy, protein, and AA supply and requirements in the Cornell Net Carbohydrate and Protein System (CNCPS). The objectives of this study were to describe updates to the CNCPS and evaluate model performance against both literature and on-farm data. The changes to the feed library were significant and are reported in a separate manuscript. Degradation rates of protein and carbohydrate fractions were adjusted according to new fractionation schemes, and corresponding changes to equations used to calculate rumen outflows and postrumen digestion were presented. In response to the feed-library changes and an increased supply of essential AA because of updated contents of AA, a combined efficiency of use was adopted in place of separate calculations for maintenance and lactation to better represent the biology of the cow. Four different data sets were developed to evaluate Lys and Met requirements, rumen N balance, and milk yield predictions. In total 99 peer-reviewed studies with 389 treatments and 15 regional farms with 50 different diets were included. The broken-line model with plateau was used to identify the concentration of Lys and Met that maximizes milk protein yield and content. Results suggested concentrations of 7.00 and 2.60% of metabolizable protein (MP) for Lys and Met, respectively, for maximal protein yield and 6.77 and 2.85% of MP for Lys and Met, respectively, for maximal protein content. Updated AA concentrations were numerically higher for Lys and 11 to 18% higher for Met compared with CNCPS v6.0, and this is attributed to the increased content of Met and Lys in feeds that were previously incorrectly analyzed and described. The prediction of postruminal flows of N and milk yield were evaluated using the correlation coefficient from the BLUP (R^2_{BLUP}) procedure or model predictions (R^2_{MDP}) and the concordance correlation coefficient. The accuracy and precision of rumen-degradable N and undegradable N and bacterial N flows were improved with reduced bias. The CNCPS v6.5 predicted accurate and precise milk yield according to the first-limiting nutrient (MP or metabolizable energy) with a $R^2_{BLUP} = 0.97$, $R^2_{MDP} = 0.78$, and concordance correlation coefficient = 0.83. Furthermore, MP-allowable milk was predicted with greater precision than metabolizable energy–allowable milk ($R^2_{MDP} = 0.82$ and 0.76, respectively, for MP and metabolizable energy). Results suggest a significant improvement of the model, especially under conditions of MP limitation.
Key words: Cornell Net Carbohydrate and Protein System, update, evaluation, dairy cattle

INTRODUCTION

A description of the Cornell Net Carbohydrate and Protein System (**CNCPS**) was first published in 1992 and 1993 in a series of 4 papers (Fox et al., 1992; Russell et al., 1992; Sniffen et al., 1992; O'Connor et al., 1993). The principal objective of the CNCPS was to serve as a tool for both research development and feed formulation for cattle (Russell et al., 1992). To fulfill these goals, the CNCPS has been evolving by incorporation of new research data and descriptions of rumen function and metabolism into mathematical equations and quantitative representations with the primary objective of field application and diet formulation. As a consequence, several updated versions have been released over the last 15 yr (Fox et al., 2000, 2004; Tylutki et al., 2008).

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One of the objectives of the CNCPS modeling process has been to incorporate enhanced knowledge in the platform to further explain differences in cattle productivity compared with expectations and to account for more of the unexplained variation in the predictions of ME and MP supply and requirements. In many cases this includes incremental changes and error corrections, and in some situations, new feed definitions and characterizations or alterations in postdigestive efficiencies of use are required to improve the predictions of nutrient requirements.

Also, several implementations of the program are used by the industry to evaluate and formulate diets, and accordingly, any improvements in the predictions of supply and requirements can immediately translate into application and improved on-farm benefits. The latest CNCPS versions 6.0 and 6.1 (Tylutki et al., 2008, Van Amburgh et al., 2010) are used as a formulation and evaluation platform by AMTS.Cattle (Agricultural Modeling and Training Systems LLC, Cortland, NY), NDS (Ruminant Management and Nutrition, Reggio Emilia, Italy), DinaMilk (Fabermatica, Ostriano, Italy), and Dalex (Dalex Livestock Solutions, Los Angeles, CA).

Since the last publication (Tylutki et al., 2008) several updates and modifications have been incorporated into the model. The objective of this paper was to describe these updates and modifications and to present a general evaluation of model performance against both literature and on-farm data. One of the major updates, a reedited feed library with contemporary AA values, is described in a companion paper (Higgs et al., 2015), and the evaluation of the library updates are described herein.

The updates to the CNCPS described here represent changes that have been made to CNCPS v6.0 (Tylutki et al., 2008) resulting in CNCPS v6.5. Updates have been made to predictions of nutrient requirements and supply, which are discussed in the following sections, but also to the feed library, which is described in a companion paper (Higgs et al., 2015). One other additional change in the description of feed chemistry that affects nutrient supply, the application of unavailable NDF as determined by a 240-h in vitro digestibility, is described in Raffrenato (2011).

MATERIALS AND METHODS

Model Updates

Maintenance Requirements. Previous versions of the CNCPS made adjustments to the maintenance requirements of growing cattle based on changes in BCS. The adjustment was based on data from the INRA system for lactating beef cattle on pasture (Petit and Agabriel, 1989). The calculations made an association between previous levels of nutrient intake, BCS, and maintenance requirements by increasing or decreasing NE_M by 5%, above or below BCS 5 on a 1-to-9 scale (Fox et al., 2004). As cattle achieved greater BCS, theoretically, they consumed more energy and thus had larger organ mass, which resulted in more energy partitioned to maintenance and less to growth. Therefore, as BCS was increased, maintenance requirements also increased and vice versa. This adjustment was evaluated for growing Holstein heifers with known composition and energy balance using a fixed diet and varying the BCS from 1 to 5 on a dairy scale (adjusted from a 1–9 scale for beef as described in Fox et al., 2004) to evaluate the accuracy of the ME-allowable gain compared with measured data.

Adjustments have also been made to the calculation of surface area. Surface area is used within the CNCPS to adjust maintenance requirements for cold stress (Fox et al., 2004). The equation used to calculate surface area in the CNCPS, up to v6.0, was from Mitchell (1928). The equation from Mitchell ($0.09 \times BW^{0.67}$) was derived from sheep weighing from 14 to 38 kg. Brody (1945) developed an equation ($0.14 \times BW^{0.57}$) using Holstein cattle (n = 50) weighing from 41 to 617 kg, and this equation was evaluated by Berman (2003) using a thermal balance model. Compared with Brody's equation, the Mitchell equation underestimated surface area by 7 to 10% at 30 to 50 kg of BW and overestimated surface area by 18% at 650 kg of BW, affecting the calculations of evaporative heat loss (Berman, 2003). Therefore, the equation of Brody was adopted for the calculation of surface area in v6.5.

Feed Fractionation and Digestion Rates. The feed fractionation scheme used in v6.5 was maintained in the format described by Tylutki et al. (2008) with the exception of the soluble protein pool that contains previously defined as NPN, and now redefined as ammonia (Higgs et al., 2015). This change was made in recognition of the AA content of the NPN fraction (Krishnamoorthy et al., 1982) and the contribution of this fraction to postruminal N flows (Choi et al., 2002a; Reynal et al., 2007). Nomenclature changes were also made to the protein fractions, where all soluble fractions are now prefaced with the letter A and insoluble fractions with the letter B. A full description of these changes is given in Higgs et al. (2015). The outcomes of these changes are a better description of the rumen ammonia balance and also the MP supply, given that MP is being supplied by the soluble fractions of feeds, and before these updates this protein fraction contributed primarily to rumen ammonia because of improper characterization and passage rates.

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