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Jersey calf performance in response to high-protein, high-fat liquid feeds with varied fatty acid profiles: Blood metabolites and liver gene expression

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ABSTRACT

Most available Jersey calf milk replacers (CMR) use edible lard as the primary fat source, which lacks medium-chain fatty acids (MCFA). However, Jersey cow milk consists of over 10% MCFA. The objective of this trial was to determine whether altering the fatty acid profile of CMR by increasing the amount of MCFA would alter liver lipid infiltration, liver gene expression, and blood metabolites when fed to Jersey calves. Fifty Jersey calves were fed 1 of 4 diets: pasteurized saleable whole milk (pSWM) from Jersey cows [27.9% crude protein (CP), 33.5% fat, dry matter (DM) basis]; CMR containing 100% of fat as edible lard (100:00; 29.3% CP, 29.1% fat, DM basis); CMR containing 20% of fat as coconut oil (CO; 80:20; 28.2% CP, 28.0% fat); or CMR containing 40% of fat as CO (60:40; 28.2% CP, 28.3% fat). Liquid diet DM intake averaged 0.523, 0.500, 0.498, and 0.512 kg/d for pSWM, 100:00, 80:20, and 60:40, respectively. Calves were fed their assigned liquid diet daily at 0600 and 1800 h from 2 d of age until 7 wk of age, and once daily until 8 wk of age. Calves were taken off trial at 9 wk of age. Calves had access to water and grain (23.8% CP, 2.71% fat, DM basis). Grain DM intake averaged 0.386, 0.439, 0.472, and 0.454 kg/d for pSWM, 100:00, 80:20, and 60:40, respectively. Liver biopsy cores were obtained from 15 calves at 42 d of age (pSWM, n = 4; 100:00, n = 4; 80:20, n = 3; 60:40, n = 4) and from 4 baseline calves <2 d of age. Liver biopsy cores were used for histological appraisal of lipid infiltration and gene expression analyses of short-, medium-, and long- chain acyl-coenzyme A dehydrogenases, sterol regulatory element binding transcription factor 1, acetyl coenzyme A carboxylase, and fatty acid synthase. Lipid infiltration and expression of selected genes were not different among diets. After an overnight fast, weekly blood samples were taken immediately before feeding at 0600 h via jugular venipuncture in all calves. Serum and plasma obtained from blood samples were used in the analyses of total protein, glucose, triglycerides, nonesterified fatty acids, and plasma urea nitrogen (PUN). Nonesterified fatty acids and PUN were the only blood metabolites affected solely by diet. Nonesterified fatty acids decreased in a linear manner with increased dietary CO inclusion. Calves fed pSWM had higher PUN than calves fed 80:20. In this trial, altering the fatty acid profile of CMR with the addition of medium-chain fatty acids from CO had minimal effects on liver lipid infiltration, liver gene expression, and blood metabolites when fed to Jersey calves.

Key words: fatty acid, Jersey calf, coconut oil, milk replacer

INTRODUCTION

Many Jersey calves are currently fed calf milk replacer (**CMR**) that is formulated to match the needs of Holstein calves. These products typically contain 20 to 28% CP and 20% fat (DM basis). Inferior diets can negatively affect growth; for example, Bascom et al. (2007) observed that Jersey calves fed a 20% CP, 20% fat (DM basis) CMR at 15% of BW (adjusted weekly) had only minimal growth and the feeding method was not recommended. They also determined that the fat percentage of CMR intended for Jersey calves should be between 16 and 33% (DM basis; Bascom et al., 2007).

In the United States, Jersey cow milk averages 4.69% fat (fluid basis), whereas Holstein cow milk averages only 3.65% fat (fluid basis; USDA-AIPL, 2011). In addition to the difference in milk fat percentage between Jersey and Holstein cows, milk from Jersey cows contains more medium-chain FA (**MCFA**) than does Holstein cow's milk. On an equal volume basis, milk fat from Jersey cows contains more C10:0 and C12:0 (both MCFA) when compared with milk fat from Holstein cows (Morales et al., 2000).

Currently, the most popular fat source used in CMR for both Jersey and Holstein calves is edible lard, which has a different FA profile than found in either Jersey

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or Holstein cow milk. Edible lard consists of long-chain FA (**LCFA**), and lacks both short-chain FA (**SCFA**) and MCFA. Coconut oil (**CO**), which consists of approximately 47% MCFA (Palmquist, 1988), may be an additional fat source in CMR formulations intended for Jersey calves.

