

# Isoacids In The Ruminant

## Introduction

The Cornell University ruminant physiologist Peter J. Van Soest has stated "As a result of evolution, ruminants have probably adapted to efficient gluconeogenesis, while the lower digestive tract has adapted to the lack of sugar and starch. The true diet of the ruminant is not what it eats, but rather, the combination of fermentation products and fermented feed that escapes from the rumen. The net changes in the ingested feed include conversion of dietary protein and nitrogen into microbial protein, and conversion of carbohydrate into a variety of non-carbohydrate products." Considering the importance of ruminal action in this light, it becomes obvious that desired changes in bovine production, whether milk or meat, very possibly could be effected by altering rumen function.

The rumen is a complex environment of biochemical reactions and bacterial and protozoal interactions interwoven one with the other. Altered metabolism due to exogenous influences can have multiple effects. Conversely, a desired production effect may be obtained through more than one nutritional approach. The following two articles provide insight as to the rationale of one such endeavor and a commercial product that has resulted. The first article provides a general background of the ruminal environment and the role of isoacids in this environment. The second article reviews the clinical findings surrounding the release of the commercial product and field observations of the effects of its use.

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## Effects of Isoacids on Ruminal Metabolism and Milk Production

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### Cellulolytic bacteria

The digestion of cellulose in the rumen requires the interaction of both cellulolytic and non-cellulolytic bacteria, as well as protozoa.<sup>1</sup> Even when the energy source is entirely roughage material, the cellulase-producing bacteria comprise only about one-fourth of the total bacterial population. Major cellulolytic species include: *Fuminococcus albus*, *Ruminococcus flavifaciens*, *Bacteroides succinogenes*, and *Butyrivibrio fibrisolvens*. Of these, *Bacteroides succinogenes* is the most active in digestion of cellulose, especially the more resistant forms. *Butyrivibrio fibrisolvens* is able to ferment a greater variety of carbohydrates than the other species,

but most strains are relatively inactive fermentors of cellulose. This species can utilize both amino acids and non-protein nitrogen sources, but requires a complete amino acid mixture for effective nitrogen assimilation.

Cellulolytic bacteria can obtain energy from -keto acids derived from deamination of amino acids. If hydrolysis of amino acids and rate of ammonia production is greater than utilization for microbial protein, the ruminal ammonia and plasma urea levels will increase greatly, resulting in a wastage of nitrogen and possible urea toxicosis to the animal. This occurs most often when the diet is deficient in carbohydrate sources of energy. It is important to provide adequate levels of carbohydrate in the diet so that most of the nitrogen will be incorporated directly into protein and ammonia production will be lower.

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### Interactions in amino acid metabolism

The -keto acids produced from amino acids can be oxidatively decarboxylated to form isoacids.<sup>1</sup> Isobutyric, isovaleric, 2-methyl-butyric, and valeric acids are produced from valine, leucine, isoleucine, and proline, respectively. These 4- and 5-carbon VFA serve as essential growth factors for cellulolytic bacteria, and may be limiting nutrients, especially when the diet contains large proportions of non-protein nitrogen.<sup>5</sup> The 4- and 5-carbon VFA can be converted to the corresponding amino acids or can serve as precursors of fatty aldehydes and higher carbon saturated fatty acids. In the rumen, non-cellulolytic bacteria supply 4- and 5-carbon VFA required by cellulolytic bacteria, and in turn utilize soluble energy sources derived from the degradation of cellulose. Many species of cellulolytic bacteria have lost the ability to transport amino acids directly across their cell membranes, and have become dependent on the conversion of VFA to amino acids. Thus, there is an interdependence among the ruminal bacteria in digestion of carbohydrate and utilization of the nutrients produced.

### Effect on Lactation

Many studies have shown that 4- and 5-carbon VFA exert a favorable effect on rumen function. Recently, the influence of these compounds on lactation have been investigated by workers from several of the major agricultural universities. Felix et al.<sup>4</sup> reported an increased growth rate during the first 30 days of lactation in younger dairy heifers fed a mixture of isoacids compared with control animals fed the basal diet of urea, corn silage, and timothy hay. In the same study, lactating cows fed corn silage, urea, and a concentrate had increased retention when these acids were fed.

Bacterial growth rate was greater when isoacids were incubated with mixed ruminal bacterial cultures.<sup>9,10</sup> A combination of all 4- and 5-carbon VFA increased protein synthesis by 19% when added to a timothy hay inoculum. Control incubation from a cow on 60% concentrate and grass hay had smaller responses. This concentrate diet contained 3.5 times as much protein as did the timothy hay diet. Gorosito, et al.<sup>6</sup> determined that low concentrations of isoacids increased cellulose digestion and ammonia utilization by mixed rumen bacteria incubated in an artificial medium with isolated plant cell walls. No response occurred when isoacids were added to whole rumen fluid from a cow fed timothy hay and a protein supplement. This fluid contained much higher levels of isoacids than did rumen fluid from the cow fed only timothy hay.

