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Relationship between residual feed intake and digestibility for lactating Holstein cows fed high and low starch diets

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ABSTRACT

We determined if differences in digestibility among cows explained variation in residual feed intake (RFI) in 4 crossover design experiments. Lactating Holstein cows (n = 109; 120 ± 30 DIM; mean ± SD) were fed diets high (HS) or low (LS) in starch. The HS diets were 30% (±1.8%) starch and 27% (±1.2%) neutral detergent fiber (NDF); LS diets were 14% (±2.2%) starch and 40% (±5.3%) NDF. Each experiment consisted of two 28-d treatment periods, with apparent total-tract digestibility measured using indigestible NDF as an internal marker during the last 5 d of each period. Individual cow dry matter (DM) intake and milk yield were recorded daily, body weight was measured 3 to 5 times per week, and milk components were analyzed 2 d/wk. Individual DM intake was regressed on milk energy output, metabolic body weight, body energy gain, and fixed effects of parity, experiment, cohort (a group of cows that received treatments in the same sequence) nested within experiment, and diet nested within cohort and experiment, with the residual being RFI. High RFI cows ate more than expected and were deemed less efficient. Residual feed intake correlated negatively with digestibility of starch for both HS (r = −0.31) and LS (r = −0.23) diets, and with digestibilities of DM (r = −0.30) and NDF (r = −0.23) for LS diets but was not correlated with DM or NDF digestibility for HS diets. For each cohort within an experiment, cows were classified as high RFI (HRFI; >0.5 SD), medium RFI (MRFI; ±0.5 SD), and low RFI (LRFI; <−0.5 SD). Digestibility of DM was similar (~66%) among HRFI and LRFI for HS diets but greater for LRFI when fed LS diets (64 vs. 62%). For LS diets, digestibility of DM could account for up to 31% of the differences among HRFI and LRFI for apparent diet energy density, as determined from individual cow performance, indicating that digestibility explains some of the between-animal differences for the ability to convert gross energy into net energy. Some of the differences in digestibility between HRFI and LRFI were expected because cows with high RFI eat at a greater multiple of maintenance, and greater intake is associated with increased passage rate and digestibility depression. Based on these data, we conclude that a cow's digestive ability explains none of the variation in RFI for cows eating high starch diets but 9 to 31% of the variation in RFI when cows are fed low starch diets. Perhaps differences in other metabolic processes, such as tissue turnover, heat production, or others related to maintenance, can account for more variation in RFI than digestibility.
Key words: digestibility depression, feed efficiency, dry matter intake

INTRODUCTION

Residual feed intake (**RFI**) has been used to assess feed efficiency in beef cattle (Richardson et al., 2004; Nkrumah et al., 2006; Lawrence et al., 2011), swine (Harris et al., 2012), poultry (Luiting et al., 1994; Mignon-Grasteau et al., 2004), and dairy cattle (Rius et al., 2012; Tempelman et al., 2015; VandeHaar et al., 2016). Residual feed intake is a tool used to evaluate feed efficiency and is the difference between what an animal consumes and what it is predicted to consume (Koch et al., 1963); it quantifies feed efficiency within a production level so it is independent of the dilution of maintenance as determined on a requirement basis. Within a given production level, cows with low RFI are deemed more efficient because they eat less than contemporaries. Low RFI cows are able to convert gross energy to net energy more efficiently because they have improved digestive and metabolic efficiencies, or have lower maintenance requirements than expected for a given BW.

The relative contributions of the specific biological mechanisms that explain differences in RFI among animals are not clear. For finishing beef steers, Richardson and Herd (2004) hypothesized that variation in RFI was due to feeding patterns (2%), activity level (10%), protein turnover and tissue metabolism (37%), body composition (5%), heat increment of feeding (9%),

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digestibility (10%), and other undefined metabolic processes (27%). Total-tract digestibility is a reflection of both diet digestibility and the digestive ability of the animal. Animals with greater digestive ability lose less energy in feces and are expected to be more energetically efficient than contemporaries consuming the same diet. Previous studies in dairy heifers (Rius et al., 2012) and beef steers (Richardson et al., 1996; Nkrumah et al., 2006) have demonstrated that animals classified as low RFI also had improved digestibility. Additionally, broilers selected divergently for digestive efficiency differed in RFI, with broilers of the high digestive efficiency line having lower RFI than birds of the low digestive efficiency line (Mignon-Grasteau et al., 2004).

