J. Dairy Sci. 100:1–12
https://doi.org/10.3168/jds.2016-12085

Relationships between body condition score change, prior mid-lactation phenotypic residual feed intake, and hyperketonemia onset in transition dairy cows

Francesca M. Rathbun,* Ryan S. Pralle,* Sandra J. Bertics,* Louis E. Armentano,* K. Cho,† C. Do,‡ Kent A. Weigel,* and Heather M. White*[1]
*Department of Dairy Science, University of Wisconsin-Madison, Madison 53706
†Division of Animal Breeding and Genetics, National Institute of Animal Science, Cheonan 21001, Korea
‡Division of Animal and Dairy Science, Chungnam National University, Daejeon 34134, Korea

ABSTRACT

Extensive efforts have been made to identify more feed-efficient dairy cows, yet it is unclear how selection for feed efficiency will influence metabolic health. The objectives of this research were to determine the relationships between residual feed intake (RFI), a measure of feed efficiency, body condition score (BCS) change, and hyperketonemia (HYK) incidence. Blood and milk samples were collected twice weekly from cows 5 to 18 d postcalving for a total of 4 samples. Hyperketonemia was diagnosed at a blood β-hydroxybutyrate (BHB) ≥1.2 mmol/L and cows were treated upon diagnosis. Dry period, calving, and final blood sampling BCS was recorded. Prior mid-lactation production, body weight, body weight change, and dry matter intake (DMI) data were used to determine RFI phenotype, calculated as the difference between observed DMI and predicted DMI. The maximum BHB concentration (BHB_{max}) for each cow was used to group cows into HYK or not hyperketonemic. Lactation number, BCS, and RFI data were analyzed with linear and quadratic orthogonal contrasts. Of the 570 cows sampled, 19.7% were diagnosed with HYK. The first positive HYK test occurred at 9 ± 0.9 d postpartum and the average BHB concentration at the first positive HYK test was 1.53 ± 0.14 mmol/L. In the first 30 d postpartum, HYK-positive cows had increased milk yield and fat concentration, decreased milk protein concentration, and decreased somatic cell count. Cows with a dry BCS ≥4.0, or that lost 1 or more BCS unit across the transition to lactation period, had greater BHB_{max} than cows with lower BCS. Prior-lactation RFI did not alter BHB_{max}. Avoiding over conditioning of dry cows and subsequent excessive fat mobilization during the transition period may decrease HYK incidence; however, RFI during a prior lactation does not appear to be associated with HYK onset.

Key words: hyperketonemia, body condition score, feed efficiency

INTRODUCTION

There has been a concerted effort to select for more efficient dairy cattle to reduce both feed costs and the carbon footprint of dairy production (Connor et al., 2013; Green et al., 2013; Macdonald et al., 2014; Hardie et al., 2015). Feed efficiency is commonly quantified as residual feed intake (**RFI**), which represents the difference between an individual animal's observed feed intake and their predicted feed intake (Potts et al., 2015), where their predicted intake is what they are expected to consume for their production based on a regression of milk energy, maintenance energy, metabolic BW, and BW change (Hardie et al., 2015). An animal with a negative RFI consumes less feed than predicted and is therefore more efficient (Potts et al., 2015). Although selection of animals for feed efficiency could result in positive progress in reducing feed costs and environmental impacts, the effect of this selection on other phenotypic traits, such as metabolic health, is largely unknown and further research on the correlation and co-selection of these traits is needed (Hardie et al., 2015).

Variation in feed efficiency is thought to reflect 5 major processes: feed intake, digestion of feed, metabolism (including variation in body composition, anabolism, and catabolism), activity, and thermoregulation (Herd and Arthur, 2009). Mobilization of body stores provides energy, specifically to animals in negative energy balance (**NEB**). Although changes in BW are accounted for within the RFI calculations, RFI is generally measured during a period of minimal BW and condition

Received September 30, 2016.
Accepted January 24, 2017.
[1]Corresponding author: heather.white@wisc.edu

change (Tempelman et al., 2015). In previous studies, RFI has not been measured during the transition period, the 3 wk before and 3 wk after calving, during which dairy cows enter NEB, rapidly mobilize adipose tissue as fatty acids, and often have elevated circulating ketone body concentrations (Grummer, 1993; Drackley, 1999; Duffield, 2000). Whereas ketone bodies can be used as a fuel source by some tissues, excessive production of these metabolites can lead to hyperketonemia (**HYK**) and have negative effects on animal health, production, and profitability (Baird et al., 1980; Herdt, 2000; McArt et al., 2015).

