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The effect of supplemental concentrate fed during the dry period on morphological and functional aspects of rumen adaptation in dairy cattle during the dry period and early lactation

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ABSTRACT

Ten rumen-cannulated Holstein-Friesian cows were used to examine the effect of feeding supplemental concentrate during the dry period on rumen papillae morphology and fractional absorption rate (k_a) of volatile fatty acids (VFA) during the dry period and subsequent lactation. Treatment consisted of supplemental concentrate [3.0 kg of dry matter (DM)/d] from 28 d antepartum (ap) until the day of calving, whereas control did not receive supplemental concentrate. Cows were fed for ad libitum intake and had free access to the dry period ration (27% grass silage, 28% corn silage, 35% wheat straw, and 11% soybean meal on a DM basis) and, from calving onward, to a basal lactation ration (42% grass silage, 42% corn silage, and 16% soybean meal on a DM basis). From 1 to 3 d postpartum (pp), all cows were fed 0.9 kg DM/d of concentrate, which increased linearly thereafter to 8.9 kg of DM/d on d 11 pp. At 28, 18, and 8 d ap, and 3, 17, 31, and 45 d pp, rumen papillae were collected and k_aVFA was measured in all cows. On average, 13.8 (standard deviation: 3.8) papillae were collected each from the ventral, caudodorsal, and caudoventral rumen sacs per cow per day. The k_aVFA was measured by incubating a standardized buffer fluid (45 L), containing 120 mM VFA (60% acetic, 25% propionic, and 15% butyric acid) and Co-EDTA as fluid passage marker, in the evacuated and washed rumen. Treatment did not affect ap or pp DM and energy intakes or milk yield and composition. Treatment increased papillae surface area, which was 19 and 29% larger at 18 and 8 d ap compared with 28 d ap, respectively. Surface area increased, mainly due to an increase in papillae width. However, treatment did not increase k_aVFA at 18 and 8 d ap compared with 28 d ap. In the control group, no changes in papillae surface area or k_aVFA were observed during the dry period. In the treatment group, papillae surface area decreased between 8 d ap and 3 d pp, whereas no decrease was observed for control. From 3 to 45 d pp, papillae surface area and k_aVFA increased for all cows by approximately 50%, but the ap concentrate treatment did not affect k_aVFA pp. In conclusion, the efficacy of supplemental concentrate during the dry period to increase papillae surface area and k_aVFA in preparation for subsequent lactation is not supported by the present study. Current observations underline the importance of functional measurements in lieu of morphological measurements to assess changes in the adapting rumen wall.

Key words: transition dairy cow, rumen adaptation, rumen papillae, rumen epithelium, volatile fatty acid absorption

INTRODUCTION

After calving, fermentable organic matter (**FOM**) intake of cows increases rapidly, resulting in a more than 2-fold increase in the production of VFA at maximal feed intake postpartum (Bergman, 1990). To maintain ruminal conditions favorable for fermentation, buffering and clearance of the produced VFA is essential (Penner et al., 2009; Aschenbach et al., 2011; Dijkstra et al., 2012). Clearance of VFA from the rumen is the result of either passage or absorption across the rumen epithelium (Gäbel et al., 2002; Aschenbach et al., 2011). Earlier work has shown that the rate of absorption of VFA depends on the pH of the rumen fluid, on the concentration and type of VFA (Thorlacius and Lodge, 1973; Dijkstra et al., 1993), and on the surface area of the rumen papillae (Dirksen et al., 1984; Melo et al., 2013).

Increased FOM intake results in an increase in VFA production and thereby in a proliferation of the rumen papillae and epithelium, through a direct effect on

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cell mitosis and apoptosis (Mentschel et al., 2001) and through growth factors of, for example, the IGF axis (Steele et al., 2015). Although growth can be rapid, the process of proliferation may take several weeks to complete (Dirksen et al., 1985; Bannink et al., 2012; Dieho et al., 2016a). It can be hypothesized that a mismatch between the rate of increase in VFA production and development of the papillae is a factor underlying problems with maintaining optimal rumen conditions for fermentation during early lactation (Dirksen et al., 1985; Krause and Oetzel, 2006; Aschenbach et al., 2011). Stimulation of the surface area of rumen papillae during the dry period may be an effective strategy to prevent high VFA concentrations and concomitant low pH rumen during early lactation (Liebich et al., 1987). However, an increase in papilla surface area does not necessarily result in a concomitant increase in fractional rate of VFA absorption (Dieho et al., 2016b). This finding casts doubt on the efficacy of increasing papillae surface area on VFA absorption capacity in the late dry period. In addition, to date, the efficacy of increasing papilla surface area during the late dry period on VFA absorption capacity during early lactation has not been supported by in vivo measurements.

