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Visceral adipose tissue mass in nonlactating dairy cows fed diets differing in energy density[1]

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ABSTRACT

Our objective was to determine dietary energy effects on feed intake, internal fat deposition, body condition score (BCS), visceral organ mass, and blood analytes in Holstein cows. Eighteen nonpregnant, nonlactating cows (BCS = 3.04 ± 0.25) were blocked based on initial BCS and were randomly assigned within each block to 2 treatments. Treatments were either high energy [HE; net energy for lactation (NE_L) = 1.62 Mcal/kg] or low energy (LE; NE_L = 1.35 Mcal/kg) diets fed as total mixed rations for 8 wk. The LE diet consisted of 81.7% forage, including 40.5% wheat straw and 28.3% corn silage, whereas the HE diet contained 73.8% forage with no straw and 49.9% corn silage (dry matter basis). Cows were fed for ad libitum intake once daily at 0800 h. Feed intake was recorded daily, blood was sampled at wk 1, 4, and 7, and BCS was assigned at wk 1, 4, and 7. Cows were killed following the 8-wk period, and visceral organs, mammary gland, and internal adipose tissues were weighed and sampled. The HE group had greater dry matter intake (15.9 vs. 11.2 ± 0.5 kg/d) and energy intakes than cows fed LE, but neutral detergent fiber intake did not differ (5.8 vs. 5.6 ± 0.25 kg/d for HE and LE). Final body weight was greater for cows fed HE (807 vs. 750 kg), but BCS did not differ between groups (3.52 vs. 3.47 for HE and LE). Omental (26.8 vs. 15.2 ± 1.6 kg/d), mesenteric (21.5 vs. 11.2 ± 1.9 kg), and perirenal (8.9 vs. 5.4 ± 0.9 kg) adipose tissue masses were larger in HE cows than in LE cows. Although subcutaneous adipose mass was not measured, carcass weight (including hide and subcutaneous fat) did not differ between HE (511 kg) and LE (496 kg). Liver weight tended to be greater for cows fed HE, but weights of gastrointestinal tract, heart, and kidney did not differ. Serum insulin tended to be greater and the glucose to insulin ratio was lower for cows fed HE. Serum concentrations of β-hydroxybutyrate and cholesterol were greater for HE cows than for LE cows but concentrations of glucose, nonesterified fatty acids, total protein, and albumin did not differ. Final BCS was correlated with masses of omental (r = 0.57), mesenteric (r = 0.59), and perirenal (r = 0.72) adipose tissue, but mesenteric adipose mass increased more as BCS increased for cows fed HE. The similar final BCS between HE and LE cows demonstrates that BCS may lack sensitivity to detect differences in visceral fat deposition that might increase risk for peripartal diseases and disorders.

Key words: adipose tissue, dry cow, energy intake

INTRODUCTION

Recent biomedical research has focused on the role of increased visceral (omental plus mesenteric) adipose tissue lipid accumulation in the pathogenesis of chronic disorders in humans such as metabolic syndrome (Gabriely et al., 2002; Yang et al., 2008; Catalano et al., 2010) and intestinal inflammatory disorders (Batra and Siegmund, 2012). In particular, enlarged mesenteric adipose tissue is implicated in development of insulin resistance and other abnormalities of the metabolic syndrome in humans (Yang et al., 2008) and rats (Catalano et al., 2010). Although dairy cattle accumulate relatively more fat in internal adipose depots and less in subcutaneous fat than do beef cattle (Wright and Russel, 1984), relatively little is known about changes in mass or function of internal fat depots in dairy cows, particularly during the periparturient period. Gibb et al. (1992) observed that fat represented 69% of the total body energy in newly calved Holstein-Friesian cows, and 20% of the total fat was associated with the digestive tract (omental and mesenteric adipose depots). Moreover, Gibb et al. (1992) determined that cows disproportionately mobilized a greater portion of that fat (40%) compared with total body fat (34%) during the first 8 wk postpartum.

