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Accounting for Energy and Protein Reserve Changes in Predicting Diet-Allowable Milk Production in Cattle

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ABSTRACT

Current ration formulation systems used to formulate diets on farms and to evaluate experimental data estimate metabolizable energy (ME)-allowable and metabolizable protein (MP)-allowable milk production from the intake above animal requirements for maintenance, pregnancy, and growth. The changes in body reserves, measured via the body condition score (BCS), are not accounted for in predicting ME and MP balances. This paper presents 2 empirical models developed to adjust predicted diet-allowable milk production based on changes in BCS. Empirical reserves model 1 was based on the reserves model described by the 2001 National Research Council (NRC) Nutrient Requirements of Dairy Cattle, whereas empirical reserves model 2 was developed based on published data of body weight and composition changes in lactating dairy cows. A database containing 134 individually fed lactating dairy cows from 3 trials was used to evaluate these adjustments in milk prediction based on predicted first-limiting ME or MP by the 2001 Dairy NRC and Cornell Net Carbohydrate and Protein System models. The analysis of first-limiting ME or MP milk production without adjustments for BCS changes indicated that the predictions of both models were consistent (r^2 of the regression between observed and model-predicted values of 0.90 and 0.85), had mean biases different from zero (12.3 and 5.34%), and had moderate but different roots of mean square errors of prediction (5.42 and 4.77 kg/d) for the 2001 NRC model and the Cornell Net Carbohydrate and Protein System model, respectively. The adjustment of first-limiting ME- or MP-allowable milk to BCS changes improved the precision and accuracy of both models. We further investigated 2 methods of adjustment; the first method used only the first and last BCS values, whereas the second method used the mean of weekly BCS values to adjust ME- and MP-allowable milk production. The adjustment to BCS changes based on first and last BCS values was more accurate than the adjustment to BCS based on the mean of all BCS values, suggesting that adjusting milk production for mean weekly variations in BCS added more variability to model-predicted milk production. We concluded that both models adequately predicted the first-limiting ME- or MP-allowable milk after adjusting for changes in BCS.
Key words: body condition score, fat mobilization, fat repletion, modeling

INTRODUCTION

Computer programs based on the NRC (2001) model formulate rations for lactating dairy cows by computing energy and protein requirements for an inputted milk production and then formulate a diet that will meet requirements for that amount of milk at the DMI predicted from BW and milk. Rations in early lactation are typically deficient in energy and assume the deficiency will be met by mobilization of body reserves. Then in mid- and late lactation, energy intake must exceed requirements for milk production to replenish body reserves before the next lactation. With current and proposed environmental regulations, precision feeding is needed to more accurately formulate diets to avoid under- or overfeeding nutrients (Cerosaletti et al., 2004) while optimizing milk and reproductive performance. Dairy nutrition models are being designed with these objectives (Tylutki and Fox, 2005). Precision ration formulation for dairy cows requires accounting for fluxes in body reserves when formulating diets. In addition, dairy nutrition models with the capability of accounting for body reserves can be used to more accurately evaluate experimental results in which milk response to dietary inputs is the variable of interest. Baldwin et al. (1987b,c) developed a mechanistic model of metabolism and digestion for lactating dairy cows and concluded that models can realistically simulate lactation and the partition of nutrients (Baldwin et al., 1987a).

Body weight changes reflect the use of energy reserves either to supplement ration deficiencies during

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early lactation or to store energy consumed above the requirements (Moe et al., 1972; NRC, 2001). The BW gain and loss after maturity is similar in composition to changes during growth (NRC, 2001) and can be used to predict changes in energy balance over the reproductive cycle (Reynoso-Campos et al., 2004). However, most dairy and beef producers monitor BCS changes in cows to manage energy reserves because frequent measurements of BW are not feasible under practical conditions. The Cornell Net Carbohydrate and Protein System (**CNCPS**; Fox et al., 2004) and the NRC (2000, 2001) models use the body reserves model as devised by Fox et al. (1999), which was developed from data on the chemical body composition and BCS of 106 mature beef cows of diverse breed types and BW. As applied to dairy cattle, the model was evaluated with the data of Otto et al. (1991) and accounted for 95% of the variation in body fat, with only a –1.6% bias (Fox et al., 1999). The model predicted 80 kg of BW change per BCS compared with 84.6 kg observed in Holstein cows slaughtered over the range of dairy BCS.

