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Effect of different levels of rapidly degradable carbohydrates calculated by a simple rumen model on performance of lactating dairy cows

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ABSTRACT

Aggregating rumen degradation characteristics of different carbohydrate components into the term modeled rapidly degradable carbohydrates (mRDC) can simplify diet formulation by accounting for differences in rate and extent of carbohydrate degradation within and between feedstuffs. This study sought to evaluate responses of lactating dairy cows to diets formulated with increasing levels of mRDC, keeping the supply of other nutrients as constant as possible. The mRDC content of feedstuffs was calculated based on a simple rumen model including soluble, washable, and nonwashable but potentially degradable fractions, as well as the fractional degradation and passage rates, of sugar, starch, neutral detergent fiber, and other carbohydrates. The mRDC term effectively represents the total amount of carbohydrates degraded in the rumen within 2 h after ingestion. Fifty-two lactating Holstein cows (of which 4 were rumen fistulated) were assigned to 4 treatments in a 4 × 4 Latin square design. Treatments were fed as a total mixed ration consisting of 25.4% corn silage, 23.1% grass silage, 11.6% grass hay, and 39.9% concentrate on a dry matter basis. Differences in mRDC were created by exchanging nonforage neutral detergent fiber-rich ingredients (mainly sugar beet pulp) with starch-rich ingredients (mainly wheat) and by exchanging corn (slowly degradable starch) with wheat (rapidly degradable starch) in the concentrate, resulting in 4 treatments that varied in dietary mRDC level of 167, 181, 194, or 208 g/kg of dry matter. Level of mRDC did not affect dry matter intake. Fat- and protein-corrected milk production and milk fat and lactose yield were greatest at 181 mRDC and decreased with further increases in mRDC. Milk protein yield and concentration increased with increasing mRDC level. Mean rumen pH and diurnal variation in ruminal pH did not differ between treatments. Total daily meal time and number of visits per meal were smaller at 181 and 194 mRDC. Despite milk production responses, increasing dietary mRDC levels, while maintaining net energy and intestinal digestible protein as well as other nutrients at similar levels, did not influence rumen pH parameter estimates and had minor effects on feeding behavior. These results indicate that aggregating rapidly degradable carbohydrate content into one term may be a simple way to further improve predictability of production responses in practical diet formulation for lactating dairy cows.
Key words: rapidly degradable carbohydrate, rumen model, milk production, dairy cow

INTRODUCTION

Milk production and composition are of major importance to the economics of a dairy farm and to a large extent depend on energy and protein intake of the cow (Huhtanen and Nousiainen, 2012; Daniel et al., 2016). Several systems calculate ME or NE_L and MP values for individual feedstuffs based on estimates of rumen fermentation and intestinal or total-tract digestibility of nutrients (Tylutki et al., 2008; Volden, 2011; CVB, 2012). Besides energy and MP supply, dairy cow performance is influenced by rumen function, the supply of rumen degradable substrates, and the profile of nutrients available in the postabsorptive metabolism (Dijkstra et al., 2012; Huhtanen and Nousiainen, 2012).

Rumen degradable substrates can be subdivided into carbohydrates and protein. Rumen degradable carbohydrates consist of different chemical components, the primary constituents being starch, NDF, sugar, and pectin. Each component has distinct ruminal degradation and fermentation characteristics. Although total VFA production is related to the intake of rumen fermentable OM, components like NDF or starch result in different proportions of individual VFA produced in the rumen (Nozière et al., 2011). Diet composition can

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also affect VFA proportions through interconversions between the major VFA (acetate, propionate, and butyrate; Sutton et al., 2003). These VFA have different effects on milk production and composition (Thomas and Martin, 1988). Therefore, each fraction of rumen degradable carbohydrates can have different effects on milk production and composition, even when energy or MP supply does not differ. Replacing starch for NDF or changing the starch source (i.e., corn vs. barley or wheat) will affect VFA molar proportions, intestinal digestibility, and metabolic responses, although not always resulting in a response in production performance (Lechartier and Peyraud, 2011; Ferraretto et al., 2013; Piccioli-Cappelli et al., 2014).

