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Fecal starch as an indicator of total-tract starch digestibility by lactating dairy cows

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ABSTRACT

To test whether total-tract starch digestibility by lactating dairy cattle could be predicted accurately from concentration of starch in fecal dry matter (FS), data from 8 digestibility trials, 30 diets, and 564 individual starch measurements were compiled from trials conducted at the University of Wisconsin-Madison. Total-tract starch digestibility by individual cows was determined from the concentrations of starch in total mixed rations and feces (rectal grab samples) and concentrations of several external or intrinsic feed markers. Fecal starch concentration was closely and linearly related to total-tract starch digestibility (R^2 = 0.94). Differences in fecal sampling time for FS, such as day within week or week, did not influence determination of FS concentration. In contrast, time of day when fecal samples were taken influenced FS concentration, but the differences were minimal (mean ± standard error of the mean = 0.4 ± 0.1). These data suggest that on-farm collection of feces from individual cows or pens of cows may be sampled only once per day. Fecal pH was not related to FS when FS was only 1 to 3%, indicating that fecal pH was not a good index of FS and not practical as a tool to assess total-tract starch digestibility for lactating dairy cows when fecal starch excretion is low. An equation was developed to predict FS using near-infrared reflectance spectroscopy of dried ground fecal samples; the equation had moderate to good accuracy (R^2 = 0.83–0.94) and a low standard error of prediction. Fecal starch concentration can be used to monitor total-tract starch digestibility.

Key words: digestibility, lactating cow, starch

INTRODUCTION

Interest in improving starch digestibility by lactating dairy cows has been stimulated by the high cost of cereal grains. An increase in total-tract starch digestibility (**TTSD**) can increase yield of milk and protein and feed efficiency (Firkins et al., 2001). Total-tract digestibility of starch in dairy cows ranges from 70 to 100% (Firkins et al., 2001; Ferraretto et al., 2013) and is influenced by numerous factors such as particle size, grain processing, and storage method (Firkins et al., 2001; Ferraretto et al., 2013); harvest maturity, moisture content, and duration of silo fermentation (Hoffman et al., 2011; Ferraretto and Shaver, 2012b); and corn endosperm type (Taylor and Allen, 2005; Lopes et al., 2009). Currently, one common method to estimate the amount of starch that escapes digestion is to sieve fecal material and qualitatively estimate the amount of grain caught by the screen (Hall, 2002). Combined with measurements of the dietary starch concentration and in vitro starch digestibility of feedstuffs, such measurements should lead to ration adjustments when the amount of grain found in feces is excessive (Hall, 2002). Commercial laboratories offer a wet chemistry measurement of starch concentration in feces; estimates of starch availability based on enzyme, yeast, or in vitro incubation; and quantitative measurements of total-tract nutrient digestibility, including starch, that require nutrient analysis of TMR and feces.

Fecal starch concentration (**FS**) proved to be an accurate indicator of TTSD by feedlot cattle (Zinn et al., 2002; Corona et al., 2005), and FS has been used to assess the effectiveness of grain processing (Zinn et al., 2007). Fernandez et al. (1982) first reported a relationship between TTSD and FS for lactating dairy cows. In a literature review, Owens and Zinn (2005) also reported a modest relationship (R^2 = 0.73) between FS and TTSD by lactating dairy cows.

More recently, J. D. Ferguson (University of Pennsylvania, Philadelphia, PA; personal communication), as referenced by Grant (2010), reported that TTSD could be estimated from FS in lactating dairy cows on commercial farms from samples of TMR and feces. Starch and lignin concentrations were determined for the TMR and pen fecal composites to calculate TTSD; a negative relationship between FS and TTSD was detected (R^2 = 0.73).

Experimental objectives of this research were to (1) develop an equation to estimate TTSD from FS mea-

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sured in controlled research trials; (2) determine the distribution and variation for FS concentrations associated with week, day within week, and time within day of sample collection; (3) examine the relationship between fecal pH and FS; and (4) evaluate the potential for developing a near-infrared reflectance spectroscopy (**NIRS**) technique and equation for quantifying FS.

MATERIALS AND METHODS

All experimental procedures and animal use protocols were approved by the Research Animal Resource Committee of the College of Agricultural and Life Sciences of the University of Wisconsin-Madison.

