J. Dairy Sci. 101:1–14
https://doi.org/10.3168/jds.2017-13337

Polyethylene glycol as an indigestible marker to estimate fecal output in dairy cows

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ABSTRACT

The objective of this study was to evaluate the accuracy of fecal output measurements using polyethylene glycol (PEG) as an external marker determined by near-infrared reflectance spectroscopy. In addition, the accuracy of dry matter intake predictions based on fecal output and digestibility estimated using an internal marker [indigestible neutral detergent fiber (iNDF)] was assessed. The experiment was conducted using 6 lactating dairy cows fed 2 different diets. Polyethylene glycol was administered twice daily into the rumen and the diurnal pattern of fecal concentrations and recovery in feces were determined. To evaluate the effects of alternative marker administration and sampling schemes on fecal output estimates, the passage kinetics of PEG in the digestive tract of dairy cows was determined and used for simulation models. The results indicate that PEG was completely recovered in feces and, thus, fecal output was accurately estimated using PEG. Good agreement between measured and predicted dry matter intake (standard error of prediction = 0.86 kg/d, R^2 = 0.81) indicates good potential to determine feed intake using PEG in combination with iNDF. The precision of cow-specific digestibility estimates based on iNDF was unsatisfactory, but for a group of cows iNDF provided an accurate estimate of dry matter digestibility. The current study indicated that, to overcome inherent day-to-day variation in feed intake and fecal output, the minimum of 4 fecal spot samples should be collected over 4 d. Preferably, these samples should be distributed evenly over the 12-h marker administration interval to compensate for the circadian variation in fecal PEG concentrations.

Key words: polyethylene glycol, dairy cow, digestibility, feed intake

INTRODUCTION

Daily feed intake is an essential part of feed efficiency measurements in dairy herds, but direct measurements are difficult to carry out without specific equipment. Thus far, such equipment has been available only on dedicated research farms. If DMI of individual animals cannot be measured directly, it must be estimated using indirect methods. Several indirect techniques to estimate DMI have been proposed and evaluated (Holloway et al., 1981; Lippke 2002; Decruyenaere et al., 2012). Attempts have been made to establish relationships between fecal components, DMI, and DM digestibility (Holloway et al., 1981) or estimate fecal output and DM digestibility using a combination of internal and external markers (Kotb and Luckey, 1972; Mayes et al., 1986; Lippke, 2002). Fecal output is closely related to DMI because it is the product of DMI and DM digestibility. Fecal output can be estimated using external markers that are administered to an animal either continuously or at frequent intervals to ensure uniform distribution of markers in feces. Nonuniform distribution necessitates frequent collection of fecal grab samples to overcome diurnal variation in marker excretion pattern. If DM digestibility is known or can be determined by reference to an internal marker, then feed intake can be estimated from fecal output. Alternatively fecal output could be used as a proxy measurement for DMI within a group of animals consuming the same diet. Assuming only a small variation in digestibility between animals, fecal output is highly correlated with feed intake. Quantitatively, the differences between diets in OM digestibility can be considerably larger than those between animals. Kuoppala et al. (2010) reported 0.06-unit difference in OM digestibility between diets based on early- or late-harvested grass silages. In contrast, Mehtiö et al. (2016) estimated a coefficient of variation of 0.017 in OM digestibility between individuals fed the same diet. In addition to effects on digestibility, diets have substantial effects on DMI (Kuoppala et al., 2010).