Differences in digestibility between high and low RFI animals may be dependent on the type of diet the animal consumes. Rougière et al. (2009) studied lines of broilers selected for digestive efficiency, which were also divergent for RFI, and determined that feeding diets of coarse particle size that increased gut retention time resulted in improved digestibility for the low but not the high digestive efficiency line. Hernandez-Sanabria et al. (2012) showed that the proportion of *Eubacterium* sp. in rumen fluid samples differed between high and low RFI cattle when a 100% concentrate diet was fed, but not when an 80% concentrate diet was fed. In contrast, Carberry et al. (2012) observed stronger relationships between RFI and rumen microbial population proportions when cattle were fed a high forage (100%) compared with a low forage (30%) diet. Both of these studies suggest that the relationship between RFI and rumen microbial communities, and thus ruminal digestion, may be affected by the type of diet fed.

We hypothesized that (1) digestibility would account for some of the variation in RFI and that low RFI cows would have improved digestibility compared with high RFI cows, and (2) this relationship would differ for diets high compared with low in starch. Our objective in the present study was to determine if digestibility accounts for variation in RFI in lactating dairy cows fed high (**HS**) and low (**LS**) starch diets.

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, described by Potts et al. (2015), were used to determine the relationship between RFI and digestibility. Lactating Holstein cows were fed diets that differed in starch concentration in experiments 1 (n = 32), 2 (n = 25), 3 (n = 32), and 4 (n = 20). Treatment effects for experiments 1 and 3 are reported in separate publications (Boerman et al., 2015a,b). Cows (n = 109) averaged (mean ± SD) 120 ± 30 DIM, 42 ± 9 kg of milk/d, and 665 ± 77 kg of BW at the beginning of the experiments. Each experiment consisted of two 28-d treatment periods during which HS or LS diets were fed. Prior to the first treatment period in each experiment, cows were fed a common diet for 14, 5, 7, and 3 d for experiments 1, 2, 3, and 4, respectively. Cows were blocked based on pre-treatment-period milk yield and parity and randomly assigned to treatment sequence. Cows were housed in individual tie stalls and milked twice daily (0300 and 1430 h) in a milking parlor. Water was available ad libitum, and tie stalls were equipped with a double-cupped watering system to prevent contamination of feed with water and a front gate to prevent other cows from stealing feed during cow movements to and from the milking parlor.

During each experiment, cows were fed HS or LS diets (Table 1). On average, HS diets were 30% (±1.8%) starch and 27% (±1.2%) NDF, and contained 30 to 35% corn grain; LS diets were 14% (±2.2%) starch and 40% (±5.3%) NDF, with soybean hulls replacing a proportion of corn grain. In experiment 3, the LS diet also contained a fat supplement and more legume silage than HS. In experiments 2 and 4, LS diets contained less forage than HS. Diets were adjusted for changes in forage DM concentration twice weekly.

Data and Sample Collection

Cows were fed once daily at 1000 h (experiments 2 and 4) or 1200 h (experiments 1 and 3) for >110% of expected intake based on intake from the previous 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. Milk samples were analyzed for fat, true protein, lactose, somatic cells, and milk urea nitrogen with infrared spectroscopy (AOAC, 1990, method 972.160) by Michigan DHIA (Universal Lab Services, Lansing, MI). Body weight for each cow was recorded 3 (experiments 2, 3, and 4) or 5 (experiment 1) times per week immediately after the morning milking. Body condition score was determined on a 5-point scale in 0.25-unit increments, where 1 = thin and 5 = fat, as described by Wildman et al. (1982), by 3 trained investigators and recorded for each cow at the beginning and end of each period.

Sampling procedures were the same for all 4 experiments. Samples of feces, orts, and feed ingredients were collected during the last 5 d of each treatment period to estimate nutrient digestibility. Samples of feces were collected every 15 h (2400, 0230, 0600, 0900, 1200, 1500,