Morphological aspects of rumen adaptation in dairy cattle during the dry period and lactation

K. Dieho, A. Bannink, Th. Schonewille, J. Dijkstra

Wageningen University, Department of Animal Sciences, Animal Nutrition Group, P.O. Box 338, 6700 AH Wageningen Building nr. 122, Room E.0220, De Elst 1, 6708 WD Wageningen

Introduction

An adequate absorption of volatile fatty acids (VFA) is an important determinant to maintain rumen pH within the physiological range. From this viewpoint , proliferation of rumen papillae is one of the factors to be considered and it has been shown that the proliferation of rumen papillae is positively correlated with the production of VFA in the rumen.
During the dry period, cows have to be fed either restrictive amounts of dry matter (DM) or a ration with a relatively low energy density (VEM/kg DM) to prevent excessive weight gain. For obvious reasons, rumen VFA production also is relatively low during the dry period, which is associated with atrophy of the rumen papillae. After calving, with the onset of lactation, the energy demand increases 2-3 fold and the rations are adjusted accordingly, increasing energy density and dry matter intake. This creates a large contrast in VFA production between the dry period and lactation. In case the production rate of VFA exceeds the capacity of the rumen papillae to absorb VFA, (sub-acute) rumen acidosis can occur, leading to impaired microbial fermentation, welfare problems and production losses. The proliferation of rumen papillae is currently believed to be of critical importance in increasing the VFA absorption capacity and prevention of problems associated with rumen acidosis. However, an integral and detailed view on the combination of morphological (papillae) and functional (VFA absorption, microbial activity) aspects of rumen adaptation under conventional husbandry and feeding practices is still lacking.
The aim of this study was to assess rumen adaptation, morphological, functional and microbial, during the dry period and lactation. Rumen adaptation to the lactation ration was studied using 2 concentrate build-up regimes. This abstract focuses on some aspects of the morphological adaptation.

Materials and methods

Twelve rumen canulated, first parity, Holstein Friesian dairy cows were housed at the Waiboerhoeve experimental farm under conventional conditions in a cubicle stall with a concrete slatted floor. The cows were dried off approximately 8 weeks before expected calving date.
During the dry period all cows received a ration consisting of 27% grass silage, 27% maize silage, 35% wheat straw and 11% soy bean meal. The rations provided (per kg DM) 775 VEM, 57 gr DVE, 3 OEB and 455 gr FOM per kg . After calving all cows received a basal ration consisting of 42% grass silage, 42% maize silage and 17 % soy bean meal, providing 975 VEM, 92 gr DVE, 13 OEB and 568 gr FOM per kg DM.
After calving cows were allocated to the fast (F) or slow (S) concentrate build-up group. In group F daily concentrate allowance was linearly increased from 0.9 kg DM at 1-3 DIM to 10.9 kg DM at 13 DIM. In group S daily concentrate allowance was linearly increased from 0.9 kg DM at 1-3 DIM to 10.9 kg DM at 43 DIM. The concentrate contained 1077 VEM, 121 DVE, 2 OEB and 667 FOM per kg DM. The basal rations were provided at libitum throughout the experiment and daily feed intake was measured using roughage intake control feed bins.
Rumen papillae were collected after total evacuation of rumen contents, from the ventral rumen sac (VRS), ventral blind rumen sac (VBS) and dorsal blind rumen sac (DBS), using a biopsy forceps, on 50, 30 and 10 days before expected calving date and on 3, 9, 16, 30, 44, 60 and 80 days after calving. After papillae collection a specially prepared buffer fluid was introduced into the reticulo-rumen for VFA absorption capacity measurement.
The surface area of the papillae was measured using ImageJ after taking digital photographs. Length and width were measured using ImageScope. The 2-sided surface area and length:width ratio were calculated. Changes in papillae surface area, length, width and length:width ratio, as well as 3 day

averages of feed intake parameters were analysed using a repeated measurements mixed model in SAS with a spatial power covariance structure.
Data for the dry and lactation period were analysed separately for feed intake and papillae measurements, with MD 3 DIM for papillae measurements allocated to the dry period as end-point measurement. Reported values are means ± SD.
The data on papillae dimensions were statistically evaluated using the following model :
$Y_{ijk} = \mu + TR_i + MD_j + BS_k + TR_i*MD_j + MD_i*BS_k + TR_i*MD_j*BS_k + e_{ijk}$

The model used for feed intake parameters was:
$Y_{ij} = \mu + TR_i + MD_j + TR_i*MD_j + e_{ij}$

Treatment group (TR), measurement day (MD) and biopsy site (BS) were treated as fixed effects, cow was treated as a random effect. The biopsy site was nested within the cow.

Results

During the dry period DMI was similar between treatment groups and measurement days. Overall mean DMI was 12.2±0.4 kg/day. During lactation DMI increased from 11.1±0.5 kg/day at 3 DIM to 24.1±0.5 kg/day at 44 DIM and to 24.3±0.4 kg/day at 80 DIM for the F and S treatment. During lactation, overall DMI intake was similar between TR but differences between MD ($P<0.01$) and the interaction between TR*MD was significant ($P<0.05$); DMI (2.1 kg/day, $p=0.02$), VEM (3166 /day, $p<0.01$), DVE (0.4 kg/day, $p<0.01$) and FOM intake (2.2 kg/day, $p<0.01$) were significantly greater at MD 16 DIM for group F.
During the dry period papillae surface area was similar between TR but declined significantly between MD ($p<0.01$). Papillae surface area taken from the VRS decreased from 34±4 to 30±5 mm^2, the VBS from 34±8 to 24±6 mm^2 and the DBS from 34±6 to 28±8 mm^2 for MD -50 DIM and MD 3 DIM respectively. Decline of the papillae surface area of the papillae taken from the VBS tended to be greater than that from VRS and DBS ($p=0.10$)
During lactation, papillae surface area doubled in both groups to 64±11, 61±15 and 63±10 mm^2 at 80 DIM for the VRS, VBS and DBS respectively. From 16 DIM to 44 DIM, group F showed a faster growth and larger papillae($p<0.05$), corresponding to the feed contrast, with an estimated maximum difference of 11 mm^2 at 30 DIM over all sites.
During lactation papillae surface area doubled to 64±11, 61±15 and 63±10 mm^2 at 80 DIM on average in the VRS, VBS and DBS respectively. During 16 DIM to 44 DIM (period with contrast in feed intake) a faster growth and larger papillae ($p<0.05$) were observed for F with a maximum difference of 11 mm^2 at 30 DIM over all sites.

Discussion and Conclusions

Although the exact mechanisms which govern papillae development are not yet fully elucidated, the observed papilla growth in both groups and the disappearance of the treatment effect after alleviation of the concentrate contrast supports the hypothesis that VFA load is a major driving force of papilla growth.
Based on the papillae data alone, it is clear no conclusions can be drawn on the functionality of the adaptation of the rumen wall with regard to its capacity to absorb VFA and maintain favourable rumen fermentation conditions during early lactation.
Analysis of the simultaneously collected data on the functional and microbial adaptation of the rumen during the dry period and early lactation is in progress.

References
Available on request.

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