Can Stable Isotopes of Carbon and Nitrogen in Hair and Feces Be Used to Predict Dairy Cow Susceptibility to Periparturient Production-related Metabolic Diseases (PRMDs)?

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Introduction

Periparturient PRMDs (fatty liver, ketosis, displaced abomasum, mastitis, +/- concurrent infections) cause decreased milk yield, medication costs, and increased culling. Progress has been made with transition diets, dietary CAD, avoiding over conditioning, and identifying when most PRMDs occur, but the incidence has remained stable. Elevated serum concentrations of FFAs, NEFAs, TG, BHBA, and hepatic TG:glycogen ratios have been correlated with increased risk of PRMDs. Cows are most susceptible to PRMDs during the rapid increase in milk secretion when a glucose drain occurs, and blood glucose and insulin concentrations are decreased. However, increased energy demand of later fetal growth and lactogenesis cause compensatory prepartum serum NEFA release. Risk of subsequent LDA has been correlated with elevated prepartum NEFA and postpartum BHBA serum concentrations. Animal substrates and metabolic by-products differ in their carbon and nitrogen isotopes. Lipid fractions have a more depleted $^{13}C/^{12}C$ ratio ($\delta^{13}C$) than protein and carbohydrate fractions. Hair $\delta^{13}C$ values reflect the C isotope composition of dietary protein, rather than the composition of the whole diet, and should become more enriched if exogenous protein is used for hair formation. However, if endogenous lipid and protein stores are mobilized for energy, the $\delta^{13}C$ values in substrates should become more depleted, and $^{15}N/^{14}N$ ratios ($\delta^{15}N$) should become more enriched. The objective of this study was to determine the usefulness of $\delta^{13}C$ and $\delta^{15}N$ from hair and feces to accurately predict which peripartum cows will develop PRMDs.

Materials and Methods

Randomly chosen, age, lactation, and parity matched primiparous, and multiparous Holstein cows at Brigham Creek Dairy (Elberta, UT) were studied. Hair and feces were sampled 21 days prepartum (P1), at parturition (P2), and 21 days postpartum (P3). Cow weekly milk production (MP) was recorded. Feces samples were frozen, freeze-dried, ground, and homogenized. Hair samples were cleaned via sonication. Samples of feces and mm lengths of hair (range of 0.3 to 0.6 mg) were weighed in tin capsules with a microbalance for analysis of %C, %N, $\delta^{13}C$, $\delta^{15}N$, and C:N ratios. Combusted samples were analyzed in duplicate using an elemental analyzer coupled to a DeltaV isotope ratio mass spectrometer to isolate C and N for $\delta^{15}N$ and $\delta^{13}C$ analysis by atomic weight. All ratios were expressed in parts per mil (‰) relative to C and N standards Pee Dee Belemnite and atmospheric nitrogen. Samples were corrected using external standards for carbon, UCLA Carrera and LSVEC, and nitrogen, USGS 25 and 26. Health score (HSC) ranking: 1 (healthy, adequate MP), 2 (illness, recovery, adequate MP), 3 (culled poor MP +/- PRMD), 4 (died), and 5 (culled/died +/- PRMD 1-5 mos postpartum). Data were analyzed using SAS. Discriminant analysis, grouping variable HSC, was performed for each pre- and postpartum hair and feces measure. PROC GLM, independent variable HSC, determined if hair and feces measures were different for cows with HSC 3, 4, 5. Significance level of $P<0.05$ for all tests.

Results

The interaction of HSC and P3 weekly average lactation was not well correlated with $\delta^{15}N$ and $\delta^{13}C$ isotopic signatures in hair. Mean $\delta^{15}N$ and $\delta^{13}C$ values in hair were less predictive of HSC. In order, the best predictor of HSC during and after the transition period was P2 feces $\delta^{13}C$ and P1 feces $\delta^{15}N$. These parameters correctly predicted 75% of cows with HSC 3, and all with HSC 4 and 5. HSC 1 cows were correctly classified 58% of the time, but incorrectly classified 21%, 7%, and 1% as HSC 3, 4, and 5, respectively.

Significance

The goal of this study was to provide a reliable predictive tool to detect subclinical cows at risk of PRMDs. Prepartum and parturient carbon and nitrogen stable isotopes in feces can identify cows at high risk of PRMDs, and may provide an economical method for early intervention to increase profit margins.