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Energy efficiency and its relationship with milk, body, and intake traits and energy status among primiparous Nordic Red dairy cattle

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ABSTRACT

Existing variation in energy efficiency and its relationship with milk yield and milk composition, body weight and body condition, feed intake, and energy status was studied in primiparous Nordic Red dairy cattle with data including 3,752 weekly records from 145 cows. Energy efficiency was defined as energy conversion efficiency (ECE) and as residual energy intake (REI) estimated based on Finnish feeding standards (REI_1) or from the current data (REI_2). The results indicated true phenotypic variation in energy efficiency of the cows. The proportion of total variance due to the animal was 0.35 for REI_1, 0.30 for REI_2, and 0.50 for ECE. The high efficiency based on ECE was associated with increased mobilization of body reserves ($r = -0.50$) and decreased dry matter intake ($r = -0.51$). With REI as an energy efficiency measure, the increased efficiency was associated with a large decrease in feed intake (REI_1: $r = 0.60$; REI2: $r = 0.74$) without any effect on body weight change (REI_1: $r = 0.13$; REI2: $r = 0.00$). Increased efficiency based on ECE and REI_1 was associated with increased milk yield (ECE: $r = 0.58$; REI_1: $r = -0.41$). A clear effect of stage of lactation on REI was found, which could be caused by true differences in utilization of metabolizable energy during lactation. However, it might also be related, in part, to the lack of knowledge of the composition of body weight change in the beginning of lactation.
Key words: energy efficiency, milk production

INTRODUCTION

Feed cost is a major expense in dairy production; therefore, cow feed intake and the ability to convert feed energy to milk energy is an important concern within the dairy industry. In addition, from an environmental point of view, improving energy efficiency in milk production is desired because it decreases nutrient and greenhouse gas emissions per animal. In addition, understanding the efficiency of energy utilization on different diets would be useful for feeding decisions and in ration formulation.

Breeding programs for dairy cows in most countries have traditionally focused on production traits (Miglior et al., 2005). The increase in milk production has led to an increase in feed intake but also in enhancement of energy conversion efficiency (**ECE**) because of lower genetic correlation between milk yield and feed intake than between milk yield and ECE (Korver, 1988). Energy conversion efficiency is calculated by dividing ECM, or milk energy output, by energy intake. However, ECE can be problematic in that higher efficiency with increased milk production is often associated with increased mobilization of body reserves, especially in the beginning of lactation. The lost body reserves need to be gained back in later lactation, which leads to decreases in efficiency at that stage. In addition, increased loss of body reserves can impair reproduction performance (de Vries et al., 1999; Roche et al., 2007) and increase risk for health problems (Collard et al., 2000).

An alternative measure for energy efficiency is residual energy intake (**REI**), which is defined as actual energy intake minus the predicted energy requirement, the latter being estimated from lactation performance, BW, BW change, and energy needed for pregnancy. Thus, REI reflects the remaining energy available after its use for milk, maintenance, and growth has been accounted for. The lower the REI value, the more efficiently energy has been utilized. In the calculation of REI, the changes in BW are modeled, and therefore REI should be less related to BW mobilization in early lactation than ECE.

Differences in energy efficiency have been reported among dairy breeds, but also between genotypes within breed (Legates, 1990; Coleman et al., 2010). In contrast, some studies observed no significant variation in REI (Prendiville et al., 2009) or ECE (Smothers et al., 1986) between breeds or genotypes. No studies have been published to date concerning energetic efficiency and its relationship with other traits in Nordic Red

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dairy cattle (**RDC**). The purpose of this study was to evaluate the existing variation in energy efficiency among the Nordic RDC cows across their first lactation, and to address the associations between the efficiency measures and production, feed intake, and body traits. In this paper, the phenotypic aspects of efficiency variation and associations are described. A separate paper will address the genetic background of the variation.

MATERIALS AND METHODS

Animals and Feeding

The data used in this study were collected in the MTT Agrifood Research Rehtijärvi MOET (multiple-ovulation embryo transfer) herd during the period from September 2006 to January 2009. Daily production and feed intake of 145 primiparous Nordic RDC cows were followed from calving to d 210 of lactation. The collected data included 3,752 weekly records. The animals were donor candidates in the Nordic embryo transfer breeding program ASMO, and thereafter most were dams of future AI bulls.

