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What is the True Supply of Amino Acids for a Dairy Cow?[1]

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ABSTRACT

Improving the prediction of milk protein yield relies on knowledge of both protein supply and requirement. Definition of protein/amino acid supply in ruminants is a challenging task, due to feedstuff variety and variability and to the remodeling of nutrient intake by the rumen microflora. The questions arise, therefore, how and where should we measure the real supply of AA in the dairy cow? This review will follow the downstream flow of AA from duodenum to peripheral tissue delivery, with a glance at the efficiency of transfer into milk protein. Duodenal AA flow comprises rumen undegradable feed, microbial protein, and endogenous secretions. Most attention has been directed toward definition of the first two contributions but the latter fraction can represent as much as 20% of duodenal flow. More information is needed on what factors affect its magnitude and overall impact. Once digested, AA are absorbed into the portal vein. The ratio of portal absorption to small intestinal apparent digestion varies among essential AA, from 0.43 (threonine) to 0.76 (phenylalanine), due to the contributions of preduodenal endogenous secretions to the digestive flow, non-reabsorption of endogenous secretions and gut oxidation of AA. Few data are available on these phenomena in dairy cows but the evidence indicates that they alter the profile of AA available for anabolic purposes. Recent comparisons of estimated duodenal flux and measured portal flux have prompted a revisit of the NRC (2001) approach to estimate AA flows at the duodenum. Changes to the model are proposed that yield predictions that better fit the current knowledge of AA metabolism across the gut. After absorption, AA flow first to the liver where substantial and differential net removal occurs, varying from zero for the branched-chain AA to 50% of portal absorption for phenylalanine. This process alters the pattern of net supply to the mammary gland. Overall, intermediary metabolism of AA between the duodenum and the mammary gland biologically explains the decreased efficiency of the transfer of absorbed AA into milk protein as maximal yield is approached. Therefore, variable, rather than fixed, factors for transfer efficiencies must be incorporated into future predictive models.
Key words: dairy cow, amino acid, gut, portal absorption

INTRODUCTION

To optimize milk production, requirements must be determined and matched with dietary supply. Such information requires studies in which the supply of both energy and protein to the cow is accurately known. But where and how do we measure this supply? This review will focus on the supply of protein and more specifically, the base units, the individual AA. In nonruminant nutrition, it is well recognized that supply and requirements must be expressed for individual AA rather than their aggregate (total protein). The biological consequence of such an approach has positive economic impacts and single AA are routinely added to commercial diets to improve animal performance and farm income in swine and poultry production.

In nonruminants, intake represents supply and any deficiency can be corrected with the simple addition of any individual AA directly to the diet. Ruminants are different: their capacity to use forages that are indigestible for the nonruminant relies on the presence of microorganisms in the rumen, reticulum, and omasum to digest such feedstuffs. Unfortunately, this ability incurs a toll. First, during passage through the reticulorumen, dietary ingredients are partially digested and reused for microbial growth. Therefore, nutrients delivered for absorption differ from those present in the diet making prediction of nutrient supply to the animal difficult. Second, because free AA are rapidly degraded in the rumen environment (Velle et al., 1997; Volden

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et al., 1998), simple addition of an AA to the diet is not an efficient option to increase AA flow at the duodenum. Instead, the AA must either be coated with a form of protection against the microorganisms (but still allow digestibility in the small intestine) or be presented in chemical forms that are more resistant to ruminal degradation or more readily absorbed through the rumen wall (e.g., hydroxy analogues).

Over the last few years, there has been renewed interest in strategies to improve the efficiency of N use in dairy cows without reducing productivity. Increased efficiency of N use is best achieved by reducing the total amount of CP fed to the animal. Such a reduction, however, must be made cautiously but can be accomplished if appropriate supplies of the critical AA are provided. This raises a number of crucial questions. How do we measure the supply of individual AA? What is the true supply of AA? In ruminants, it is clear that AA intake is a meaningless way to express the real supply of AA to the animal. Should we then look at duodenal supply or perhaps small intestinal disappearance? Is either really net supply? Would it be better to measure AA appearing in the portal circulation that drains the whole gut? Answering these challenging questions requires knowledge of AA metabolism between intake and absorption. Recognizing and understanding the complex interactions of gut AA metabolism will enable the development of better predictive models to formulate diets that contain less total CP but are better balanced to meet AA requirements. Such an approach will improve the efficiency of conversion of diet N into milk protein.

This review will focus on specific aspects of present knowledge and suggest improvements to current prediction models taking into account gut metabolism of AA. For simplicity and to reflect the paucity of data on nonessential AA flows in dairy cows, this review will focus on essential AA (**EAA**), even though data for these are also scarce. Nonetheless, future models will also need to consider metabolism of nonessential AA as these are extensively used by gut tissues to maintain integrity and functionality.

DUODENAL FLOW

A first measurement of protein supply to the ruminant is protein flow at the entrance of the small intestine. This measurement is performed through placement of a cannula at the proximal duodenum, with the challenge to obtain representative samples coupled with a good estimate of DM flow (Harmon and Richards, 1997). Duodenal flow of CP encompasses 3 major fractions: RUP, microbial crude protein (**MCP**), and endogenous protein. The contribution of each fraction to the total flow is directly related to the diet composition and DM intake and varies widely, with the MCP fraction usually supplying the majority of the proteins (Clark et al., 1992). The origin of these proteins will directly affect estimation of the net supply from the diet. Although AA absorbed from RUP plus most of that derived from MCP may be considered as a new supply of AA to the animal, the endogenous fraction mainly constitutes a recycling of previously absorbed AA used to build body proteins that are returned into the lumen of the gut prior to the duodenum. Endogenous proteins originate from various sources, including mucoproteins, saliva, sloughed epithelial cells, and enzyme secretions into the abomasum (Tamminga et al., 1995).

Therefore, determination of the true net supply of protein (and of AA) flowing to the duodenum requires that the contribution from preduodenum endogenous proteins be subtracted from measured total duodenal flow. In practice, however, a number of simplifications are usually adopted. Rumen microbial protein flow, due to its potentially large contribution and associated variation, has received much attention and different methods have been developed for measurement (see review in Broderick and Merchen, 1992). Consequently, in most studies where protein flow at the duodenum is measured, MCP is determined and RUP is calculated as the difference between total CP and MCP flows, with any contribution from endogenous protein ignored. Indeed, although it is critical to determine what fraction of duodenal flow represents recycled material, and thus accurately determine the real net supply, the endogenous fraction has received little attention in ruminants. This has not only been because of a lack of recognition of the relative importance of the endogenous contribution but also because of the technical challenges associated with its measurement. Even when allowance is made for endogenous inputs, these are often based on data from studies conducted in rather artificial conditions having little relevance to the feeding regimen of high-yielding dairy cows. Thus, NRC (2001) adopted an average value of 1.9 g of N/kg of DMI for the endogenous contribution to duodenal flow based on data obtained in studies using animals receiving either only intragastric infusions of volatile fatty acids (Ørskov et al., 1986) or fed diets with very low protein supply and degradability (Hart and Leibholz, 1990; Hannah et al., 1991; Lintzenich et al., 1995). Similarly, the French system uses a value equivalent to 1.7 g of N/kg of DMI (Vérité and Peyraud, 1989). More appropriate estimates of endogenous protein flows, pertinent to "real" situations, require use of tracer techniques but, even with these, caution is needed. Endogenous secretions estimated from ^{15}N-urea infusion (Brandt et al., 1984; Leng and Nolan, 1984) include use of urea for microbial protein