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An investigation into genetic and phenotypic variation in time budgets and yield of dairy cows

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ABSTRACT

Time budgets (TB) of lactating Holstein cows in a freestall loose housing system were recorded twice in early and late lactation to study genetic and phenotypic variation in TB. Time budget traits were recorded using focal animal scanning at 10-min intervals for full 24-h sessions. The study included 243 first-lactation cows, with 389 TB records in early lactation (50 to 123 d in milk) and 403 records in late lactation (152 to 248 d in milk). Milk was recorded at 3-wk intervals during the same periods, and yield was expressed as energy-corrected milk. Time budget traits were analyzed with mixed linear models to obtain estimates of genetic variation (heritability) and permanent animal variance (repeatability). Correlations between TB traits and energy-corrected milk yield were estimated at the individual cow level. In early lactation, the cows spent, on average, 5.0 h eating and 1.8 h at feed gates without eating while they were still locked in the gates. Cows lay down for 10.4 h and stood in stalls for 3.2 h. The cows also spent 2.8 h standing in aisles, but only 0.5 h in the milking area. In late lactation, cows spent 1 h more lying, but less time standing in stalls and less time eating and at the feed gates. Time budget traits were moderately repeatable although highly consistent across lactation stages. Estimates of heritability were moderate for eating time (0.20) but almost zero for lying time. Correlations showed that cows with higher yield spent more time eating and less time lying. As there is a trade-off between lying time and eating time, lying time approached lower limits for cows with highest yields. It is suggested that time is viewed as an important but restricted resource that cows may be short of while trying to maintain high yields.
Key words: heritability, lying time, eating time, correlated changes

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INTRODUCTION

Recently, genetic selection and improved management has been successful in increasing daily milk yield of dairy cows. However, with increased milk production the cow also has an increased need for energy intake, which may stimulate appetite but also affects time needed for eating and ruminating. More time for eating and rumination can only be obtained by reducing the amount of time spent on other types of behavior, as was found under housed conditions where high-yielding cows spent more time eating but a shorter time lying than low-yielding cows in the same barn (e.g., Fregonesi and Leaver, 2001; Bewley et al., 2010). Similarly, old data suggest that grazing time and time spent ruminating was related to milk production in both Friesian and Jersey cows in all stages of lactation (Brumby, 1959). However, cows may compensate for shorter eating time by becoming faster at eating and ruminating. Biting rate correlated positively with genetic merit for milk yield in Irish Friesians (Bao et al., 1992), and O'Connell et al. (2000) found that high-merit Holstein cows had higher biting rates and spent a greater proportion of time ruminating than medium-merit cows. Thus, with continued selection for higher milk yield, we should expect that cows will develop various strategies to cope with the increased need for energy, although primarily by increasing eating time at the expense of other activities (Ingvartsen et al., 2003).

Time, as well as energy, is a limited resource for the cow, and it can be spent on feed intake and other activities such as walking between different resources, waiting, and resting; thus, high-producing cows that spend more time eating will have less time available for other activities. Currently available experimental evidence for these relationships is scarce and insufficient. Hence, it needs to be investigated whether increased milk production induces a tradeoff situation between eating and other important activities.

Previous results (Munksgaard et al., 2005) showed that, under time constraints, dairy cows chose to spend

an increased proportion of their available time lying and their feed intake decreased. However, to some degree, the cows compensated for a reduction in eating time by an increased speed of feed intake. Furthermore, experimental manipulation of time budgets (**TB**) for dairy cows restricting their possibility to lie down has been shown to induce a range of stress responses, such as changes to responsiveness of the hypothalamic-pituitary-adrenal axis (Munksgaard and Simonsen, 1996; Fisher et al., 2002) and reduced plasma growth hormone (Munksgaard and Løvendahl, 1993). Furthermore, results by Jensen et al. (2005) showed that heifers were willing to work to obtain 12 to 13 h of lying time using a demand function experiment. Thus, obtaining sufficient lying time is indeed a high priority in dairy cattle.

External factors, such as the housing conditions and composition of the feed ration, also have an effect on the time allocated to different activities. Improved management practices can help alleviate problems with the TB by reducing waiting time. At the individual level, cows may also differ in previous experience and learned behaviors, which may affect their individual TB, together with their genetic background, including their breeding value for production.

Our hypothesis was that components of the dairy cow TB have genetic variation, and those components closely connected to production traits are both genetically and phenotypically correlated. As such, these components may be affected by genetic differences in the production traits. This experiment was designed to study TB of first-lactation dairy cows, in early and in late lactation, to obtain estimates of phenotypic and genetic variation and correlations to milk yield at the individual level within the early and late stages of lactation.

MATERIALS AND METHODS

Design and Animals, Housing, and Feeding

The study included 243 Holstein cows in their first lactation belonging to the Future Genetics Nucleus Herd, kept at the Skølvad Experimental Station (Gredstedbro, Denmark). The herd included first-parity cows that were submitted to a single lactation performance test ending at 305 DIM, after which the cows left the herd. The herd also included Red Dane cows that were kept in the same group but were otherwise not taking part in the study. The cows were offspring of 59 sires and 231 dams with 65 maternal grandsires. The cows were produced by intensive use of multiple ovulation and embryo transfer to give more full-sib groups that improve the ancestry structure for use in genetic studies. Full ancestry of the cows was known for at least 3 generations and was retrieved from the national herd book database.

The animals arrived as heifers at Skølvad at 3 mo of age, coming from the several herds where they were born. They were raised on a diet formulated to restrict growth rate to approximately 800 g/d. Pregnant heifers were introduced to the dairy barn about 4 mo before expected calving, and were then fed the diet also offered to cows in milk, although in restricted amounts. After calving, the cows were included in the group of milking cows and fed ad libitum on a TMR throughout lactation. Cows were milked mornings and afternoons in a herringbone parlor, where they received supplementary concentrates in fixed amounts of 1.0 kg per milking. During and following milking, the feed gates were in locking mode from 0430 to 0800 h and 1500 to 1745 h to reduce bullying of subordinate and small cows and with a view to avoid contact of newly emptied udders with bedding material. The cows were kept indoors in a freestall barn with at least 1 stall per cow and 1 feeding space per cow. The stalls (length to brisket board = 2.10 m, width = 1.20 m) were equipped with mattresses. Cows were allocated to either of 2 groups in the right or left side of the barn (Figure 1), with cows remaining in their group throughout lactation.

Milk Recording

Milk yields were recorded for 1 d at 3-wk intervals, and composite samples from morning and afternoon milkings were assayed for content of fat, protein, lactose, and somatic cells using a CombiFoss 4000 (Foss-Electric, Hillerød, Denmark) operated by the regional milk recording society (RYK, Varde, Denmark). Yield was expressed as ECM per day, calculated based on yield and composition using the formula of Sjaunja et al. (1990), where lactose was calibrated using the monohydrate form:

$$\text{ECM} = \text{milk kg} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 157 \times \text{lactose \%} + 20.7)/3{,}140. \quad [1]$$

All available milk records obtained in early or late parts of lactation were used for estimating individual cow averages for each part of lactation as described later.

Protocol for Observation of Behavior

Behavior was observed twice in early and twice in late lactation (Figure 2). Any Holstein cow in the herd was available to and used by the experiment. Cows entered the experiment in the order given by date of