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Calf Note #276 - Maternal BHB and Rumen Development in Calves

Introduction

The dry period is a critical time—not only for the cow, but also for the developing calf. During this period, the fetus is growing rapidly, and changes in the cow's metabolic status can influence how tissues and organs develop before birth. One indicator of this metabolic status is β-hydroxybutyrate, or BHB, a ketone body that increases when cows are in negative energy balance.

An interesting new published research trial, conducted in China (Zheng et al. 2026), examined how elevated maternal BHB during the dry period affects the calf, particularly the development of the rumen.

The Research

In this study, researchers worked with multiparous Holstein cows during the dry period under commercial dairy conditions. A total of approximately 50–60 cows were initially enrolled, and 48 cows with complete data were ultimately included in the study. Cows were similar in body condition, parity, and expected calving date, and all were managed similarly in terms of housing, diet, and general care.

Blood samples were collected from cows at several time points during the dry period to determine circulating BHB concentrations. Based on these measurements, cows were divided into two groups: a low-BHB group and a higher-BHB group. Importantly, BHB concentrations in both groups were below levels typically associated with clinical ketosis, so the comparison reflects differences within a normal or subclinical range.

All cows carried single calves, and calves were managed using standard commercial practices after birth. Calves received colostrum shortly after birth, followed by additional feedings within the first several hours of life, and were otherwise managed similarly across groups.

To evaluate rumen development, calves were humanely euthanized at specific time points. Some calves were evaluated within the first day of life, and others at approximately one month of age. Rumen tissue was collected at these times to assess both structural development and indicators of function.

Results

Calves born to cows with higher BHB concentrations had similar birth weights compared to calves from cows with lower BHB, suggesting that overall fetal growth was not impaired. However, when researchers looked more closely at the rumen, clear differences emerged.

Calves from cows with higher BHB had rumens that were heavier, but this increase in mass did not reflect improved function. In fact, the structural development of the rumen was compromised. The rumen papillae—the finger-like projections responsible for absorbing volatile fatty acids—were shorter and narrower. Because papillae provide the surface area needed for absorption, these changes suggest a reduced capacity for nutrient uptake. In practical terms, the rumen may be less efficient at absorbing fermentation products, which are critical for energy metabolism as the calf transitions to solid feed.

In addition to these structural changes, there were important alterations in the rumen epithelium itself. The rumen lining is not just a passive surface; it is an active barrier that regulates absorption and protects the animal from microbial and chemical challenges. In calves from high-BHB cows, markers of epithelial integrity—such as tight junction proteins—were reduced. This suggests that the barrier function of the rumen may be weaker, potentially allowing greater penetration of harmful compounds or pathogens.

At the same time, markers of inflammation were increased. This indicates that the rumen tissue was in a more activated or stressed state, even early in life. A rumen that is both structurally underdeveloped and experiencing increased inflammatory signaling may not function optimally, particularly during the critical early stages of development when the calf is adapting to solid feed.

Possible Mechanisms

These structural and inflammatory changes appear to be linked to alterations in key regulatory pathways. One of the most important is PPARγ, a transcription factor that plays a central role in epithelial cell differentiation, lipid metabolism, and control of inflammation. In calves from high-BHB cows, expression of PPARγ was reduced. This is significant because PPARγ helps regulate the growth and renewal of rumen epithelial cells, as well as their ability to metabolize short-chain fatty acids such as butyrate.

When PPARγ activity is reduced, several downstream effects can occur. Cell proliferation and differentiation may be impaired, leading to less developed papillae. The expression of genes involved in nutrient transport and metabolism may be reduced, limiting the rumen's ability to absorb and utilize fermentation products. At the same time, the normal anti-inflammatory role of PPARγ is diminished, allowing inflammatory pathways—such as NF-κB signaling—to become more active.

In addition, elevated maternal BHB itself may act as a signaling molecule that influences fetal tissue development. BHB is not just a passive indicator of energy balance; it can directly affect gene expression and cellular signaling pathways. In this context, elevated maternal BHB during the dry period may "program" the developing rumen, altering how epithelial cells grow, differentiate, and respond to their environment after birth.

Implications

One of the most important aspects of this work is that these effects occurred at BHB concentrations below those typically associated with clinical ketosis. In other words, the cows did not appear clinically ill, yet there were measurable and meaningful effects on the calf's rumen development. This highlights that even moderate metabolic stress during the dry period can have consequences for the next generation.

Overall, these findings reinforce an important concept: the calf's future is influenced before it is born. The structure and function of the rumen—so critical for later growth and performance—can be shaped by the metabolic environment of the dam during late gestation.

Managing dry cow nutrition to minimize excessive negative energy balance and elevated BHB is not only important for the cow—it may also be critical for proper rumen development in the calf. While we often focus on colostrum and early feeding after birth, this work reminds us that some of the most important influences on calf performance begin well before the calf is born.

Reference

Zheng, J., Y. Zhang, X. Zhao, Y. Gai, F. Luo, Z. Gu, S. Mao, G. Ma, M. H. Ghaffari, and Y. Chen. 2026. Maternal β-hydroxybutyrate during the dry period is associated with altered epithelial cell regulation and rumen morphology of offspring as calves. J. Dairy Sci. TBC. https://doi.org/10.3168/jds.2025-27835.

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