For lactating dairy cows, the CNCPS and NRC models estimate energy and protein requirements for maintenance and pregnancy, and the amount remaining above intake is used to estimate ME- and MP-allowable milk production, respectively (Fox et al., 2004). The changes in BCS are not accounted for in predicting ME and MP balances. The objective of this study was to develop and compare 2 empirical models to eliminate biases in energy retention by adjusting the predicted ME- and MP-allowable milk production after consecutive changes in observed BCS have been accounted for.

MATERIALS AND METHODS

Model Development

Two empirical models were developed to estimate milk production based on changes in BCS. Empirical reserves model 1 (**ERM1**) was based on the reserves model described by the NRC (2001), whereas empirical reserves model 2 (**ERM2**) was developed based on literature data on BW changes in lactating dairy cows.

Milk Energy and Body Content of Energy and Protein. For both empirical models, the energy contained in milk production is computed using milk fat and milk true protein contents, as described by the NRC (2001). This energy in milk (**MkE**), as shown in Equation [1], is assumed to be the NE_L:

$$MkE_i = 0.0929 \times MkF_i + 0.0563 \times MkTP_i + 0.192 \quad [1]$$

where MkE_i is the energy content of milk (Mcal/kg), MkF_i is the milk fat content (g/100 g), $MkTP_i$ is the milk true protein content (g/100 g), and the subscript i is the ith time period.

The BCS is a 5- (Wildman et al., 1982) or 9-point (Cantrell et al., 1981; Herd and Sprott, 1986) scale system that is highly related to body fat in cows (Houghton et al., 1990; Buskirk et al., 1992; NRC, 2000, 2001). Other scale systems that are used around the world (CSIRO, 1990) can be interconverted. Because the body reserves model used by the NRC (2001) is based on that developed by the NRC (2000), a BCS scale of 1 to 9 is used. Equation [2] is used to convert a BCS scale of 1 to 8 (**$BCS_{[1-8]}$**), as used by the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 1990), to a BCS scale of 1 to 5 (**$BCS_{[1-5]}$**) and Equation [3] converts $BCS_{[1-5]}$ to a BCS scale of 1 to 9 (**$BCS_{[1-9]}$**), and vice versa. As adopted by the NRC (2000, 2001), shrunk BW (**SBW**) is computed from BW as shown in Equation [4] and empty BW (**EBW**) is estimated from SBW as shown in Equation [5], which is used to predict body reserves:

$$BCS_{[1-5],i} = \frac{(BCS_{[1-8],i} - 1) \times 4}{7} + 1 \quad [2]$$

$$BCS_{[1-9],i} = (BCS_{[1-5],i} - 1) \times 2 + 1 \quad [3]$$

where $BCS_{[1-5],i}$ is the BCS on a scale of 1 to 5, $BCS_{[1-8],i}$ is the BCS on a scale of 1 to 8, and $BCS_{[1-9],i}$ is the BCS on a scale of 1 to 9,

$$SBW_i = BW_i \times 0.96 \quad [4]$$

$$EBW_i = SBW_i \times 0.851 \quad [5]$$

where SBW_i is shrunk BW (kg) and EBW_i is empty BW (kg).

Empirical Reserves Model 1. This model is based on the equations published by Fox et al. (1999) in which $BCS_{[1-9]}$ and EBW are used to compute the amount of body fat (**TF**; Equation [6]) and protein (**TP**; Equation [7]):

$$TF_i = (0.037683 \times BCS_{[1-9],i}) \times EBW_i \quad [6]$$

$$TP_i = (0.200886 - 0.0066762 \times BCS_{[1-9],i}) \times EBW_i \quad [7]$$

where EBW_i is empty BW (kg), TF_i is the amount of body fat (kg), $BCS_{[1-9],i}$ is the BCS (on a scale of 1 to 9), and TP_i is the amount of body protein (kg).

For mature lactating cows, a change in BW does not necessarily indicate changes in tissue reserves, and vice versa. Andrew et al. (1994) and Gibb et al. (1992) ana-