Received June 15, 2017.
Accepted January 18, 2018.
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Several external markers have been introduced and applied in digestibility studies with ruminants. Chromium sesquioxide has been the most widely used external marker since early 1950s (Kane et al., 1950), but a water-soluble compound, polyethylene glycol (**PEG**), proposed for ruminants by Sperber et al. (1953) has gained recent interest since the introduction of improved analytical methodology (Landau et al., 2002). Earlier PEG utilization was hampered by the lack of simple and accurate analytical techniques, but near infrared reflectance spectroscopy (**NIRS**) appears to provide substantial improvements to obsolete techniques. Recent studies have demonstrated that PEG concentrations can be accurately determined using NIRS (Landau et al., 2002; Hassoun et al., 2013; Casasús and Albanell, 2014). If PEG concentrations in feces can be accurately determined using NIRS, it could be used in large-scale studies to estimate fecal output; however, as a soluble compound, PEG associates with the liquid phase of rumen digesta. Rumen liquid has considerably higher passage rate than rumen particles and, as a consequence, soluble compounds exhibit higher diurnal variation in fecal concentrations than insoluble substances. A rapid passage rate entails technical challenges in achieving uniform marker distribution in feces (i.e., small diurnal variation in fecal marker concentrations). If marker is uniformly distributed in feces, only a few spot samples need to be collected to attain reliable estimates of fecal output. These problems associated with soluble markers could be alleviated by increasing the frequency of marker administration or increasing the number of fecal spot samples. However, increased frequencies of marker administration or sample collection tend to decrease the benefits provided by the cost effective NIRS analysis of PEG.

The objective of the current study was to evaluate the accuracy of fecal DM output measurements in lactating dairy cows using PEG as an external marker determined by NIRS. In addition, the accuracy of DMI predictions based on fecal output and digestibility using internal marker was assessed. To evaluate the effects of alternative marker administration and sampling schemes on fecal DM output estimates, the passage kinetics of PEG in the digestive tract was determined.

MATERIALS AND METHODS

Animals, Diets, and Experimental Design

Six multiparous Nordic Red dairy cows equipped with 10-cm i.d. rumen cannulas (Bar Diamond, Inc., Parma, ID) were used as experimental animals, in compliance with the Finnish Act on the Use of Animals for Experimental Purposes (2013). The experimental procedures were approved by the National Animal Experiment Board. Cows were, on average, 105 DIM (SD 70.1) and weighed 698 kg (SD 63.0) at the beginning and 735 kg (SD 90.7) at the end of the experiment. Cows were housed in a tiestall barn with continuous access to water and salt blocks. They were milked twice daily at 0700 and 1645 h. The diet was offered 4 times daily at 0545, 0900, 1600, and 1900 h, according to appetite, allowing at least 5% for the refusals that were collected daily shortly before the first morning meal.

The experiment consisted of 3 periods that lasted for 26, 26, and 11 d, respectively. Two different diets were fed to introduce responses in terms of feed intake and fecal output and to assess the diet effects on marker behavior. To allocate these diets to cows on periods 1 and 2, animals were divided into 2 groups of 3 cows. In period 1, the first group was offered TMR that consisted of (on DM basis) 40% of concentrates (**TMR-40**) whereas the second group received TMR that consisted of 60% of concentrates (**TMR-60**). The diets were switched between groups at the beginning of period 2. Polyethylene glycol was administered twice daily into the rumen and the circadian pattern of fecal excretion and recovery in feces were determined. In period 3, cows remained on the same diet as on period 2 and PEG passage kinetics in the digestive tract were determined based on a single dose of PEG administered into the rumen and excretion pattern of PEG determined in feces.

The forage component of TMR consisted of grass silage that was prepared from a primary growth of sward mainly comprised of timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*). Concentrate mixture consisted (g/kg of DM) of barley (270), oats (250), molassed sugar beet pulp (250), solvent-extracted rapeseed meal (210), and mineral premix (20; Mahti Mira, Hiven Oy, Paimio, Finland). Chemical composition of grass silage, concentrate mixture, and experimental diets is presented in Table 1.

NIRS Calibration

For NIRS calibration, 66 fecal samples with determined PEG concentrations were prepared. In period 1, feces were collected on d 11 from each animal before the start of PEG administration. Between 0 to 4 g of PEG 6000 (average molecular weight 5,000–7,000, Merck KGaA, Darmstadt, Germany) was first dissolved in 25 mL of hot water in glass beakers, then mixed with 250 g of fresh feces on a metal tray lined with plastic foil. The beaker was rinsed with hot water to transfer PEG quantitatively to feces. The mixture of PEG and feces