J. Dairy Sci. 100:1–9
https://doi.org/10.3168/jds.2017-12775

Neglect of lactation stage leads to naive assessment of residual feed intake in dairy cattle

B. Li,*†[1] B. Berglund,* W. F. Fikse,* J. Lassen,† M. H. Lidauer,‡ P. Mäntysaari,‡ and P. Løvendahl†
*Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden
†Department of Molecular Biology and Genetics, Aarhus University, DK-8830 Tjele, Denmark
‡Natural Resources Institute Finland, Green Technology, FI-31600 Jokioinen, Finland

ABSTRACT

Residual feed intake (RFI) is a candidate trait for feed efficiency in dairy cattle. We investigated the influence of lactation stage on the effect of energy sinks in defining RFI and the genetic parameters for RFI across lactation stages for primiparous dairy cattle. Our analysis included 747 primiparous Holstein cows, each with recordings on dry matter intake (DMI), milk yield, milk composition, and body weight (BW) over 44 lactation weeks. For each individual cow, energy-corrected milk (ECM), metabolic BW (MBW), and change in BW (ΔBW) were calculated in each week of lactation and were taken as energy sinks when defining RFI. Two RFI models were considered in the analyses; RFI model [1] was a 1-step RFI model with constant partial regression coefficients of DMI on energy sinks (ECM, MBW, and ΔBW) over lactation. In RFI model [2], data from 44 lactation weeks were divided into 11 consecutive lactation periods of 4 wk in length. The RFI model [2] was identical to model [1] except that period-specific partial regressions of DMI on ECM, MBW, and ΔBW in each lactation period were allowed across lactation. We estimated genetic parameters for RFI across lactation by both models using a random regression method. Using RFI model [2], we estimated the period-specific effects of ECM, MBW, and ΔBW on DMI in all lactation periods. Based on results from RFI model [2], the partial regression coefficients of DMI on ECM, MBW, and ΔBW differed across lactation in RFI. Constant partial regression coefficients of DMI on energy sinks over lactation was not always sufficient to account for the effects across lactation and tended to give roughly average information from all period-specific effects. Heritability for RFI over 44 lactation weeks ranged from 0.10 to 0.29 in model [1] and from 0.10 to 0.23 in model [2]. Genetic variance and heritability estimates for RFI from model [2] tended to be slightly lower and more stable across lactation than those from model [1]. In both models, RFI was genetically different over lactation, especially between early and later lactation stages. Genetic correlation estimates for RFI between early and later lactation tended to be higher when using model [2] compared with model [1]. In conclusion, partial regression coefficients of DMI on energy sinks differed across lactation when modeling RFI. Neglect of lactation stage when defining RFI could affect the assessment of RFI and the estimation of genetic parameters for RFI across lactation.
Key words: residual feed intake, dairy cattle, energy sink, lactation stage, genetic parameter

INTRODUCTION

Alternative feed efficiency (**FE**) traits have been explored recently to select for efficient animals that better use feed energy for production without sacrificing animal health or fertility in the long run. Residual feed intake (**RFI**), as one proposed FE trait, has been widely studied in pig, chicken, beef cattle, and dairy cattle (Berry and Crowley, 2013; Wolc et al., 2013; Patience et al., 2015; Tempelman et al., 2015). Generally, RFI is defined as the difference between an animal's actual feed intake and its expected feed intake based on energy requirements for body maintenance and production (Koch et al., 1963). Individuals with lower RFI are considered to be more efficient. In dairy cattle, milk production, body maintenance, and BW change (**ΔBW**) are usually included as key energy sinks when defining RFI. The expected feed intake of cows is derived from partial regressions of the feed intake on energy sinks (VandeHaar et al., 2016).

Defining RFI in lactating dairy cows is more complicated than defining RFI in growing animals due to the metabolic changes that occur during lactation cycles (Berry and Crowley, 2013). In early lactation, the milk production of dairy cows increases more sharply than feed intake, and body reserves need to be mobilized to