These acids also enhanced cell wall digestion in intact forages and filter paper. The greatest response was seen in the filter paper, which did not contain amino acids, but cellulose digestion in the alfalfa hay also was increased, suggesting that crude protein may not be an accurate indicator of dietary levels of isoacids.

Isoacids have been shown to increase the production of milk and its constituents in dairy cattle. The persistency of lactation, total milk production, and body weight were improved in cows fed urea and corn silage by adding these acids to the diet.<sup>5</sup> Two different mixtures of isoacids decreased plasma urea nitrogen and ruminal ammonia nitrogen, resulting in greater microbial protein synthesis and improved urea nitrogen utilization. Increased ruminal acetate concentration indicated that isoacids stimulated ruminant fermentation. In another study, isoacids increased the production of milk, 4% fat-corrected milk, protein, solids-not-fat, and total solids in dairy cows fed corn silage, corn gluten meal, and urea.<sup>7</sup> Milk fat percent was lower when isoacids were fed, but total fat production was not significantly different because of the increased milk yield. Peirce-Sandner<sup>8</sup> fed a blend of isoacids to cows on diets containing corn silage, a forage, and either soybean meal, cottonseed meal, or corn gluten and urea as the protein source. Compared with controls, cows fed isoacids produced 7% more milk and fat-corrected milk over a 305 day lactation in all but the animals on diets containing cottonseed meal. Improved feed efficiency was associated with greater milk production. Milk fat percent was not significantly different, but yield was greater because of increased milk production. Milk protein percent was lower, but amount produced was not different.

Fieo et al.<sup>3</sup> found no significant differences in milk production, milk fat, milk protein, or feed efficiency in dairy cows with ammonium salts of isoacids, but blood growth hormone levels were higher in these animals. Cook<sup>2</sup> proposes that isoacid receptors are present in the rumen and/or the liver, and that interaction between the acid and the receptor molecule results in an increase in plasma growth hormone and a decrease in insulin levels. Growth hormone is considered to possess lactogenic activity, whereas insulin decreases transport of nutrients to the mammary gland in favor of other organs. This effect of isoacids outside the rumen may be related to the increase in milk production and feed efficiency.

### Conclusion

The 4- and 5-carbon VFA, or isoacids, have been shown experimentally to increase the productivity

and efficiency of lactation in dairy cattle. A commercially available feed supplement, containing calcium salts of these isoacids, has recently been introduced. The combined use of this product in early lactation to improve feed efficiency when dietary intake of nutrients cannot keep up with demands, followed by exogenous growth hormone in the last part of lactation, may be an economically feasible method for the dairyman to increase milk volume.

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# Isoacids — An Overview

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Recently there has been much excitement regarding the use of isoacids as a feed additive. In the fall of 1985, isoacids became available as a new FDA-approved feed additive for dairy cows by Eastman® Chemical Co., under the trade name Eastman IsoPlus Nutritional Supplement. News releases in 1986 reported promising results obtained by Dr. Steven Nissen at Iowa State University in research with one of the isoacids, 2-ketoisocaproic acid. The objective of this paper is to explain what isoacids are, their mode of action, and the results of the early feeding trials of IsoPlus™.

Isoacids are the branched ketoacids resulting from the natural rumen degradation of their corresponding amino acids. IsoPlus™ is the calcium salt of four volatile fatty acids (isobutyric, isovaleric, valeric, and 2-methylbutyric). Valeric acid is a straight chain 5-carbon fatty acid. The other three are isoacids (branched-chain fatty acids). Isobutyric, isovaleric, and 2-methylbutyric are produced in the

rumen mainly by oxidative deamination and decarboxylation of the amino acids valine, leucine, and isoleucine respectively<sup>1,2,3</sup> (Figure 1). Valeric acid is produced mainly from carbohydrate or from amino acids such as proline.<sup>2,4</sup>

Research has shown that supplementation of isoacids can increase milk production or weight gain in ruminants. These nutrients boost milk production by three ways. First, it improves ruminal digestion of cellulolytic components (fiber). Secondly, more microbial protein is produced. Thirdly, there are extraruminal effects such as sparing of amino acids at the mammary gland.

Isoacids are essential nutrients and enhance the growth of fiber (cellulose/hemicellulose)-digesting microorganisms in the rumen.<sup>1,5</sup> This results in more efficient feed utilization, making more energy available for increased milk production. Isoacids have a favorable response on rumen acetate production as can be seen in Table I.<sup>5,7</sup> Rumen acetate production is a measure of the rate of fermentation.

Supplementation of isoacids can potentially increase microbial protein synthesis from nonprotein nitrogen (NPN). In the rumen, microbes are able to combine volatile fatty acids with NPN to form

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