Fecal Starch Equation

To develop an equation to estimate TTSD from FS, data from 8 trials at the University of Wisconsin-Madison from 1997 to 2012 were compiled. These trials are described in Table 1. Across all trials, lactating Holstein cows ranged from 29 to 151 DIM at the start of the trials. Cow within each experiment served as the experimental unit except in the trial by Ferraretto et al. (2012), where gate feeders (RIC system, Insentec, Marknesse, the Netherlands; 1.40 m deep, 0.80 m wide, and 0.75 m high; 2 cows per gate) served as the experimental unit. All diets were fed as a TMR with daily DMI for individual cows or gates calculated as feed delivered daily minus daily refusals. Starch intake was corrected for the concentration of starch remaining in the refusals. Fecal grab samples were collected from each cow twice at 1000 and 2200 h during the last 3 d of each period for Bal et al. (1997) and at 1100 and 2300 h on d 24 through 26 for Schwab et al. (2002); or thrice at 1000, 1600, and 2200 h during the last 3 d of each period for Bal et al. (2000a) and at 0800, 1400, and 2000 h during the last 3 d of each period for Bal et al. (2000b). Six fecal grab samples were collected at 8-h intervals covering each 4-h clock period over 3 consecutive days during each period for Lopes et al. (2009), or during wk 8 of the treatment period for Gencoglu et al. (2010), or during wk 4 and 8 of the treatment period for Ferraretto et al. (2012). For all trials, TMR and fecal samples were dried at 60°C for 48 to 72 h in a forced-air oven and ground through a 1-mm screen with a Wiley mill (Arthur H. Thomas, Philadelphia, PA; Bal et al., 1997). To calculate digestibility from concentrations of nutrients in the TMR and feces, external or intrinsic marker techniques were employed (Table 1). Analysis of starch, rare-earth markers, lignin, and indigestible NDF were conducted as described in the individual papers. Apparent TTSD for each cow fed each diet in each period was calculated using the following equation (Bal et al., 1997):

$$\text{Apparent TTSD (\% of DM)} = 1 - [(\text{TMR marker concentration/fecal marker concentration}) \times (\text{FS concentration/TMR starch concentration})].$$

The distribution of FS was determined using data from 15 trials conducted at the University of Wisconsin-Madison from 1997 to 2012. Trials included in the distribution plot were the 8 trials used to determine the TTSD equation, plus Ferraretto and Shaver (2012a), Akins et al. (2014), and 6 unpublished trials (Arndt et al., 2009; Ferraretto and Shaver, 2013; Fredin et al., 2013a,b; Lopes et al., 2013a,b). Distribution data included cow, gate, or pen as the experimental unit with samples obtained from continuous-lactation or Latin square trials. Fecal grab sampling methods and TTSD calculations for all trials were similar to procedures described previously. Starch concentration in feces was analyzed as described by Ferraretto et al. (2012) for the experiments by Ferraretto and Shaver (2012a), Akins et al. (2014), and the 6 unpublished trials (Arndt et al., 2009; Ferraretto and Shaver, 2013; Fredin et al., 2013a,b; Lopes et al., 2013a,b).

Fecal Starch Sampling Variation

The effect of fecal sampling time on FS for day within week, week, and time within day was determined within a trial conducted in our laboratory (Akins et al., 2014). One-hundred twenty-eight cows stratified by DIM (90 ± 33 DIM), breed (Holstein and Holstein × Jersey crossbred), and parity (primi- and multiparous) were assigned randomly to 1 of 16 pens with 8 cows per pen in the University of Wisconsin sand-bedded freestall barn (Emmons Blaine Dairy Research Center, Arlington, WI). Each pen contained 3 primiparous Holstein, 3 multiparous Holstein, and 2 multiparous Holstein × Jersey crossbred cows that were used in a continuous-lactation trial with a 4-wk covariate period followed by a 12-wk treatment period. All cows received the same diet during the covariate period followed by a change to 1 of 4 treatment diets during the test period. Diets were fed once daily as a TMR. Pens were supplied with TMR to allow 5% refusals, with daily DMI determined on a pen basis throughout the trial. Daily pen refusals were recorded and removed each morning before delivery of fresh feed. Fecal samples were collected just before feeding (0 h) and 12 h postfeeding during the last 2 d of the covariate period and in wk 6 and 12 of the treatment period. Fecal samples were