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# Evaluation of Net Energy Expenditures of Dairy Cows According to Body Weight Changes over a Full Lactation

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## ABSTRACT

Equations that predict daily dry matter intake (DMI) of a lactating cow could be evaluated by comparing the predicted accumulation of energy in body weight (BW) over the course of lactation with the observed BW evolution. However, to do so requires that first the energy balance calculations from observed DMI are evaluated. The purpose of the work reported here was to determine the degree of deviation of predicted from observed BW, according to net energy for lactation ($NE_L$) balance calculated from weekly observations of DMI, BW, and fat-corrected milk production in 21 sets of full-lactation data, and to determine an appropriate correction of the $NE_L$ bias for subsequent DMI prediction evaluations. When the National Research Council maintenance equation $0.08 \times BW(kg)^{0.75}$ was used in energy balance calculation, BW was overpredicted with an increasing difference between the cumulative predicted BW and observed BW as lactation progressed. Placing all the error of BW prediction into maintenance energy expenditures resulted in a best-fit equation of 0.096 ± 0.003 Mcal/kg of $BW^{0.75}$. A time-dependent equation was also developed, in which weekly maintenance expenditures were determined as the $NE_L$ expenditure to yield a zero $NE_L$ balance and could be described by a second-order polynomial equation related to week of lactation (WOL) where maintenance $NE_L = [-0.0227(\pm 0.0098) \times WOL^2 + 1.352(\pm 0.456) \times WOL + 78.09(\pm 4.92)$ Mcal/kg of $BW^{0.75}] \times 10^{-3}$. Average maintenance energy expenditure at the onset of lactation was approximately 0.08 Mcal/kg of $BW^{0.75}$, and this value increased to a plateau at wk 15 of lactation of approximately 0.098 Mcal/kg of $BW^{0.75}$. Standard deviations between data sets of weekly maintenance parameter estimates throughout lactation were large but consistent at approximately 25% of the mean. Revision of the maintenance energy expenditure estimate substantially improved BW prediction by the energy balance model. On average, the 0.096 Mcal of $NE_L$/kg of $BW^{0.75}$ equation resulted in the best BW predictions, although substantial variation existed around this value.
**Key words:** maintenance energy expenditure, energy balance, dairy cow

## INTRODUCTION

With the advent of the dynamic computer model to describe biological systems, there has arisen the potential to predict the response of an animal over time to various interventions. In models of lactation, instantaneous milk production rates by dairy cows are typically calculated from rates of nutrient flow from the diet. In turn, DMI prediction equations typically require daily milk production and BW as inputs. Such equations carry an implicit description of energy balance between intake and use. In a static prediction at one point in time, there is little penalty to being off by a small fraction from the true energy balance. In a dynamic model, however, in which any imbalance between predicted intake and use of energy accumulates in body stores, a small deviation could rapidly escalate errors in BW prediction over simulated time.

In the process of developing approaches to predict daily DMI in a dynamic simulation of dairy cow performance, it is important to first evaluate and correct, if necessary, the energy accumulation in body stores implied from observed DMI and milk production rates. McNamara and Baldwin (2000) found, using a model of the metabolic transactions in the lactating cow (Baldwin, 1995), that in response to dietary changes, body fat accumulation was either over- or underpredicted in simulations of more than a few weeks. They concluded that the model's precision in predicting long-term dynamic changes in energy-utilizing reactions was inadequate. Heuer et al. (2001) also observed, in a model designed to predict herd mean $NE_L$ energy balance for the first 12 wk of lactation (**WOL**), that the predicted $NE_L$ balance was generally higher than calculated $NE_L$ balance in all weeks of lactation. However, at the individual cow level, they observed that the standard deviation was often larger than the mean difference.

A companion paper (Ellis et al., 2006) describes the performance of selected DMI prediction equations in a

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**Table 1.** Summary of evaluation data sets