The aim of the present experiment was therefore to examine the effect of feeding supplemental concentrate during the last 4 wk of the dry period on rumen papillae morphology and fractional absorption rate of VFA (k_a**VFA**) during the dry period and early lactation. Feeding supplemental concentrate during the dry period was expected to increase papillae surface area and k_aVFA in that period and to positively affect surface area and k_aVFA in the early weeks of subsequent lactation.

MATERIALS AND METHODS

The experimental procedures were approved by the Animal Care and Ethics Committee of Wageningen University & Research (Wageningen, the Netherlands) and conducted under the Dutch Law on Animal Experiments.

Animals, Experimental Design, and Management

Nine weeks before the expected calving date, 10 rumen-cannulated (10 cm i.d., Bar Diamond Inc., Parma, ID; cannulated during the first lactation) Holstein-Friesian dairy cows [second (n = 8) and fourth (n = 2) lactation] entered the randomized block design with repeated measurements experiment. Cows were paired based on parity, expected calving date, and milk yield of the previous lactation. Within pairs, cows were randomly assigned to either a control (**CON**, n = 5) or a supplemental concentrate treatment group (**SUP**, n = 5). Samples were collected 28, 18, and 8 d antepartum (**ap**), and at 3, 17, 31, and 45 d postpartum (**pp**). Dry and lactating animals were housed in separate groups in a freestall barn with a slatted concrete floor. Stalls were fitted with rubber mattresses covered with sawdust. On sampling days, before morning feeding, cows were moved to a tiestall at ~0830 h for the experimental procedures. Cows were milked at 0530 and 1530 h. Milk production was recorded at each milking and, each week, samples from 4 consecutive milkings (same days every week) were analyzed for fat and protein contents (ISO, 1999; Qlip NV, Zutphen, the Netherlands). During the dry period, cows were weighed at weekly intervals, and during lactation, BW was automatically recorded in the milking parlor.

Rations and Chemical Analyses

Throughout the dry period, all cows had free excess to the dry period ration (Table 1). From 28 d ap onward, the cows allocated to SUP were fed 3 kg DM/d of supplemental concentrate. From the day of calving onward, all cows had free access to the lactation ration (Table 1), and daily concentrate allowances were identical for both treatment groups. All cows were fed for ad libitum intake (minimum 10% refusals). From calving to 3 d pp, cows received 0.9 kg DM/d of concentrate. Thereafter, concentrate allowance increased at a rate of 1.0 kg of DM/d to a maximum of 8.9 kg of DM/d on 11 d pp. The maximum concentrate allowance was maintained until the end of the experiment. Concentrate composition (Table 1) did not differ for the ap and pp periods. Daily intake (kg/d) of the rations was measured individually using computerized feed bins with automatic weighing (Insentec, Marknesse, the Netherlands). Maximum stocking density was 2 cows per feed bin, with cows having access to all feed bins. Feed was prepared daily and fed at 1000 h. All cows had free access to water throughout the experiment. The individual daily concentrate allowance was made available in equal portions over six 4-h periods using a concentrate dispenser (Manus VC5, DeLaval, Steenwijk, the Netherlands). During the visits, concentrate was fed in a series of small portions and cows were shielded from herdmates, effectively preventing other cows stealing concentrate. Roughage and concentrate samples were taken once a week, stored at −20°C pending analysis, and analyzed as described by Dieho et al. (2016a). Additional weekly roughage samples were used for determination of DM content by forced-air oven drying. If necessary, the basal ration formulation (on a product basis) was adjusted for changes in ration ingredient DM content.

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