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Sensitivity of two metabolic models of dairy cattle digestion and metabolism to changes in nutrient content of diets

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Abstract

To better understand how specific nutrients influence predicted outputs by two metabolic nutritional models (MOLLY and NRC) a sensitivity analysis was completed. This analysis examined the responses of the nutritional models when nutrient content of the diets was changed. Three diets were formulated and simulated in two nutritional models. These same diets were then simulated after 10 g/kg of diet DM then replacing it with the same mass of neutral detergent fibre, acid detergent fibre, starch, lignin, crude protein (CP), soluble CP, rumen undegradable protein, fat, or ash. Sensitivity estimates were calculated as the percent change in response variable from the diet with added nutrient compared to the original diet. Approximately 0.75 of the sensitivity estimates were less than 0.01 indicating that most changes to single nutrient concentrations did not have large impacts on simulated outputs. The incidence of large sensitivity estimates varied between models. Within the confines of this study, both models were more responsive to nutrient changes that altered protein content than to nutrient changes that altered energy content of the diet. Both models had nutrient inputs that had little or no impact on the outputs evaluated in this study. However, neither model was completely unresponsive to changes

Abbreviations: ADF, acid detergent fibre assayed using sodium suplhite and expressed inclusive of residual ash; CP, crude protein; DM, dry matter; ME, metabolizable energy; MP, metabolizable protein; NANMN, non-ammonia non-microbial N; aNDF, neutral detergent fibre assayed using amylase and sodium sulphite then expressed inclusive of residual ash; NDF, generic representation for all methods of analysis for neutral detergent fibre; NRC, National Research Council; RUP, rumen undegradable protein; VFA, volatile fatty acids

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in any nutrient; suggesting that accurate description of nutrient supply inputs for these models is important and should be considered when evaluating predictions from the models. By coupling the knowledge of how specific nutrient inputs influence model predictions with desired animal outcomes, nutritionists that use these models can better allocate their feed and economic resources and time.

Keywords: Dairy cow; Nutrient model; Sensitivity; Prediction

1. Introduction

Nutrient requirement models for dairy cattle are largely empirical in nature and based on observational descriptions from research studies. They also are generally linear in form and may not be accurate or precise in their predictions (Bateman et al., 2001a,b). To overcome some of these inadequacies, more mechanistic models based on biological mechanisms have been developed (Baldwin et al., 1977, 1987; France et al., 1982; Gill et al., 1989; Dijkstra et al., 1992). The nutrient inputs for these models are chemical entities that feed into various flux pathways within the animal following digestion. A criticism of these models is that some chemical entities that are not readily available for routine usage and therefore the mechanistic models are not easily adaptable for field use. To overcome this limitation, Hanigan et al. (2006) developed an interface that mapped nutrients used by the NRC (2001) to inputs needed by the model of Baldwin (MOLLY; Baldwin et al., 1977, 1987). Under normal usage, this translation leaves many variables unresolved and reliant upon default libraries for initial values. Analytical determination of many of these variables can be costly which further limits the use of these models for field application. A better understanding of the relative impacts of different nutrients on model outputs will allow end users to better partition their resources when determining which nutrients to analyze or manipulate in the ration.

Parameterization of equations in models is largely based on regression techniques of empirically collected data. These data are assumed to have been collected without bias or measurement error which is a false assumption required due to limitations in parameter estimation techniques (Firkins et al., 1998). Alternatively, model parameters may be estimated using library values for feed composition (Bateman et al., 2005). This technique also introduces potential error by not accounting for variation in feed composition when calculating nutrient inputs. The technique of using library defaults for nutrient contents of feedstuffs is generally employed when evaluating models (Kohn et al., 1998; Hristov et al., 2004); although it is impossible to completely separate errors in the structure of the models from errors in their default libraries (Greenwood et al., 1999; Schwab et al., 2003).

There is interest in understanding and accounting for variation in feedstuff composition when formulating diets to be fed to lactating dairy cows (Kertz, 1998). However, the impact of this variation on predictions of nutrient models is largely unknown and may be unquantifiable. By better understanding the relative impacts of nutrient variations on model predictions, users will be better able to allocate resources and time when choosing those nutrients to manipulate through diet changes.

Our objectives were to complete a sensitivity analysis for MOLLY (Baldwin et al., 1977, 1987) while using the nutrient input map described by Hanigan et al. (2006) in order to