J. Dairy Sci. 98:1–11
http://dx.doi.org/10.3168/jds.2015-9541

Modeling of daily body weights and body weight changes of Nordic Red cows

P. Mäntysaari*[1] and E. A. Mäntysaari†
*Milk Production, and
†Biometrical Genetics, Green Technology, Natural Resources Institute Finland (Luke), FIN-31600 Jokioinen, Finland

ABSTRACT

Increased availability of automated weighing systems have made it possible to record massive amounts of body weight (BW) data in a short time. If the BW measurement is unbiased, the changes in BW reflect the energy status of the cow and can be used for management or breeding purposes. The usefulness of the BW data depends on the reliability of the measures. The noise in BW measurements can be smoothed by fitting a parametric or time series model into the BW measurements. This study examined the accuracy of different models to predict BW of the cows based on daily BW measurements and investigated the usefulness of modeling in increasing the value of BW measurements as management and breeding tools. Data included daily BW measurements, production, and intake from 230 Nordic Red dairy cows. The BW of the cows was recorded twice a day on their return from milking. In total, the data included 50,594 daily observations with 98,418 BW measurements. A clear diurnal change was present in the BW of the cows even if they had feed available 24 h. The daily average BW were used in the modeling. Five different models were tested: (1) a cow-wise fixed second-order polynomial regression model (FiX) including the exponential Wilmink term, (2) a random regression model with fixed and random animal lactation stage functions (MiX), (3) MiX with 13 periods of weighing added (PER), (4) natural cubic smoothing splines with 8 equally spaced knots (SPk8), and (5) spline model with no restriction on knots but a smoothing parameter corresponding to a fit of 5 degrees of freedom (SPdf5). In the original measured BW data, the within-animal variation was 6.4% of the total variance. Modeling decreased the within animal variation to levels of 2.9 to 5.1%. The smallest day-to-day variation and thereafter highest day-to-day repeatabilities were with PER and MiX models. The usability of modeled BW as energy balance (EB) indicator were evaluated by estimating relationships between EB, or EB indicators, and modeled BW change. In all cases the modeling increased the correlation and thus the reliability of the BW measurements. From all of the tested models, the best predictive value was attained by the random regression model with fixed and random animal lactation stage functions. Based on results, modeling of BW significantly increases the usefulness of BW as an EB predictor and management indicator.
Key words: body weight, function smoothing, modeling, dairy cow

INTRODUCTION

The BW of the cow changes depending on the stage of lactation (Koenen et al., 1999). In the beginning of lactation insufficient feed intake and the genetic drive for high milk production leads to mobilization of energy from body reserves (Mäntysaari et al., 2010, 2012). This leads to a decrease in BW. Later in lactation, with increased feed intake and decreased milk yield, the lost body reserves are gained back, leading to an increase in BW.

Even though a reasonable period of negative energy balance (**EB**) at the beginning of lactation is acceptable for today's high-producing cows, deep and long-lasting negative EB can cause health and reproduction problems (de Vries et al., 1999; Collard et al., 2000). One way to cope with the development of metabolic stress and health problems related to prolonged negative EB is to consider postpartum EB in a selection goal in the breeding program. This requires measurements of EB from large population of animals. Calculation of EB based on energy input and output ($\mathbf{EB_{inout}}$ = energy intake − energy required for milk and maintenance) requires knowledge of milk production and composition, feed DMI, BW, and the energy density of the diet. At the farm level, these measurements are difficult to measure. Further, in calculation of EB_{inout}, considerable error can accumulate because of use of standard estimates for energy requirements (DiCostanzo et al., 1990; Chwalibog, 1991).

