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Effect of prepartal ad libitum feeding of grass silage on transcriptional adaptations of the liver and subcutaneous adipose tissue in dairy cows during the periparturient period

S. Selim,*[1] T. Kokkonen,* J. Taponen,† A. Vanhatalo,* and K. Elo*
*Department of Agricultural Sciences, PO Box 28, FI-00014 University of Helsinki, Finland
†Department of Production Animal Medicine, University of Helsinki, Paroninkuja 20, FI-04920 Saarentaus, Finland

ABSTRACT

Prepartal energy overfeeding may predispose cows to a state of increased insulin resistance with greater lipolysis after parturition. The aim of the study was to evaluate the effects of prepartal overfeeding in terms of abundant grass silage ration on the liver and subcutaneous adipose tissue (SAT) gene expression around parturition. Sixteen multiparous Finnish Ayrshire dairy cows were fed ad libitum either grass silage [high energy, HE; 144 MJ/d of metabolizable energy (ME) intake, n = 8] or a mixture of grass silage, wheat straw, and rapeseed meal [55:40:5 (CON), 109 MJ/d of ME, n = 8] during the dry period (58.2 ± 4.89 d, mean ± standard deviation). Tissue biopsies and blood samples were collected at −14 (±4.98), 1, and 7 d relative to the actual parturition date. The HE cows had greater total dry matter intake, ME intake, and ME balance during the dry period than the CON cows. Compared with CON, the increases in body weight and body condition score were greater in HE during the dry period. Milk yield during the first 2 wk of lactation was not different between the groups. Plasma glucose, nonesterified fatty acids, insulin, glucagon, and β-hydroxybutyrate did not differ between the groups during the transition period. Dietary treatment did not affect hepatic triglyceride content; however, a delayed increase in hepatic total lipid content was observed in the HE cows at d 1 postpartum. Hepatic cytosolic phosphoenolpyruvate carboxykinase 1 mRNA expression was lower in HE than in CON at d 1 and 7 postpartum. Adiponectin receptor 1 and 2 mRNA abundance tended to be lower in SAT of HE than CON. Lower lipoprotein lipase, leptin, and stearoyl-coenzyme A desaturase mRNA abundances were observed at d 7 postpartum in SAT of the HE cows compared with the CON cows. We concluded that prepartal ad libitum feeding of grass silage may decrease insulin sensitivity and lipogenesis in SAT during peripartal period and may attenuate the increase of hepatic gluconeogenic capacity from propionate compared with a controlled-energy diet.
Key words: prepartal energy, gluconeogenesis, insulin resistance, lipogenesis, dairy cow

INTRODUCTION

Transition period requires a complex coordination of metabolism in multiple tissues to support the onset of milk synthesis (Block et al., 2001; Grummer et al., 2004). A physiological state of peripheral insulin resistance develops during late pregnancy and plays a key role in the exacerbation of adipose tissue (**AT**) mobilization near calving (Bell, 1995). Changes in AT secretion of adipokines adiponectin (**ADIPOQ**) and leptin (**LEP**), which in the context of obesity play an important role in insulin resistance in humans and rodents (Antuna-Puente et al., 2008), may affect insulin sensitivity also in dairy cows. Ji et al. (2012) reported that excess energy intake prepartum resulted in greater expression of *ADIPOQ* and led to an enhanced rather than compromised insulin signaling pathway. Selim et al. (2014) observed that overfeeding energy during the first 3 wk of the dry period combined with decreasing energy allowance during the last 3 wk before parturition did not affect the expression of *ADIPOQ*, *ADIPOQ* receptors, or *LEP* in subcutaneous adipose tissue (**SAT**) of transition dairy cows. The conflicting results suggest that the role of adipokines in dairy cows during the transition period is not fully elucidated.

One of the key consequences of excessive FA mobilization after calving is lipid accumulation in the liver. Murondoti et al. (2004) observed that overfeeding energy during late pregnancy caused a diminished activity of hepatic gluconeogenic enzymes during early lactation, and they attributed this to fatty infiltration of the liver. However, Hammon et al. (2009) reported that increased liver lipid content did not impair the expression of hepatic gluconeogenic genes and Selim et al. (2014) concluded that excess dietary energy intake prepartum resulted in lower expression of hepatic

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[1]Corresponding author: shaimaa.selim@helsinki.fi

gluconeogenesis, whereas no differences in liver lipid content was observed. Nevertheless, based on enzyme activity and gene expression studies, overfeeding energy prepartum may negatively affect hepatic gluconeogenesis, as well as FA β-oxidation (Murondoti et al., 2004; Loor et al., 2006; Selim et al., 2014).

