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A method to estimate cow potential and subsequent responses to energy and protein supply according to stage of lactation

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ABSTRACT

Milk responses to dietary change are influenced by the relative production level, that is, the distance between observed production and potential production. The closer the animal is to its potential, the smaller the expected response is to extra nutrients. Therefore, the aim of this work was to provide a method to quantify cow potential, to estimate subsequent responses to changes in nutrient supply. The observed efficiencies in net energy for lactation (NE_L) and metabolizable protein (MP) are proposed as a basis to estimate the relative production level of the animal. The rationale for using NE_L and MP efficiency (ratios of milk energy yield/NE_L above maintenance supply and milk protein yield/MP above maintenance supply) builds on the uniformity of the observed relationships between size of the milk responses and extra NE_L supply and MP supply, when centered on a given efficiency. From there, a pivot nutritional situation where MP and NE_L efficiency are 0.67 and 1.00, respectively, was defined, from which milk responses could be derived across animals varying in production potential. An implicit assumption of using response equations centered on reference efficiency pivots is that the size of the response to a fixed change in nutrient supply, relative to the pivot, is identical for animals with different production capacities. The proposed approach was evaluated with 2 independent data sets, where different dietary treatments were applied during the whole lactation. In these data sets, MP and NE_L above maintenance supply were calculated weekly using the recently updated INRA Systali feed units system. Differences in NE_L and MP supply above maintenance between the extreme dietary treatments were large, on average 667 g of MP/d and 13 MJ of NE_L/d (3.11 Mcal/d) in the first data set, and 513 g of MP/d and 29 MJ of NE_L/d (6.93 Mcal/d) for the second data set. Milk energy yield and milk component yields were predicted with root mean square prediction errors between 7.6 and 13.5% and concordance correlation coefficients between 0.784 and 0.934, respectively. Assessed by the Akaike's information criterion, significant differences existed in the accuracy of prediction for milk energy yield and milk component yields between stages of lactation. However, the effects of stage of lactation were not consistent between data sets and, for most of the predicted variables, relatively small. We concluded that the pivot concept can be used to predict milk energy yield and milk component yields responses to dietary change with a good accuracy for diets that are substantially different and across all stages of lactation.
Key words: energy, protein, response, potential, milk composition

INTRODUCTION

In the context of an increasing demand for feed efficiency, the importance of accurately predicting animal responses to dietary changes is growing. In dairy cows, several quantitative reviews of the literature (Huhtanen and Nousiainen, 2012; Jensen et al., 2015; Daniel et al., 2016) or specific experiments (Brun-Lafleur et al., 2010) have generated equations that aim to predict milk yield or milk composition response to a dietary change. However, the accurate application of these equations on the farm requires an estimation of the production potential of the cows in question. For example, on a farm where the observed production is 30 kg/d and the maximum production potential is also 30 kg/d, one expects zero response to an increase in feed quality. However, on a farm where the observed production is 30 kg/d but the maximum production potential is 50 kg/d one clearly expects a positive response to supplementation. Thus, a need exists to estimate the relative production level, that is, how far the animal is from its potential. Although the concept of potential appears useful, this notion is partly theoretical and often refers,

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as stated above, to the maximum production achievable in a nonlimiting environment (Neal and Thornley, 1983; Vetharaniam et al., 2003). In the context of predicting responses, a more useful definition would be the maximum production that can be achieved by a given animal in a standardized nutritional status. For the prediction of such a potential, herd-test day models, which include fixed effects (farm, gestation, length of dry-period, calving month, and so on) and random effects (genetic and permanent environment), represent a valuable approach (Leclerc, 2008). However, such models assume that the differences in nutritional environment are adequately captured by the fixed effect of farm, and for prediction purposes require information from the previous lactation. The objective of this work was to propose an alternative approach to determine the relative production level of the dairy cow and derive subsequent expected milk responses to changes in MP and NE_L supply that could be easily applied on-farm. The MP and NE_L efficiencies were proposed as status indicators to determine the relative production level, distance between the observed production, and the potential production; the rationale and quantitative basis for this choice are presented in the paper. The second objective of this work was to evaluate the method for predicting milk yield and milk component yields responses to changes in MP and NE_L supply using 2 independent data sets.

MATERIALS AND METHODS

Relationship Between Size of Milk Responses and MP and NE_L Efficiencies

Milk responses to nutrient supply are usually modeled by quadratic or exponential equations. This reflects the widely established principle of diminishing returns (Brody, 1945). At the metabolic level, once nonproductive MP requirements and NE_L maintenance requirement are discounted (see Sauvant et al., 2015a,b and Appendix 1 for details of calculations used in this study), the principle of diminishing returns to increasing MP and NE_L supply is mostly explained by a change in partitioning. This is induced by a limitation of the mammary gland synthesis capacity. As NE_L above maintenance increases, energy partitioning progressively shifts from milk to body lipid. Similarly, with increasing MP supply above maintenance, nitrogen partitioning progressively shifts from milk protein to urinary nitrogen. These effects were observed using milk protein and energy yield equations developed by meta-analysis (Figure 1; Daniel et al., 2016). In the illustrated example, the marginal MP efficiency or partitioning (i.e., the slopes of the curves in Figure 1a) decreases from 0.38 to 0.19 when MP supply increases from 993 to 1,493 g/d. A further increase from 1,493 to 1,893 g/d results to a decrease in marginal MP efficiency from 0.19 to 0.04. The consequence of this partitioning is that the overall global MP efficiency (**MPeff** = milk protein yield/MP supply above maintenance) decreases from 0.86 to 0.67 (when MP supply above maintenance increases from 993 to 1,493 g/d) and from 0.67 to 0.55 (when MP supply above maintenance increases from 1,493 to 1,893 g/d). With respect to energy (Figure 1b), a similar relationship was found between marginal NE_L efficiency in milk and the global NE_L efficiency (**NE_Leff** = milk energy/NE_L supply above maintenance). When NE_L supply increases from 65 to 95 MJ/d (15.54 to 22.71 Mcal/d) and from 95 to 125 MJ/d (22.71 to 29.88 Mcal/d), the marginal NE_L efficiency decreases from 0.27 to 0.17 and from 0.17 to 0.06, respectively, and global NE_Leff decreases from 1.36 to 1.00 and from 1.00 to 0.79, respectively. With these positive relationships observed between global and marginal efficiencies, we hypothesized that MP and NE_L efficiencies could provide a mean to estimate the relative production level of the animal (i.e., how far the animal is from potential), and thereby provide the basis for predicting response to dietary changes in MP and NE_L. It should be noted that the potential here does not refer to genetic potential, in the sense of maximum production achieved in a truly nonlimiting environment; instead, it refers to cow performance on a standardized nutritional situation within its given environment. Therefore, this notion of potential includes current and past environmental effects on the cow production capacity.

Estimation of Pivots from Which to Predict Milk Responses

Using data collected from a large number of experiments [see Daniel et al. (2016) for the full list of references], Figure 2 shows the relationships between milk protein yield and MP supply above maintenance (panel a) and between milk energy and NE_L supply above maintenance (panel b). On Figure 2, the dashed lines represent the global efficiencies MPeff = 0.67 (panel a) and NE_Leff = 1 (panel b). These efficiency lines intersect most of the curves within the range of data (i.e., from low- to high-producing animals); therefore, it was decided to use the fixed efficiency values as a reference point, or pivot, that is relevant across the whole range of production levels. In predicting responses, the reference efficiency line can be seen as being a rail along which the response curve would move up or down according to animal potential. This principle, already