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Effect of diet fermentability and unsaturated fatty acid concentration on recovery from diet-induced milk fat depression

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ABSTRACT

Diet-induced milk fat depression is caused by highly fermentable and high-unsaturated fatty acid (FA) diets, and results in reduced milk fat concentration and yield, reduced de novo FA, and increased *trans* isomers of the alternate biohydrogenation pathways. The hypothesis of the current experiment was that a diet higher in fermentability and lower in unsaturated FA (UFA) would accelerate recovery compared with a high-UFA and lower-fermentability diet. Eight ruminally cannulated and 9 noncannulated multiparous Holstein cows were randomly assigned to treatment sequences in a replicated Latin square design. During each period milk fat depression was induced for 10 d by feeding a low-fiber, high-UFA diet [25.9% neutral detergent fiber (NDF) and 3.3% C18:2]. Following the induction phase, cows were switched to recovery treatments for 18 d designed to correct dietary fermentability, UFA, or both fermentability and UFA concentration. Treatments during recovery were (1) correction of fiber and UFA diet [control; 31.8% NDF and 1.65% C18:2], (2) a diet predominantly correcting fiber, but not UFA [high oil (HO); 31.3% NDF and 2.99% C18:2], and (3) a diet predominantly correcting UFA, but not fiber concentration [low fiber (LF); 28.4% NDF and 1.71% C18:2]. Milk and milk component yield, milk FA profile, ruminal pH, and 11 rumen microbial taxa were measured every third day during recovery. Milk yield decreased progressively in HO and control, whereas it was maintained in the LF diet. Milk fat concentration increased progressively during recovery in all treatments, but was on average 9% lower in LF than control from d 12 to 18. Milk fat yield increased progressively in all treatments and was not different between control and LF at any time point, but was lower in HO than control on d 15. Milk *trans*-10 C18:1 and *trans*-10,*cis*-12 conjugated linoleic acid decreased progressively in all treatments, but was higher in HO than control from d 3 to 18 [136 ± 50 and 188 ± 57% (mean ± SD)], whereas LF caused a smaller increase in these FA compared with control (67 ± 25 and 90 ± 22%). Additionally, milk *trans*-11 C18:1 and *cis*-9,*trans*-11 conjugated linoleic acid was decreased in control and LF and increased in HO during recovery. Selected microbial species observed changed during recovery, but major treatment differences were only observed for *Streptococcus bovis*. The LF diet that was similar in UFA but 3.4% units lower in NDF compared with to the control had a similar decrease in alternate *trans* biohydrogenation intermediates in milk. The HO diet that was similar in NDF but 2.0% units higher in UFA compared with the control had higher alternate *trans* biohydrogenation intermediates in milk compared with control. However, recovery of milk fat yield was similar between treatments at most time points.
Key words: milk fat depression, dairy cow, conjugated linoleic acid

INTRODUCTION

Milk fat is the most variable milk component on farms and is especially responsive to nutritional factors. Classical diet-induced milk fat depression (**MFD**) is a specific reduction in milk fat concentration and yield commonly observed when dairy cows are fed highly fermentable and high-unsaturated fatty acid (**UFA**) diets (Bauman and Griinari, 2001). Specific *trans* FA, such as *trans*-10,*cis*-12 CLA, formed as intermediates during altered ruminal biohydrogenation of linoleic acid have been identified as the causative factors of diet-induced MFD (Harvatine et al., 2009). The alternate biohydrogenation (**BH**) pathway results from a change in rumen environment, altered rumen microbial population, or a large amount of UFA requiring BH (Lourenço et al., 2010; Weimer et al., 2010). Diet-induced MFD has been extensively studied (reviewed by Harvatine et al., 2009); however, recovery from MFD and mechanisms to accelerate recovery have only recently been investigated

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Table 1. Example treatment sequences in the 3 × 3 Latin square design investigating the effect of dietary fiber and unsaturated fatty acid (UFA) concentration on recovery from milk fat depression[1]

Treatment sequence	Period 1, 10/18 d	Washout, 7 d	Period 2, 10/18 d	Washout, 7 d	Period 3, 10/18 d
1	MFD/Control	Control	MFD/LF	Control	MFD/HO
2	MFD/HO	Control	MFD/Control	Control	MFD/LF
3	MFD/LF	Control	MFD/HO	Control	MFD/Control

[1]Milk fat depression (MFD) was achieved by feeding the induction diet (low fiber, high UFA) during the first 10 d of each period. Treatments were a high fiber, low UFA diet (control), a diet correcting UFA, but not fiber level (Low fiber: LF), and a diet correcting fiber, but not UFA (high oil: HO) fed for 18 d during the recovery phase. Monensin was fed in all diets.

