

Perspectives in ruminant protein efficiency, recycling, and amino acids

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There are a number of issues related to protein nutrition of dairy cattle that remain enigmatic to researchers yet are critical to appropriate formulation of diets for dairy cattle. This presentation will discuss several of these areas, with the goals of describing the issues and providing a brief overview of my current perspectives on the topic.

Urea recycling

Historically, dairy diets contained excess crude protein to ensure that metabolizable protein (MP) supply to the cow was adequate to support lactation. Under these conditions, there were no concerns about meeting the need of ruminal microbes for ruminally available nitrogen (RAN), because these over-formulated diets provided excess RAN. With efforts to improve reproduction, reduce diet cost, and reduce environmental degradation, dietary crude protein concentrations have decreased in recent years, leading to concerns that RAN could become limiting in lower protein diets.

RAN is provided to the microbes through ruminally degraded dietary protein (RDP) as well as through recycling of urea to the rumen, either through saliva or through transport across the ruminal wall. Our predications of RDP are reasonably accurate, but predictions of ruminal urea recycling are not very good. We also have difficulty in determining how efficiently microbes capture ammonia.

It is possible to find situations where dairy cows respond to urea supplementation with increases in intake and production. However, even in those cases, there is abundant blood urea that is excreted in the urine rather than recycled to the gut (Røjen et al., 2011). This suggests there might be features of urea recycling that limit the efficiency of urea transfer. Most research on urea recycling uses intravenous infusion of doubly-labeled urea to assess urea kinetics, but this method cannot separate movement of urea into the rumen from movement into other regions of the gut (i.e., the intestine); this limits our ability to accurately predict RAN.

Effects of amino acid supplements on bovine metabolism

Amino acids are the building blocks of protein. Tissues therefore require amino acids for protein synthesis, but amino acids also play important roles in metabolism and metabolic regulation. Methionine is the predominant methyl donor in the body, and methyl groups are transferred in hundreds of reactions. Choline and creatine synthesis are the quantitatively most important consumers of methyl groups. Choline supplementation presumably reduces the need for endogenous synthesis and spares methyl groups, although endogenous synthesis of choline may not be adequate for optimal performance, even if methyl groups are made available.

As regulatory molecules, amino acids can control rates of protein synthesis (Arriola Apelo et al., 2014). Amino acid supply may affect concentrations of regulatory hormones, and they also act within cells to stimulate protein synthesis through mTOR-related pathways. mTOR

is a key regulatory kinase, with the mTORC1 complex being capable of phosphorylating other regulatory proteins within the cell, ultimately increasing protein synthesis. Thus, amino acid supply may affect protein synthesis not only by providing substrate, but also by regulating the protein synthetic machinery with the cell.

Amino acid requirements

The NRC (2001) model describes metabolizable protein (MP) requirements for lactating cows as a maintenance requirement plus a requirement for lactation, assuming a constant 67% efficiency of MP use for milk protein synthesis. This estimate of efficiency is greater than reality (Arriola Apelo et al., 2014), which leads to an overestimation of the cow's response to protein supplementation (i.e., an underestimation of the requirement). Moreover, the efficiency is not likely constant over broad ranges of MP supply, but rather decreases with increasing supply.

There are various reasons that efficiency of MP use for milk protein is not constant. One explanation is that populations of cattle yield response surfaces (milk protein vs. MP supply) that differ from those of individual cows. For example, a single cow may demonstrate a nearly linear response to MP supply until her capacity for milk protein synthesis is maximized, at which point there is a plateau in the response. In a population of cows with different maximal production levels, the pooling of the individual responses leads to a response surface with a slope that begins decreasing at the point where the first cow's performance is maximal and continues to decrease until a plateau is reached at the maximal production level of the highest producing cow.

From a metabolic perspective, one can suggest that individual cows should not have constant efficiencies of amino acid use because there are multiple tissues/pathways in the body that compete for amino acids (Arriola Apelo et al., 2014). As amino acid supply increases, concentrations also increase. At low concentrations, catabolic pathways will be minimal, which allows a large portion of the amino acid to be used for protein synthesis by the mammary gland. However, as concentrations increase with supply, catabolic pathways progressively increase, leading to a smaller fraction of the amino acid being used for protein synthesis. Moreover, the efficiency of amino acid use for protein synthesis likely differs among amino acids, because the catabolic and anabolic pathways of different amino acids have differing affinities for the amino acids.

References

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