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Performance and metabolic profile of dairy cows during a lactational and deliberately induced negative energy balance with subsequent realimentation

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ABSTRACT

Homeorhetic and homeostatic controls in dairy cows are essential for adapting to alterations in physiological and environmental conditions. To study the different mechanisms during adaptation processes, effects of a deliberately induced negative energy balance (NEB) by feed restriction near 100 d in milk (DIM) on performance and metabolic measures were compared with lactation energy deficiency after parturition. Fifty multiparous cows were studied in 3 periods (1 = early lactation up to 12 wk postpartum; 2 = feed restriction for 3 wk beginning at 98 ± 7 DIM with a feed-restricted and control group; and 3 = a subsequent realimentation period for the feed-restricted group for 8 wk). In period 1, despite NEB in early lactation [−42 MJ of net energy for lactation (NE_L)/d, wk 1 to 3] up to wk 9, milk yield increased from 27.5 ± 0.7 kg to a maximum of 39.5 ± 0.8 kg (wk 6). For period 2, the NEB was induced by individual limitation of feed quantity and reduction of dietary energy density. Feed-restricted cows experienced a greater NEB (−63 MJ of NE_L/d) than did cows in early lactation. Feed-restricted cows in period 2 showed only a small decline in milk yield of −3.1 ± 1.1 kg and milk protein content of −0.2 ± 0.1% compared with control cows (30.5 ± 1.1 kg and 3.8 ± 0.1%, respectively). In feed-restricted cows (period 2), plasma glucose was lower (−0.2 ± 0.0 mmol/L) and nonesterified fatty acids higher (+0.1 ± 0.1 mmol/L) compared with control cows. Compared with the NEB in period 1, the decreases in body weight due to the deliberately induced NEB (period 2) were greater (56 ± 4 vs. 23 ± 3 kg), but decreases in body condition score (0.16 ± 0.03 vs. 0.34 ± 0.04) and muscle diameter (2.0 ± 0.4 vs. 3.5 ± 0.4 mm) were lesser. The changes in metabolic measures in period 2 were marginal compared with the adjustments directly after parturition in period 1. Despite the greater induced energy deficiency at 100 DIM than the early lactation NEB, the metabolic load experienced by the dairy cows was not as high as that observed in early lactation. The different effects of energy deficiency at the 2 stages in lactation show that metabolic problems in early lactating dairy cows are not due only to the NEB, but mainly to the specific metabolic regulation during this period.
Key words: negative energy balance, dairy cow, performance, metabolic parameter

INTRODUCTION

The onset of lactation in dairy cows is accompanied by low DMI and low energy availability, both of which slowly increase during the first week postpartum. During the same period, milk production steeply increases. Consequently, the energetic requirements of the early lactating cow are not met by her energy intake. This status is called a negative energy balance (**NEB**), and is described in most studies of newly lactating cows except those of Kessel et al. (2008) and van Dorland et al. (2009). A more adequate term that Butler et al. (2003) proposed might be "lactation-induced NEB" as this situation occurs naturally after calving and depends on the amount of milk yield and simultaneous DMI. The NEB in early lactation can be accompanied by health disorders (Bertoni et al., 2009).

Negative energy balance is associated with mobilization of body reserves, predominantly localized in fat and muscle tissue, because of homeorhetic control with highest priority for nutrient partitioning toward the mammary gland (Bauman and Currie, 1980). The priority of milk production after parturition is expressed by increased milk yield despite the physiological NEB. Plasma NEFA and ketone body concentrations increase during this early lactation stage and peak before maximum milk yield. The lactation-induced NEB may last up to 14 wk of lactation, whereas the peak of milk yield is found between wk 4 and 8 postpartum (NRC, 2001).