If the BW could be measured accurately, the change in BW should reflect the energy status of the cow and

Received March 6, 2015.
Accepted June 18, 2015.
[1]Corresponding author: paivi.mantysaari@luke.fi

therefore the change in BW could be used as an EB indicator. For example, in the study of Coffey et al. (2001) and Friggens et al. (2007) the EB was calculated based on the changes in BW and BCS by converting the BW changes into weights of body lipid and protein. In the study of Mäntysaari and Mäntysaari (2010), a multiple linear regression model including BW and BW change was used to predict EB on the first test day. The goodness of EB prediction based on changes in BW depends on the correctness of the BW measurement. The correctness of the BW and daily BW change measures are also important when the feed efficiency of cows are presented as residual feed energy intake (**REI**) because the REI is estimated by modeling the total energy intake by energy in milk production, energy needed to maintain BW, and energy needed or released in BW change. In the study of Mäntysaari et al. (2012), a clear effect of stage of lactation was found on REI. It was suggested that this was partly caused by inaccuracy in BW change measures in the beginning of lactation.

The individual BW measurements of the cow are affected by the udder, gut, and bladder fill. The variation in BW due to milk volume can be minimized by weighing the cows after the milking. If the BW is measured by the same time of the day and the daily feeding procedure is constant, no big difference in the gut fill would be expected. However, changes, for example in forage batch or weather as well as estrus, can influence the intake of the cow, resulting in changes in gut fill (West, 2003; Huhtanen et al., 2007). This normally occurring variation in after milking BW of cows with steady body tissue weight is hereafter called random measurement noise. Also, fault or miscalibration of the scale can cause incorrect BW measurements in automatic weighing systems. With daily weighing, one incorrect measurement causes error in 2 consecutive BW change measures. Therefore, it is important to detect and reduce noise in the measurements.

To use BW change as an indicator of EB and in calculation of REI requires frequent BW measurements. The increased popularity of automated weighing systems in commercial farms has made it possible to use BW measurements to estimate energy status but also for other management and diagnostic purposes (Maltz, 1997; van Straten et al., 2009; Frigo et al., 2010; Alawneh et al., 2012). In the study of Frigo et al. (2010), the data from 2 experimental herds showed that selection for reduced BW loss decreased disease incidence in the early stage of lactation. In van Straten et al. (2009), a calculated relative BW loss from daily BW measurements was proposed as a predictor for impaired reproduction performance. Alawneh et al. (2012) presented methods how daily BW monitoring might be used as a tool for early detection of lameness in dairy cattle. Maltz (1997) noticed that approximately 50% of health problems were identified by BW changes up to 3 d before the milk yield drop that set off the health alarm.

One way to handle and minimize the effects of systematic error and random noise in BW measurements is to fit a parametric or time series model into the BW measurements and thereafter use the predicted BW in calculations. The accuracy of the prediction model is important; a poorly fitting model can even increase the bias. The objectives of this study were to examine the accuracy of different models in predicting BW of the cows based on daily BW measurements and to investigate the usefulness of modeling in increasing the value of BW measurements as management and breeding tools.

MATERIALS AND METHODS

Animals and Feeding

Data were collected during years 2003 to 2004 and 2009 to 2013. The data included 230 Nordic Red dairy cows from the Luke (former MTT Agrifood Research Finland) Minkiö dairy cattle research herd. Of the cows, 177 were primiparous multiple ovulation and embryo transfer nucleus herd test cows and the remaining 53 were multiparous cows. All available daily observations between lactation d 2 to 305 from these cows were included in the data. From the years 2003 to 2004 only the measurements during the indoor feeding period were used, but from years 2009 to 2013 the BW data were included from the pasture season also. In total, the data included 50,594 daily observations with 98,418 individual BW measurements.

All cows were housed in a freestall barn. Cows were milked twice a day (0630 and 1600 h) in a 2 × 6 autotandem milking parlor. The cows had ad libitum feeding. During the years 2003 to 2004 cows were fed a TMR containing grass silage and commercial concentrate mix (45–57% of DM). Feeding of the cows during years 2003 to 2004 is described in detail in Khalili et al. (2006) and Mäntysaari et al. (2006). During the indoor period from 2009 to 2013 all cows were fed grass silage and home blend concentrate mix. The concentrate was given from concentrate feeding stations. The proportion of concentrates in the diet depended on the stage of lactation and the digestibility of the grass silage. When the concentration of digestible organic matter in DM of silage was between 680 to 700 g/kg of DM, the concentrates were offered so that the proportion of concentrate in the diet DM became 52% during lactation d 1 to 150, 47% during d 151 to 250, and 37% thereafter.