(Rico and Harvatine, 2013; Rico et al., 2014a,b). The current experiment uses a similar experimental model to investigate recovery from MFD.

Dietary starch, fiber, and UFA concentration, rate of fermentation, and monensin are some of the risk factors for MFD. Monensin is commonly fed to dairy cows to increase feed efficiency; however, it has been associated with lower milk fat concentration concomitantly with increased milk *trans* FA, including *trans*-10 C18:1 and *trans*-10,*cis*-12 CLA, and reduced concentration of de novo synthesized FA in milk (Duffield et al., 2008). In addition, monensin supplementation in high-UFA diets increased the concentration of intermediates of the alternate BH pathway in rumen fluid and milk (AlZahal et al., 2008; He et al., 2012). The current experiment was conducted with monensin in all diets.

We recently reported the time course of the induction of and recovery from classical diet-induced MFD (Rico and Harvatine, 2013). Briefly, MFD was induced to near maximal levels in 9 d by feeding a low-fiber and high-UFA diet (29.5% NDF, 27% starch, and 3.4% C18:2). After correction of both dietary fiber and UFA concentration (36.9% NDF, 18% starch, and 1.6% C18:2), recovery from MFD occurred progressively, as milk fat yield was not different from control on d 11 and was completely recovered by d 19 (Rico and Harvatine, 2013). This correction of both dietary fiber and UFA concentration represents a near best-case scenario for recovery of milk fat, but results in a substantial decrease in diet energy density and risks loss of milk yield.

The objective of the current study was to investigate the effect of dietary NDF and UFA concentration on the time course of recovery of milk fat synthesis and reestablishment of normal rumen FA BH pathways and microbial populations in diets supplemented with monensin. We hypothesized that increasing fermentability (3.4% unit lower NDF) with a similar UFA concentration compared with the control would accelerate recovery of normal rumen BH more than a diet with similar fermentability but higher UFA (2.0% units) compared with the control. This is expected because diet fermentability can alter rumen microbial populations, whereas UFA are the substrates for formation of *trans* FA and also modify rumen microbial populations.

MATERIALS AND METHODS

Experimental Design and Treatments

The experiment was conducted from August to November of 2011. All experimental procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. Eight ruminally cannulated and 9 noncannulated multiparous Holstein cows (127 ± 37 d postpartum; mean ± SD) were randomly assigned to 1 of 6 treatment sequences in a Latin square design (example sequences in Table 1). Cows were housed in a tiestall barn located at the Pennsylvania State University Dairy Production Research and Teaching Center.

Each period was divided into a 10-d induction phase and an 18-d recovery phase (Table 1). During each period, short-term MFD was first induced by feeding a low-fiber, high-UFA diet (induction; 25.9% NDF, 7.1% FA, and 3.3% C18:2; Table 2). The recovery treatments that followed were a diet correcting dietary fiber and UFA (control; 31.8% NDF, 4.2% FA, and 1.65% C18:2); a diet correcting fiber, but not UFA [high oil (**HO**); 31.5% NDF, 6.6% FA, and 2.99% C18:2]; and a diet correcting UFA, but not fiber level [low fiber (**LF**); 28.4% NDF, 4.3% FA, and 1.71% C18:2]. The HO represents higher UFA and LF represents lower fiber relative to the control, respectively. Cows were fed the control diet during a 7-d washout between periods. The combination of the washout and induction provided 17 d between experimental diets and minimized the possibility of carry-over between experimental diets. Monensin (Rumensin 90; Elanco Animal Health, Greenfield, IN) was top-dressed to all cows at a rate of 450 mg/cow per day in 1.0 kg (DM basis) of cookie meal for the duration of the experiment. All cows received bST (Posilac; Elanco Animal Health) every 14 d.