Received February 21, 2017.
Accepted July 24, 2017.
[1]Corresponding author: bingjie.li@slu.se

meet the energy demand (Berglund and Danell, 1987; Roche et al., 2009; Banos and Coffey, 2010). In later lactation, the feed intake of cows is kept at a relatively high level and body reserves are gradually restored (Mao et al., 2004; Vallimont et al., 2010). Generally, the commonly used RFI model employs constant partial regressions of feed intake on energy sinks. Considering the complexity of the metabolic changes of cows across lactation, it is possible that the partial regression coefficients of feed intake on milk production, body maintenance, and ΔBW could vary across lactation. Therefore, the general RFI model with constant partial regression coefficients of feed intake on energy sinks might not always hold for the entire lactation period, which might influence the estimation of RFI. Most previous studies corrected for the influence of lactation stages on RFI by using a systematic effect of DIM or lactation week on feed intake, or by including random regression terms in the model for the influence of lactation stage on cow random variances (Mäntysaari et al., 2012; Hardie et al., 2015; Tempelman et al., 2015). However, these commonly used corrections of lactation stages on RFI have ignored the potential influence of lactation stage on the partial regression coefficients of feed intake on energy sinks, and very few studies have been carried out to explore this potential influence when defining RFI. Lu et al. (2017) investigated the influence of management and environmental factors on partial efficiency of converting feed intake to energy sinks for RFI using a Bayesian multivariate modeling method, where the linear and quadratic effects of DIM on the partial efficiency of feed intake on energy sinks tended to be insignificant when 42-d records between 50 and 200 DIM were studied.

Previous studies reported heritability estimates for RFI in dairy cattle that ranged widely from 0.00 to 0.38 (Berry and Crowley, 2013; Tempelman et al., 2015; Manzanilla-Pech et al., 2016) and tended to vary across lactation (Tempelman et al., 2015). In dairy cattle, the genetic correlation for RFI across lactation has rarely been reported. A recent study showed a low genetic correlation for residual energy intake between early lactation and lactation wk 20 in Nordic Red cows (Liinamo et al., 2015).

The objectives of the current study were to investigate the influence of lactation stage on the partial regression coefficients of feed intake on energy sinks when modeling RFI, and also to estimate the genetic parameters for RFI across lactation in dairy cattle. Two RFI models were studied in which partial regression coefficients of feed intake on energy sinks were allowed or not allowed to change across lactation. Genetic parameters for RFI were estimated across lactation and were compared between the 2 RFI models.

MATERIALS AND METHODS

Animals, Feeding, and Data Recording

Cows in our study were from the Danish Cattle Research Center (**DCRC**; Foulum, Denmark) and the Ammitsbøl Skovgaard research herd (Skovgaard, Vejle, Denmark). From the raw data set containing records for 1,749 lactations of 890 Holstein cows, our study included data from 823 primiparous Holstein cows that calved between 1995 and 2015. Cows had been involved in some experiments on the farm (Nielsen et al., 2003; Løvendahl et al., 2010; Løvendahl and Chagunda, 2011). Studied Holstein cows included all Holstein cows from the DCRC studied by Li et al. (2016).

Cows were fed a TMR in weigh bins at DCRC (RIC System, Insentec B.V., Marknesse, the Netherlands). A planned quantity of concentrates was dispensed during each milking in the automatic milking system and leftover quantity was recorded. At Skovgaard, cows were kept and fed in tiestalls, with TMR dispensed manually. Components in the TMR were mainly maize, whole-crop, and grass silage supplied with sugar-beet expellers and protein concentrates. The energy content of feed could be slightly different between trials but was generally constant within each trial. The TMR and concentrates offered to cows and the feed refusals were measured individually to calculate the individual feed intake per cow. The DM contents of the TMR and concentrates were analyzed regularly, and the compositions were aligned and merged with feed intake records to obtain daily DMI per cow. A weekly average DMI per cow was calculated as the average of 7 DMI daily records in each lactation week. Energy intake per cow was not available.

Cows were milked twice daily at Skovgaard and had voluntary access to automatic milking systems at DCRC. The approach of ICAR (2016) was used with a moving average over 3 d to obtain daily milk yield (**MY**), where the daily MY was obtained from the average milking rate (calculated from the sum of the yield over 3 d divided by the sum of milking intervals in the same period) multiplied by 24 h. Milk composition was measured in all samples from every milking taken over a consecutive 48-h period every week. Milk composition was analyzed by using CombiFoss equipment (Foss, Hillerød, Denmark) operated by Eurofins (Vejen, Denmark). Composition data from each milking were used to calculate yields of fat, protein, and lactose, which were smoothed by the moving average method to obtain daily yields. Calculated daily yields were averaged per week of lactation to get the weekly average yields, similar to the DMI records. At Skovgaard, BW per cow was recorded every week during lactation wk