Coconut oil has been formulated into CMR and used in prior experiments (Jenkins et al., 1985; Piot et al., 1999; Graulet et al., 2000; Mills et al., 2010), but not in CMR for Jersey calves. Mills et al. (2010) found evidence of fatty liver development when preweaned Holstein calves were fed a CMR (28% CP, 23% fat; DM basis) containing CO with a total FA profile of 32% medium-chain triglycerides (**TG**). Mills et al. (2010) suspected that this type of fatty liver most likely represents the calf liver's inability to metabolize dietary fat in a timely manner.

Carbon chain length of dietary FA is important because it determines when and via which route the FA reaches the liver (Hocquette and Bauchart, 1999). The SCFA and MCFA up to 8 carbons in length can be absorbed in the abomasum, and MCFA up to 12 carbons in length can be absorbed in the small intestine. In these scenarios, NEFA first enter the portal vein, and then travel directly to the liver. In contrast, LCFA are absorbed into enterocytes, re-esterified into TG, and then incorporated into a chylomicron before release into the lymphatic system. Chylomicrons absorbed from the diet arrive at the liver after travel through the lymphatic system, arterial system, capillary beds, and venous system. Given the different routes, dietary SCFA and MCFA reach the liver faster in comparison to LCFA (Singh, 1997).

Because of the association between MCFA intake and liver metabolism, we studied Jersey calves fed liquid diets with varying amounts of MCFA from CO and assessed liver histology to evaluate degree of fat infiltration and liver gene activity. Genes of interest were short-chain acyl-CoA dehydrogenase (**SCAD**), medium-chain acyl-CoA dehydrogenase (**MCAD**), long-chain acyl-CoA dehydrogenase (**LCAD**), sterol regulatory element-binding transcription factor 1 (**SREBF-1**), fatty acid synthase (**FASN**), and acetyl-CoA carboxylase (**ACACA**). It was also of interest to study select blood metabolites involved with both lipid metabolism (NEFA and TG) and overall metabolism [glucose, plasma urea nitrogen (**PUN**), and total protein (**TP**)] to track pattern changes due to diet, time, or both.

The first hypothesis of this study was that feeding CMR diets containing 0, 20, or 40% of total fat as CO to Jersey calves would result in either linear or quadratic effects on lipid deposition in the liver, gene expression in the liver, and blood metabolites. The second hypothesis was that feeding a CMR diet containing 20% of total fat as CO to Jersey calves would result in similar lipid deposition in the liver, gene expression in the liver, and blood metabolites when compared with Jersey calves fed pasteurized Jersey saleable whole milk. Results of diet effects on DMI, total fat intake, individual FA intake, body growth, and health measures for these same animals are reported in detail in a companion paper (Bowen Yoho et al., 2013). Tables 1 to 3 summarize those data.

MATERIALS AND METHODS

Animals and Treatments

Animal procedures described herein were approved by The Ohio State University Institutional Animal Care and Use Committee (Protocol #2010A00000186). Calves were enrolled in the study as they were born until a total of 50 calves was reached (male, n = 18; female, n = 32). Calves were individually housed and fed at the Waterman Dairy Farm at The Ohio State University. The trial was conducted from November 2010 to August 2011. A randomized complete block design with 4 treatments was used. Calves were blocked by sex, parity of dam, and date of birth, and assigned to 1 of 4 liquid feeds. One liquid feed was pasteurized (72°C for 30 s) saleable whole milk (**pSWM**; n = 12) from the Jersey herd at Waterman Dairy. The pSWM was 27.9% CP, 33.5% fat (DM basis). The other 3 liquid feeds were CMR varying in FA profile. These 3 CMR were intended to be isonitrogenous and isocaloric, with dried whey, whey protein concentrate, dried whey product, dried skim milk, and dried milk protein included as protein sources. The CMR diets differed only in FA profile, which was a result of the fat sources used. Diet 100:00 (n = 13) contained only edible lard as the fat source (Cow's Match-Jersey Blend, 29.3% CP, 29.1% fat (DM basis); Land O'Lakes Animal Milk Products, Shoreview, MN). Diet 80:20 (n = 13) contained edible lard (80%) and CO (20%) as fat sources (this was 28.2% CP, 28.0% fat; DM basis). Diet 60:40 (n = 12) contained edible lard (60%) and CO (40%) as fat sources (28.2% CP, 28.3% fat; DM basis). All CMR diets were formulated and blended by Land O'Lakes Animal Products Company and were nonmedicated. Composition of diets is summarized in Table 1. The CMR was reconstituted to 15% milk powder (ca. 13.8% solids) and fed at 40.0 to 43.0°C. Calves were fed their respective liquid diet twice daily (0600 and 1800 h) from 2 d of age until 7 wk of age, and once daily until weaning (8 wk of age). During the first week of life, all calves were fed 1.9 L of liquid at each feeding. During wk 2 through 8 of life, calves were fed 2.27 L of liquid