All cows were fed ad libitum a TMR containing home blend concentrate mix (mix A) and grass silage. Mix A included (g/kg) barley (301), oat (300), sugar beet pulp (109), rapeseed meal (259), and mineral and vitamin mix (31). Grass silage was prepared from a first-cut timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward using a formic acid-based additive. The amount of concentrate in TMR was 37% in DM. In addition to the TMR, cows received an additional concentrate (mixes A and B) given on top of the TMR. Mix B included (g/kg) barley (158), oat (140), sugar beet pulp (118), rapeseed meal (554), and mineral and vitamin mix (30).

The amount of the top fed concentrate depended on the stage of lactation and digestibility of the grass silage. When the digestibility of the OM of silage was between 680 and 700 g/kg of DM, the proportion of concentrate in the diet was 52% during lactation d 1 to 150 and 45% thereafter. The amount of concentrate decreased or increased by 2 percentage units for each 10 g/kg of DM increase or decrease in digestibility of the silage. The proportion of mix A and B in top fed concentrate was adjusted so that the CP concentration in concentrate was 19.5% in DM during the lactation d 1 to 150 and 18.5% thereafter.

The cows were housed in a tie-stall barn. The TMR was mixed in a mixer wagon (Järvenpään Konepaja, Forssa, Finland). Feeding of TMR and additional concentrate was carried out by a feeding robot (TR feeding robot, Pellonpaja Ltd., Ylihärmä, Finland); feeds were offered 5 times a day. To ensure ad libitum feeding, at least 5% daily refusals were required.

Data Recording, Sampling, and Analyses

Daily milk yield was recorded twice a week. Milk protein, fat, and lactose were analyzed once a week on lactation wk 1 to 8 and once a month thereafter at the laboratory of Valio Ltd. (Seinäjoki, Finland) using an infrared analyzer (MilkoScan FT6000, Foss Electric, Hillerød, Denmark). Individual feed intake was recorded daily. However, feed intakes were not recorded during the pasture period. Cows were weighed once a week after morning milking during lactation wk 1 to 8, every other week during wk 9 to 16, and every fourth week thereafter. Body condition scores of the cows were assessed on a scale of 1 to 5 (1 = skinny to 5 = very fat) with intervals of 0.25 (Edmonson et al., 1989) in the calving week and every other week thereafter.

A sample of grass silage was taken twice a week. These subsamples were combined to give a 3-wk sample for analysis. Samples were stored at −20°C. Thawed samples were analyzed for DM, ash, CP, NDF, VFA, lactic acid, water-soluble carbohydrates, ammonia-N, and in vitro OM digestibility. Concentrate samples were collected once a week and combined to give a 6-wk sample for analysis. The concentrate samples were analyzed for DM, ash, CP, ether extract, and NDF. The analyses of grass silage and concentrate samples were performed using procedures described previously by Mäntysaari et al. (2007). Chemical composition and calculated energy and protein values of the grass silage and the concentrates are given in Table 1.

Blood samples for plasma NEFA analyses were taken from each animal from coccygeal vein at 1, 2, 3, and 5 wk postpartum. Blood was collected in heparinized tubes and stored on ice until centrifuged at −4°C for 15 min at 2,000 × *g*. Plasma samples were frozen and stored at −20°C for latter analyses, and NEFA were analyzed using an analytical kit (NEFA C kit, Wako Chemicals GmbH, Neuss, Germany).

Study Variables and Statistical Analyses

Metabolizable energy content for grass silage was based on in vitro (Nousiainen et al., 2003) OM digestibility (16 MJ/kg of digestible OM). The ME concentration of the concentrates was calculated from digestible nutrients (MAFF, 1975, 1984). The digestibility coefficients for the components were taken from the Finnish feed tables (MTT, 2006). Energy and nutrient content of the TMR were calculated from values of the constituents and the proportion of each component