To successfully use RFI as a selection tool, an understanding of the effect of negative RFI on animal health and longevity is needed. To determine if selection based on RFI will influence subsequent lactation HYK incidence, the associations between body stores mobilization, HYK onset, and RFI were examined. The objectives of our research were (1) to determine the relationship between BCS across the transition period and HYK onset, and (2) to determine the relationship between prior lactation RFI and subsequent lactation BCS change and HYK incidence.

MATERIALS AND METHODS

All experimental protocols were approved by the University of Wisconsin-Madison College of Agricultural and Life Sciences Animal Care and Use Committee.

Transition Cow Study

Study Design and Diets. From October 9, 2014, until October 30, 2015, all primiparous and multiparous cows due to calve at the University of Wisconsin-Madison Emmons Blaine Dairy Cattle Research Center in Arlington, Wisconsin, were enrolled in the study. Five hundred seventy-one Holstein cows were enrolled into the study 28 d before their expected calving date. One cow was removed from the study due to severe mastitis and lameness. Previous lactation 305-d mature equivalent (**305ME**) milk production and genetic merit (milk and fat yield PTA) were recorded for each cow.

Cows were fed a corn silage and wheat straw based TMR during the dry period and a corn silage- and alfalfa silage-based TMR after calving. The feed ingredients and calculated composition for the dry and lactating TMR are shown in Table 1. During the study, dry cows were housed in a freestall barn and moved to a bedded pack 3 wk before calving. After calving, fresh cows were housed on either a bedded pack or a freestall pen. In addition to being fed a TMR, fresh cows housed on the bedded pack were offered ad libitum dry hay.

Weekly TMR and hay samples were collected, frozen, and later dried at 55°C for 48 h in a forced-air oven to determine DM content and ground to pass a 1-mm screen in a Wiley mill (model #4, Thomas Scientific, Swedesboro, NJ). Ground samples were composited by month and analyzed (Dairyland Laboratories Inc., Arcadia, WI). The nutrient composition of the TMR and hay are shown in Table 2.

Blood and Milk Sampling. Blood samples were collected after the morning feeding twice weekly to achieve 4 sample time points between 5 and 18 d relative to calving (**DRTC**) for each cow. Hyperketonemia was diagnosed as blood BHB $\geq$1.2 mmol/L.

Cow-side BHB testing was completed directly after blood sampling using a Precision Xtra meter (Abbott Laboratories, Abbott Park, IL), a human electronic hand-held blood glucose and ketone body meter that has a sensitivity of 91% and a specificity of 94% for detecting HYK in bovine blood samples when compared with laboratory assays (Iwersen et al., 2009). Milk samples were collected on the same days as blood samples, during the morning milking. As a part of routine fresh cow management, cows were checked daily with a semiquantitative urine dipstick for the first 10 d postpartum. If a cow tested positive for HYK by the urine analysis on a nonsampling day, a blood sample was collected and tested with the Precision Xtra meter by farm staff. If the cow was diagnosed with a blood BHB $\geq$1.2 mmol/L, a blood and milk sample were taken that day (if the cow had not yet been milked) or the following day (if diagnosis occurred after milking) and those samples were included in the data set, resulting in 5 samples collected for some cows. After collection of a blood and milk sample, the cow was treated according to the standard treatment protocol for HYK (oral drench of 300 mL of propylene glycol once daily for 3 d).

Milk samples were analyzed for fat and true protein contents by infrared analysis and SCC by flow cytometry (AgSource Milk Analysis Laboratory, Menominee, WI) using a CombiFoss 6600 FT+/FC (FOSS Electric, Hillerød, Denmark), and milk fat content was corrected to account for morning-only milk sampling (DeLorenzo and Wiggans, 1986). Yields of FCM and ECM were calculated according to NRC (2001) equations. Individual cow milk weights were also collected for the first 30 d postpartum.

BCS. Cows were body condition scored according to a 5-point scale (Wildman et al., 1982; Ferguson et al., 1994). All cows were body condition scored at 3 time points: −28 DRTC (dry BCS; **DBCS**), at calving (+1 DRTC; **CBCS**), and at the time of the last blood sample (**LSBCS**) around +18 d relative to calving.