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Residual feed intake is repeatable for lactating Holstein dairy cows fed high and low starch diets

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ABSTRACT

Residual feed intake (RFI) is a tool to quantify feed efficiency in livestock and is commonly used to assess feed efficiency independent of production level, body weight (BW), or BW change. Lactating Holstein cows (n = 109; 44 primiparous and 65 multiparous), averaging (mean ± standard deviation, SD) 665 ± 77 kg of BW, 42 ± 9 kg of milk/d, and 120 ± 30 d postpartum, were fed diets of high (HI) or low (LO) starch content in 4 crossover experiments with two 28-d treatment periods. The LO diets were ∼40% neutral detergent fiber (NDF) and ∼14% starch and the HI diets were ∼26% NDF and ∼30% starch. Individual dry matter intake (DMI) of a cow was modeled as a function of milk energy output, metabolic BW, body energy change, and fixed effects of parity, experiment, cohort nested within experiment, and diet nested within cohort and experiment; RFI for each cow was the residual error term. Cows were classified as high (>0.5 SD of the mean), medium (±0.5 SD of the mean), or low (<−0.5 SD of the mean) RFI. On average, for the linear model used to determine RFI for individual cows, each unit increase in milk energy output, metabolic BW, or body energy gain was associated with 0.35, 0.09, or 0.05 kg increase in DMI, respectively. When compared with LO diets, HI diets increased energy partitioning to body energy gain and tended to increase DMI. The correlation between RFI when cows were fed HI diets and RFI when cows were fed LO diets was 0.73 and was similar across each parity and experiment. Fifty-six percent of cows maintained the same RFI classification (high, medium, or low RFI) and only 4 of 109 cows changed from high RFI to low RFI or vice versa when diets were changed. Milk:feed, income over feed cost, and DMI were also highly repeatable (r = 0.72, 0.84, and 0.92, respectively). We achieved significant changes in milk yield and component concentration as well as energy partitioning between HI and LO diets and still determined RFI to be repeatable across diets. We conclude that RFI is reasonably repeatable for a wide range of dietary starch levels fed to mid-lactation cows, so that cows that have low RFI when fed high corn diets will likely also have low RFI when fed diets high in nonforage fiber sources.

Key words: dairy cow, residual feed intake, feed efficiency, repeatability, dietary starch

INTRODUCTION

Residual feed intake (**RFI**) is calculated as the residual in the linear model to predict feed intake of individual animals, and thus is essentially the difference between an individual's observed feed consumption and its predicted feed consumption. An animal with a negative RFI consumes less than expected for its level of production and thus is more efficient when RFI is used to define feed efficiency. Because RFI is independent of production level, recent attention has been given to using RFI as a tool to assess feed efficiency in dairy cattle for purposes of genetic selection (Connor et al., 2013; Green et al., 2013; Macdonald et al., 2014). The heritability of RFI is 0.15 to 0.19 in lactating dairy cattle (van Arendonk et al., 1991; Tempelman et al., 2015) and 0.22 to 0.38 in growing dairy heifers (Williams et al., 2011; Pryce et al., 2012). If RFI is to be used in selection strategies, it is important to know if it is repeatable across the range of diets commonly used on commercial dairy farms.

Residual feed intake was moderately repeatable across 2 consecutive feeding periods for replacement beef heifers classified as high (>0.5 SD), medium (±0.5 SD), and low (<−0.5 SD) RFI (Durunna et al., 2012). However, in that study, only 49% of all heifers maintained their feed efficiency classification from one period to the next; 28% of all heifers changed their RFI ranking by more than ±1 SD, but only 6% of heifers changed from the high RFI group to the low RFI group or vice versa. Connor et al. (2013) determined that RFI was repeatable across weeks (0.47) for Holstein dairy cows in early lactation. Kelly et al. (2010a,b) investigated repeatability of RFI in beef heifers across growing and finishing stages when fed grower and finisher diets and determined that RFI measured during the growing pe-

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riod and RFI measured during the finishing period were moderately correlated (r = 0.62). However, Durunna et al. (2011) examined the repeatability of RFI between 2 consecutive periods for beef steers fed a grower diet, and subsequently a finisher diet, and observed that RFI was less repeatable (r = 0.33).