| Data set | Source | Treatment | Parity | WOL[1] | n[2] |
|---|---|---|---|---|---|
| 1 | Mohrenweiser and Donker, 1967 | Diet 1 - Early alfalfa pre, early alfalfa postcalving | 1 | 2 to 39 | 9 |
| 2 | Mohrenweiser and Donker, 1967 | Diet 2 - Early alfalfa pre, late alfalfa postcalving | 1 | 2 to 39 | 10 |
| 3 | Mohrenweiser and Donker, 1967 | Diet 3 - Late alfalfa pre, early alfalfa postcalving | 1 | 2 to 40 | 10 |
| 4 | Mohrenweiser and Donker, 1967 | Diet 4 - Late alfalfa pre, late alfalfa postcalving | 1 | 2 to 40 | 10 |
| 5 | Wohlt and Clark, 1978 | Diet 1 - no supplemental nitrogen | Mostly >1 | 1 to 42 | 10 |
| 6 | Wohlt and Clark, 1978 | Diet 2 - urea | Mostly >1 | 1 to 42 | 10 |
| 7 | Wohlt and Clark, 1978 | Diet 3 - soybean meal | Mostly >1 | 1 to 42 | 10 |
| 8 | Wohlt and Clark, 1978 | Diet 4 - urea and soybean meal | Mostly >1 | 1 to 42 | 10 |
| 9 | Wohlt and Clark, 1978 | Diet 5 - soybean meal (2× inclusion level) | Mostly >1 | 1 to 42 | 10 |
| 10 | DePeters et al., 1985 | 2× milking, H to M diet at 28 kg/d, M to L diet at 23 kg/d[3] | >1 | 1 to 42 | 12 |
| 11 | DePeters et al., 1985 | 2× milking, H to M diet at 25 kg/d, M to L diet at 20 kg/d[3] | 1 | 1 to 42 | 7 |
| 12 | DePeters et al., 1985 | 3× milking, H to M diet at 25 kg/d, M to L diet at 20 kg/d[3] | 1 | 1 to 42 | 8 |
| 13 | DePeters et al., 1985 | 3× milking, H to M diet at 28 kg/d, M to L diet at 23 kg/d[3] | >1 | 1 to 42 | 13 |
| 14 | Holter and Hayes, 1992 | CP balanced using 1 grain | 1 | 2 to 45 | 14 |
| 15 | Holter and Hayes, 1992 | CP balanced using 2 grains | 1 | 2 to 45 | 14 |
| 16 | Holter and Hayes, 1992 | CP balanced using 1 grain | >1 | 2 to 45 | 22 |
| 17 | Holter and Hayes, 1992 | CP balanced using 2 grains | >1 | 2 to 45 | 22 |
| 18 | Holter et al., 1993 | No RUP protein-fat supplement | 1 | 2 to 37 | 10 |
| 19 | Holter et al., 1993 | RUP protein-fat supplement | 1 | 2 to 37 | 10 |
| 20 | Holter et al., 1993 | No RUP protein-fat supplement | >1 | 2 to 37 | 13 |
| 21 | Holter et al., 1993 | RUP protein-fat supplement | >1 | 2 to 37 | 13 |

[1]WOL = Week of lactation; period of time for which data set reported DMI, FCM, and BW.

[2]Number of animals used in treatment groups.

[3]Dietary treatment change; H = high energy, M = medium energy, and L = low energy diets, based on daily milk production for each cow.

dynamic model of energy flows in the lactating dairy cow. The test variable used to compare model predictions with observations, and thereby evaluate the DMI prediction equations, is the integrated instantaneous $NE_L$ balance, expressed as weekly BW throughout lactation. Published data on DMI, BW, and milk production over a full lactation were collected for this goal. To use a predicted $NE_L$ balance as the test variable, it was necessary to first evaluate $NE_L$ balances obtained from the observations alone. The purpose of the work reported here was to determine the degree of deviation of predicted from observed BW according to $NE_L$ balance calculated from observations in the collated data sets and to determine an appropriate correction of the bias for subsequent DMI prediction evaluations (Ellis et al., 2006). The bias was placed in maintenance expenditures so that a time-independent, as well as a time-dependent, equation relating maintenance expenditures to WOL could be developed.

## MATERIALS AND METHODS

### Data Sets

The database used to evaluate predicted BW and determine a new description of maintenance energy expenditures consisted of 777 data points from 21 sets of lactation performance data averaged from groups of 7 to 22 Holstein cows (Table 1). Information about the data sets is summarized in Table 1. Criteria for data set selection were that weekly BW, DMI, and 4% FCM production for at least 37 WOL were reported and that information was given on parity and diet. Data plots from the publications were scanned into Adobe Photoshop Elements (Adobe Systems, Inc., San Jose, CA), a grid was snapped over the image, and lined up with the x- and y-axes to an appropriate scale. Data points were extracted and recorded to 1 or 2 decimal places for each WOL.

### Energy Balance Model

Energy balance at each WOL was calculated from daily $NE_L$ flows in Mcal/d as:

$$NE_L \text{ Balance} = NE_L \text{ Intake} - NE_L \text{ for Milk Production} - NE_L \text{ for Maintenance} \quad [1]$$

The $NE_L$ equivalents of body mass, according to NRC (1988), were assumed so that BW change ($\Delta BW_i$) in kilograms per day was 0.203 times $NE_L$ balance (Mcal/d; equation 1) if the $NE_L$ balance was negative and 0.195 times $NE_L$ balance if positive. The older NRC (1988) factors were used because information on BCS, required for calculating the newer NRC (2001) factors, was not available from the data sets. Assuming a BCS of 3.5, BW change would be 0.196 and 0.171 times $NE_L$ balance for negative and positive balances, respectively, according to NRC (2001). Analysis showed that the