The major mechanisms to control ruminal pH are buffering by saliva, removal of VFA by ruminal absorption, or passage to the small intestine (Dijkstra et al., 2012). Higher ruminal VFA production through increased carbohydrate supply and fermentation rate not compensated by increased ruminal VFA absorption or buffering will lower average ruminal pH or increase diurnal variation in ruminal pH. This change in pH dynamics can affect nutrient availability and thus affect production performance (Dijkstra et al., 2012).

Meeting the animal and microbial nutrient requirements in diet formulation will optimize cost-effective animal performance while minimizing nutrient excretion into the environment. Inclusion of several formulation bounds, required to account for dietary carbohydrate characteristics, including levels of various sources and differences in rate of degradation between and within feedstuffs, increases the complexity of diet formulation. The amount of rumen degradable carbohydrates depends on the rumen soluble, washable, and nonwashable but potentially degradable fractions, as well as the fractional degradation rate (k_d) and fractional passage rate (Van Duinkerken et al., 2011). As k_d is a nonlinear characteristic representing the fraction of substrate being degraded per unit of time, this value cannot be used directly in linear programming for diet formulation (Volden, 2011). Aggregating rumen degradation characteristics of the different carbohydrate components per feedstuff into terms such as modeled rapidly degradable carbohydrates (**mRDC**) and modeled total degradable carbohydrates (**mTDC**) can simplify diet formulation and still capture the effect of total carbohydrate supply as well as rate of degradation. In the present study, mRDC and mTDC are calculated for individual feedstuffs based on a simple rumen model.

The objective of our study was to evaluate production responses of lactating dairy cows to diets that were formulated to increasing mRDC levels, keeping the supply of other nutrients as constant as possible.

MATERIALS AND METHODS

The experiment was conducted at the Trouw Nutrition Dairy Research Facility (Kempenshof) in Boxmeer, the Netherlands. The experiment was conducted under approval of the Dutch Animal Ethics Committee according to the Experiments on Animals Act, 1977.

Animals and Experimental Design

Fifty-two lactating Holstein dairy cows (8 primiparous and 44 multiparous) averaging 144 ± 62.7 DIM, 22.0 ± 3.15 kg of DM/d and 31.3 ± 6.13 kg of milk/d at the start of the experiment were used. Four of the multiparous cows had a rumen fistula (10 cm i.d., Bar-Diamond, Parma, ID). Animals were housed in a slatted-floor free-stall barn and had free access to water at all times.

The experiment was set up as a 4 × 4 Latin square design with 4 treatments and 4 periods. Each period consisted of 2 wk of adaptation and 1 wk of measurements. Cows were assigned to a block consisting of 4 animals, according to milk yield, DMI, and DIM, based on the average value of these parameters obtained in the last 4 wk before start of the experiment. The rumen-fistulated animals formed one block. Within each block, cows were randomly assigned to 1 of 4 different treatment sequences.

Body weights were recorded automatically 4 times per week (twice after the morning milking and twice after the evening milking).

Dietary Treatments and Feeding

The 4 treatments consisted of increasing levels of mRDC at 167, 181, 194, and 208 g of mRDC/kg of DM. Concentrate ingredient composition was used to create the differences in mRDC level for the lowest and highest mRDC diets (Table 1; low mRDC and high mRDC concentrate, respectively). The basal forage mixture consisted of grass silage, corn silage, and grass hay and was identical for all treatments (Table 2). Animals were fed ad libitum TMR, which consisted of the forage mixture supplemented with different amounts of the low mRDC concentrate or the high mRDC concentrate to create the differences between treatments (Table 3). The TMR were formulated to be iso-energetic based on NE_L (Van Es, 1978), and iso-nitrogenous based on intestinal digestible protein (**DVE**) and degraded protein balance in the rumen (Tamminga et al., 1994). The TMR provided adequate net energy and intestinal digestible protein for a cow consuming 22 kg of DM/d and producing 32 kg of milk/d.