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Analysis of water intake and dry matter intake using different lactation curve models

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ABSTRACT

The objective was to evaluate 6 different lactation curve models for daily water and dry matter intake. Data originated from the Futterkamp dairy research farm of the Chamber of Agriculture of Schleswig-Holstein in Germany. A data set of about 23,000 observations from 193 Holstein cows was used. Average daily water and dry matter intake were 82.3 and 19.8 kg, respectively. The basic linear mixed model included the fixed effects of parity and test-day within feeding group. Additionally, 6 different functions were tested for the fixed effect of lactation curve and the individual (random) effect of cow-lactation curve. Furthermore, the autocorrelation between repeated measures was modeled with the spatial (power) covariance structure. Model fit was evaluated by the likelihood ratio test, Akaike's and Bayesian information criteria, and the analysis of mean residual at different days in milk. The Ali and Schaeffer function was best suited for modeling the fixed lactation curve for both traits. A Legendre polynomial of order 4 delivered the best model fit for the random effect of cow-lactation. Applying the error covariance structure led to a significantly better model fit and indicated that repeated measures were autocorrelated. Generally, the best information criteria values were yielded by the most complex model using the Ali and Schaeffer function and Legendre polynomial of order 4 to model the average lactation and cow-specific lactation curves, respectively, with inclusion of the spatial (power) error covariance structure. This model is recommended for the analysis of water and dry matter intake including missing observations to obtain estimation of correct statistical inference and valid variance components.
Key words: dairy cow, lactation curve, water intake, dry matter intake

INTRODUCTION

Water and feed intake are measured automatically and completely in many test stations or dairy research farms, (e.g., Coffey et al., 2002; Kramer et al., 2008a; Hüttmann et al., 2009). In the future, water and feed intake will become more important for dairy management because of their effect on cow health (González et al., 2008; Lukas et al., 2008) as well as for dairy breeding because of their relationship with cow's energy status and the corresponding liability to diseases in the first part of lactation (Veerkamp and Thompson, 1999; Coffey et al., 2002; Hüttmann et al., 2009). Furthermore, the inclusion of feed intake in future breeding programs is becoming conceivable as cost for feed concentrates increases. Unfortunately, recording daily feed intake is difficult and costly, and hence only feasible in test stations or research herds (Hüttmann, 2007). In contrast, individual recording of water intake is less expensive (Kramer et al., 2008a). Because the correlation between these traits is high (r = 0.73; Kramer et al., 2008a), water intake may be suitable as an information trait for feed intake and could be included in dairy programs instead of feed intake. Although necessary for valid statistical inference and correct variance component estimation, literature on model analysis of water and feed intake data are scarce (van der Werf, 2001; Sawalha et al., 2005; Kramer et al., 2008b).

Today, random regression (**RR**) models are increasingly used for the estimation of breeding values and commonly recommended for statistical analysis in this field (e.g., Koenen and Veerkamp, 1998; Veerkamp and Thompson, 1999; Coffey et al., 2002). Such models allow the estimation of cow-specific lactation curves with additional random regression coefficients (Schaeffer and Dekkers, 1994; Schaeffer, 2004). In contrast, conventional fixed regression (**FR**) models only include the fixed effect of lactation curve estimated with universal average regression coefficients, which are the same for all cows (van der Werf, 2001). In a previous study, Kramer et al. (2008a) analyzed the relationship of water and feed intake in the course of lactation. They used the estimated parameters of the Ali and Schaeffer (1987)

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Table 1. Numbers of cows, observations (Obs.), missing observations, means, standard deviations, and range (minimum, maximum) of the 2 analyzed traits

Trait	Cows (n)	Obs. (n)	Missing obs. (n)	Mean	SD	Minimum	Maximum
Water intake (kg/d)	193	22,660	468	82.3	19.0	10.7	155.6
DMI (kg/d)	193	22,624	496	19.8	4.0	3.8	34.8

function for both the fixed and random regression coefficients to model average and cow-specific lactation curves. In the German national genetic evaluation of milk yield, the Wilmink function (Wilmink, 1987) is currently used to model fixed regression coefficients, and a Legendre polynomial of order 2 is used to model random regression coefficients on day of lactation (VIT, 2008). Modeling lactation curves for milk yield has frequently been discussed in the literature, whereas modulation of water or feed intake over the lactation is rare (e.g., Wood, 1967; Guo and Swalve, 1995; van der Werf, 2001; Silvestre et al., 2006).

The objective of the present study was to analyze daily water and DMI with different lactation curve models. In doing so, 1) the best function for the average lactation curve was evaluated and chosen as the basis for 2) the evaluation of the best (co)variance function to model cow-specific lactation curves.

MATERIALS AND METHODS

Data

Data were recorded on the Futterkamp dairy research farm of the Chamber of Agriculture of Schleswig-Holstein, Germany, between March 2005 and April 2006. The dairy herd was subdivided into a research herd and a production herd. The research herd, comprising nearly 70 cows at a time, was divided into 2 feeding groups (group A and group B). Different experiments with feed additives (e.g., propylene glycol for group A and glycerin for group B) were being performed within the research herd. For such feeding experiments, it is important to have cows in early and mid lactation with high milk yield. Thus, for every feeding experiment, cows in early and mid lactation moved from the production into the research herd and vice versa. Complete lactation length could therefore not be recorded because most of the cows in late lactation had already left the feeding groups. During data collection, 3 feeding experiments were being performed. Dry matter intake was not recorded during the maximal interval of 3 wk between the feeding experiments. Hence, nearly 23,000 cow-days were accumulated from a total of 193 Holstein cows in parities 1 to 9. Lactation days were between 6 and 230. Twenty-three cows had observations in 2 lactations. Cows were milked twice daily and fed an ad libitum TMR. The feeding and water troughs (Insentec, Marknesse, the Netherlands) were equipped with an individual cow identification system; hence, cows were only able to access the troughs one at a time. Each visit to the water and feeding troughs was routinely recorded and the amount of collected feed and water were accumulated to daily yields. Extreme values that deviated more than 4 SD from the mean were removed from the data set. Thus, observations ranged between 10.7 and 155.6 kg of water intake and between 3.8 and 34.8 kg for DMI (Table 1), and the average DM content of the TMR was about 45% during the data collection period. In addition, only lactations with at least 15 test-days were considered in the analysis. Furthermore, the first and last days of each feeding experiment were excluded and data from 3 more days were discarded because of general technical problems. A total of 800 records (3.4% of all records) were omitted from data analysis.

Data Analysis

Preliminary investigations were performed using SAS software (SAS Institute, 2005) for analysis of fixed effects. Only the significant fixed effects were included in the following FR model:

$$y_{ijkm(DIM)} = \mu + P_i + GTD_j + f_{iw}\,(DIM) + c_k + e_{ijkm},$$

where y_{ijkm} is the observation vector of water intake or DMI; μ is the overall mean; P_i is the fixed effect of the ith parity class (i = 1,..., 3 for first, second, and third or greater); GTD_j is the fixed effect of the jth test-day within feeding group (j = 1,..., 664); f_{iw} (DIM) describes 6 functions (w = 1,..., 6) to model the ith lactation curve as described below, where DIM is days in milk, c_k is the random effect of the kth cow (k = 1,..., 193), and e_{ijkm} is the random error.

In a first step, the fixed effect of the average lactation curve was modeled by the following 6 functions of DIM. These functions were chosen because they are commonly accepted and well established in the literature for modeling lactation curves of different traits:

1) Guo and Swalve (1995; **GS**):