Many of the dairy cows used in current estimates of RFI were fed diets that were high in concentrate. In the future, competition for feed grains might limit their availability for use in dairy cattle diets. The goal in selecting for feed efficiency in dairy cows is to find cows that are efficient across many types of diets, so that those efficient when fed the high starch diets typical of the Midwestern United States at present will also be efficient when consuming lower starch diets that might be fed currently in other areas of the world or in the future when high starch concentrates could be less available. The objective of this experiment was to determine if RFI is repeatable when lactating dairy cows are fed diets that differ markedly in starch content. We hypothesized that RFI and other measures of feed efficiency would be repeatable across high and low starch diets fed to lactating dairy cows.

MATERIALS AND METHODS

Cows, Experimental Design, and Diets

Experimental procedures were approved by the Institutional Animal Care and Use Committee of Michigan State University. Data from 4 separate crossover experiments were used to determine the repeatability of RFI across high and low starch diets. Lactating Holstein cows were fed diets that differed in starch content in experiments 1 (n = 32; 22% primiparous), 2 (n = 25; 40% primiparous), 3 (n = 32; 50% primiparous), and 4 (n = 20; 55% primiparous). Treatment effects for experiments 1 and 3 have been reported as separate publications (Boerman et al., 2015a,b). Mean DIM, BW, and milk yield for cows across all 4 experiments (mean ± SD) were 120 ± 30 d, 665 ± 77 kg, and 42 ± 9 kg/d, respectively, at the beginning of the first experimental period. Each experiment consisted of two 28-d treatment periods during which experimental diets were fed. During each experiment, cows were fed a common diet for 3 to 14 d before the first treatment period (14, 5, 7, or 3 d for experiments 1, 2, 3, and 4, respectively). Because individual RFI is relative to cohorts, which were defined as cows that consumed the same diet at the same time (i.e., same diet sequence within an experiment), it was not necessary to include a washout period between the 2 treatment periods. Because all cows within a cohort underwent diet changes at the same time, this probably had a minimal effect on RFI ranking within cohort.

Within each experiment, cows were blocked based on parity as well as BW and milk yield data from the common-diet-period and randomly assigned to treatment sequence. Throughout each experiment, cows were housed in individual tie stalls in the same barn and milked twice daily (0300 and 1430 h). Water was available ad libitum and feed was offered once daily at 1000 h (experiments 2 and 4) or 1200 h (experiments 1 and 3) at >110% of expected intake based on intake of the previous day. Tie stalls were equipped with a double-cupped watering system to prevent contamination of feed with water and with side panels and a front gate to prevent other cows from stealing feed during cow movements.

During the 28-d treatment periods for each experiment, cows were fed high (**HI**) or low (**LO**) starch diets, which were formulated to be markedly different in starch content. Ingredient and nutrient composition of HI and LO diets fed throughout each of the 4 experiments are shown in Table 1. On average, all HI diets contained about 30 to 35% corn grain and were measured to be about 26% NDF and 30% starch. The LO diet in experiment 1 was formulated to be 12% starch by replacing ground corn with soybean hulls. The LO diet in experiment 2 was formulated to be 16% starch by replacing ground corn and wheat straw with soybean hulls. The LO diet in experiment 3 was 16% starch and was formulated by replacing ground corn and portions of high moisture corn and wheat straw with legume silage, soybean hulls, whole cottonseed, and a palmitic acid enriched FA supplement (98% total FA). In experiment 4, the LO diet was 12% starch, being derived by replacing ground corn, wheat straw, and portions of both corn and legume silages with soybean hulls and whole cottonseed. Although diets across experiments were formulated with different concentrations of ingredients, distinct differences in starch content between HI and LO were achieved within the experiment, and in all cases milk production or nutrient partitioning was altered by diet. Diets were adjusted for changes in forage DM concentration twice weekly to maintain the desired composition.

Sample Collection and Analysis

Cows were fed once per day and orts were removed and weighed daily before feeding. Milk yield was recorded electronically at each milking, and milk samples were obtained from 4 consecutive milkings per week (d 6, 7, 13, 14, 20, 21, 27, and 28 of each period in experiments 1, 2, and 4; d 4, 5, 11, 12, 18, 19, 25, and 26 of each period in experiment 3). Milk samples were

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