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An NEB may occur later in lactation during insufficient supply and quality of feed. This is seen in pastured high-yielding dairy cows and in dairy cows fed a TMR without taking into account the different performance levels and individual requirements of the cow. In this respect, energy density of the diet can be a limiting factor affecting performance. In these situations, dairy cows need to adapt to maintain homeostasis. Homeostasis is the property that regulates the internal environment and tends to maintain a stable physiological condition (Cannon, 1929; Bauman and Currie, 1980), such as the established lactation after the NEB period; that is, in mid lactation or in the so-called production phase of lactation, during which the metabolic priority of the mammary gland no longer exists. Induced NEB at this stage of lactation resulted in a decreased milk yield with elevated NEFA concentration (Carlson et al., 2006).

Performance and physiological reactions in dairy cows are influenced by homeorhetic and homeostatic control. To our knowledge, studies of homeorhetic and homeostatic control in early and mid lactation have not yet been carried out. Therefore, the objective of this study was to quantify and compare the performance and physiological reactions in dairy cows during NEB in early lactation and a deliberately induced NEB by feed restriction following early lactation. The hypothesis tested was that performance is differently affected by a marked NEB during homeorhetic and homeostatic control in dairy cows.

MATERIALS AND METHODS

Animal experiments were carried out at the Agricultural Experimental Unit Hirschau of the Technical University of Munich, Germany, and were approved by the responsible department for animal welfare affairs.

Animals

Fifty multiparous Holstein dairy cows (3.2 ± 0.2 parities, mean ± SEM) were studied from wk 1 prepartum to about wk 26 postpartum. The lactating herd was housed in a freestall barn. From 10 d before expected calving until d 5 postpartum, animals were fed individually in calving pens with straw bedding.

Period 1 was wk 1 prepartum to 12 postpartum, where all animals were treated as one group. In period 2, animals were allocated equally to either a control group (**C**, n = 25) or a restriction group (**R**, n = 25) according to the extent of NEB the cows experienced in period 1. The restriction phase (period 2) lasted for 3 wk and started at 98 ± 7 DIM. The week before feed restriction was classified as wk 0, where all cows were treated as one group. After 3 wk of feed restriction, period 3 started and lasted for 8 wk, during which R cows were (re)fed similarly to C cows (realimentation period).

Feeding Regimen

Animals in period 1 received a partial mixed ration 1 (**PMR 1**, Table 1) for ad libitum intake of basic feed (silages, hay) with separate and limited intake of concentrates. The PMR 1 was calculated to meet the demands for energy and protein of a cow (650 kg of BW) producing 21 kg of milk/d with an assumed DMI of 16 kg of DM/d. The PMR 1 was given once daily at 0930 h. Feed bins for recording individual PMR intake were connected to electronic balances. In addition to PMR 1, concentrate (**CONC**, Table 1) was fed at 1.3 kg of DM/d for the first 5 d of lactation. On d 6 postpartum, cows received 1.8 kg DM of CONC/d, which was increased up to 8.9 kg DM/d in the following 35 d. Thereafter, CONC was fed according to individual extra requirements for milk production. The CONC was offered in transponder-access feeding stations by an automatic feeding program (DeLaval Alpro, Glinde, Germany). Calculations for energy and protein supply followed the recommendations of the German Society of Nutrition Physiology (GfE, 2001).

At the start of period 2, R cows received PMR 1 with additional hay to reduce the energy content (**PMR 2**, Table 1). Furthermore, CONC was limited to 0.4 kg DM/d for all R cows during period 2. The amount of PMR 2 was limited in each week of period 2 to maintain an energy deficiency of a least 30% of the calculated requirements. Consequently, the protein supply was reduced correspondingly to obtain a stable energy:protein ratio. The C cows were maintained on PMR 1 ad libitum as in period 1. In period 3, R cows had free access to PMR 1 until the end of the study. The CONC was set from 0.4 to 4.5 kg DM/d (the mean value of the C group) in wk 1 of realimentation. During the remainder of period 3, CONC was adapted weekly for all animals as described above. For each cow, daily DMI (PMR and CONC) was recorded continuously. Changes of the diets were carried out all at once within a day. All animals had free access to fresh water.

Feed Samples and Analyses

Samples of all forages and CONC were collected weekly; samples of PMR 1 and PMR 2 were obtained twice per week. For analysis of DM, fresh feeds were weighed, dried for 24 h at 60°C, and reweighed. Sam-