Peroxisome proliferator-activated receptor γ and α (*PPARG* and *PPARA*) are key transcriptional factors controlling lipid metabolism via their target genes in the liver and AT (Bionaz et al., 2013). The greater abundance or activation of *PPARG* may increase insulin sensitivity in AT and decrease FA mobilization, whereas *PPARA* may alleviate liver lipid accumulation by increasing oxidation of NEFA and enhancing very low-density lipoprotein synthesis (Bionaz et al., 2013). In addition, *PPARA* may have a role to control the increase of gluconeogenesis early postpartum (Bionaz et al., 2013).

A better understanding of coordinated changes in transition cow metabolism at the molecular level in responding to prepartal overfeeding may help to develop strategies to decrease the incidence for metabolic diseases. Recent studies have evaluated the effect of prepartal overfeeding of energy in corn-based diets on the liver or SAT gene expression (Ji et al., 2012; Graugnard et al., 2013; Khan et al., 2014). In these studies energy overfeeding is accompanied by increased intake of corn starch, which may modulate glucose absorption from small intestine. Our objective was to assess the effects of ad libitum feeding of grass silage (low starch) throughout the dry period on the liver and SAT gene expressions of transition dairy cows. The hypothesis was that overfeeding of grass silage during the dry period would enhance lipogenesis prepartum and induce a more pronounced SAT mobilization postpartum characterized by changes in SAT gene expression. Additionally, we hypothesized that overfeeding energy would modify the transcriptional activity of the expression of hepatic genes related to glucose metabolism and FA β-oxidation during the transition period.

MATERIALS AND METHODS

Animals, Diets, and Experimental Design

The experimental procedures were approved by the National Animal Ethics Committee in Finland (Hämeenlinna). At the beginning, 16 nonlactating Finnish Ayrshire dairy cows were selected to participate in the study based on parity (4.0 ± 1.26; mean ± SD), BW (733 ± 103.8 kg), and BCS using a 5-point scaling system (3.48 ± 0.539; Edmonson et al., 1989) in a randomized complete block design. An average 305-d milk yield from the previous lactation of the experimental cows was 10,503 kg. Cows were paired based on the previously mentioned criteria and the expected calving date, and cows within pairs were randomly assigned to dietary treatment groups. The experimental feeding started 58.2 ± 4.89 d before the actual parturition date and continued until calving. The dietary treatments were either ad libitum feeding of a high-energy diet (**HE**) or a controlled-energy diet (**CON**). Chemical composition of diets is presented in Table 1. The HE diet contained grass silage (digestible OM = 634 g/kg of DM), whereas the CON diet contained a mixture of grass silage (55%, digestible OM = 667 g/kg of DM), wheat straw (40%, digestible OM = 457 g/kg of DM), and rapeseed meal (5%, digestible OM = 700 g/kg of DM). The diets were formulated to maintain a 100 g/kg of DM difference in NDF concentration. Targeted ME intakes during the dry period were 140 (~140% of energy requirement of pregnant dairy cows; LUKE, 2015) and 105 MJ/d (~100% of energy requirement of pregnant dairy cows) for HE and CON, respectively. For the TMR of CON diet, round bales of straw were preprocessed in a mixer wagon for 40 min before grass silage was added to the mixer. After the addition of grass silage, TMR was mixed for 30 min and, finally, after the addition of rapeseed meal for 10 min. Grass silage or TMR was offered to cows 3 times daily at 0700, 1300, and 2000 h. During the close-up period, commercial concentrate mixture (Raisioagro Ltd., Raisio, Finland) was added to both groups starting from 1 kg/d at d 10 to 6 before the expected calving date and 2 kg/d until parturition. Cows had free access to water.

After parturition, all cows were offered wilted grass silage ad libitum and an increasing amount of commercial concentrate. The concentrate ration comprised the same concentrate as before calving and a protein supplement (Raisioagro Ltd.). The proportions of cereal concentrate and protein supplement were 91 and 9% during the first week of lactation and 87 and 13% during the second week of lactation, respectively. The total amount of concentrate after calving was 5 kg/d at the day of parturition, 7 kg/d at d 7 postpartum (6 kg/d of cereal concentrate + 1 kg/d of protein supplement), and 11 kg/d at d 14 postpartum (9 kg/d of cereal concentrate + 2 kg/d of protein supplement). Individual feed ingredients were sampled weekly, and the forage samples were composited before analysis to form a monthly sample. Samples of each concentrate (cereal concentrate, rapeseed meal, and protein supplement) were pooled to form a 2-mo sample for chemical analyses. Contents of DM, OM, CP, and NDF in the feeds and in vitro OM digestibility of forages were determined using methods described by Salin et al. (2012). The ME contents of forages were calculated based on the concentration of digestible OM in feed DM (D-