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Accumulation of lipids in the visceral adipose depots whose venous circulation drains to the liver (Ibrahim, 2010) could subject the liver to large amounts of NEFA and adipose-synthesized adipokines that may affect hepatic function, as observed in other species (Lafontan and Girard, 2008). The potential involvement of such factors in metabolic disorders of dairy cows has been discussed (Drackley et al., 2005; Sordillo et al., 2009). An "overnutrition syndrome" in periparturient dairy cows has been identified that shares many common features with the metabolic syndrome in humans and rodent models (Janovick et al., 2011). Our studies indicate that energy nutrition during the entire dry period, not just shortly prepartum, plays a determining role in periparturient hepatic and adipose metabolism and gene expression (Dann et al., 2006; Douglas et al., 2006; Loor et al., 2006; Ji et al., 2012). Consumption of excess energy relative to requirements during the dry period by allowing free access to moderate-energy diets leads to greater blood NEFA and BHBA, as well as hepatic fat accumulation postpartum (Dann et al., 2006; Douglas et al., 2006; Janovick et al., 2011). The extent to which visceral and other abdominal adipose tissues (e.g., perirenal) differentially accrete lipid in response to differences in diet (amount or source of energy) over short times such as a typical dry period length is not known.

Our hypothesis was that nonlactating cows fed a high-energy diet similar to those that have caused fatty liver in other studies (Douglas et al., 2006; Janovick et al., 2011) would accumulate more internal adipose tissue mass than cows fed a low-energy diet. Our objective was to determine dietary energy effects on feed and energy intake, BCS and BW, abdominal adipose tissue mass, carcass mass, visceral organs mass, and peripheral blood metabolites in nonlactating cows.

MATERIALS AND METHODS

Experimental Design, Treatments, and Cow Management

Eighteen nonpregnant, nonlactating Holstein cows (BW = 656 ± 29) were used in a completely randomized design study. Cows averaged 3.0 parities (range 2 to 4). Cows were stratified by initial BCS into 3 blocks (<3.0, 3.0 to 3.75, and ≥4.0). Within each block, cows were randomly assigned to treatments of either high energy (**HE**; NE_L = 1.62 Mcal/kg) or low energy (**LE**; NE_L = 1.35 Mcal/kg) diets fed as TMR for ad libitum intake for 8 wk (Table 1). The HE diet contained 73.8% forage from alfalfa silage, alfalfa hay, and corn silage, whereas the LE diet contained 81.7% forage, including 40.5% wheat straw (DM basis). Cows were offered the TMR once daily at 0800 h in amounts to allow 5 to 10% orts, and they had unlimited access to fresh water. The LE diet was formulated to be similar to high-bulk diets fed in previous experiments to limit energy intake when consumed at maximal DMI (Dann et al., 2006; Richards et al., 2009; Janovick and Drackley, 2010). Diets were mixed in a Keenan Klassik 140 mixer wagon (Richard Keenan & Co. Ltd., Borris, County Carlow, Ireland) equipped with knives and serrated paddles; straw in large square bales was chopped directly by the mixer without preprocessing.

Cows were housed in indoor pens (10 × 15 m) equipped with individual electronic transmission gates and transponders (American Calan Inc., Northwood, NH) for access to feed. Each pen had 10 sand-bedded freestalls with at least one stall per cow. The experiment was conducted at the University of Illinois Dairy Cattle Research Unit (Urbana) from November 2007 through February 2008. Experimental procedures were approved by the Institutional Animal Care and Use Committee at the University of Illinois.

Feed and Blood Sampling and Laboratory Analyses

The amounts of TMR offered and orts removed were recorded daily and samples were collected every 2 wk. The TMR were sampled after feeding by remixing each cow's feed with a shovel and then obtaining grab samples, which were composited by diet. Feed and orts samples were oven-dried at 105°C for 24 h to measure DM content. Weekly TMR samples were pooled into 3 composites for nutrient analysis. All samples were analyzed at a commercial laboratory (Dairy One, Ithaca, NY) for contents of CP (method 984.13; AOAC International, 2000), NDF (Van Soest et al., 1991; using heat-stable α-amylase and sodium sulfite), ADF (method 973.18; AOAC International, 2000), and fat (method 2003.05; AOAC International, 2000). The NE_L content was estimated using summative equations as described by NRC (2001).

Blood was sampled from a tail artery or vein at wk 1, 4, and 7 into evacuated serum tubes (SST; Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) containing clot activator. Blood samples were centrifuged at 1,800 × *g* (Eppendorf Centrifuge 5804, Brinkmann Inst. Inc., Westbury, NY) to obtain serum. Serum samples were assayed for glucose, urea N, creatinine, total protein, cholesterol, BHBA, and minerals using an auto-analyzer (Hitachi 917, Roche Diagnostic Corp., Indianapolis, IN), and diagnostic kits as described (Carlson et al., 2007), at the Small Animal Clinic Diagnostic Laboratory of the College of Veterinary Medicine (University of Illinois, Urbana). Serum samples were assayed for albumin, alkaline phosphatase, aspartate