Tikrit University
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Volatile Fatty Acid

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Volatile Fatty Acid

Volatile fatty acids (VFA), produced by fermentation of organic matter in the rumen, can have a major effect on production and product composition in ruminants. The relative proportions in which VFA are produced, are influenced by a number of factors, including substrate composition, substrate availability and rate of depolymerization, and microbial species present. Interactions between these factors hamper conclusions with respect to the effect of one single factor. Molar proportions of VFA in rumen fluid are generally assumed to represent the proportions in which they are produced. Evidence is presented that individual VFA absorption rates vary with changes in pH or VFA concentration and hence, that this assumption need not be valid. Attempts to predict the supply of VFA based on substrate degradation in the rumen and stoichiometric parameters have not been satisfactory. Future attempts should include the differential VFA absorption rates, as well as provisions for the effect of amount and rate of degradation, pH and microbial species preferences on type of VFA produced. Such improvements, together with simplifications of the current detailed models of digestion and metabolism, and improved characterization of animals, should then allow better predictions of ruminant performance.

VFA form the major source of energy absorbed ln ruminants. Since the proportions of these acids can be manipulated by dietary means it is lmportant to measure their utilization and to as certain if there are differences between that of acetrc, propionic and butyric acids. A high pro_ portion of acetic acid has often been ascribed as a reason for the poorer utilization of high roughage diets. This, however, has been difficulito verify in normally fed animals since it is only possible to add about15% of VFA or VFA salis to a diet before problems arise with food intake and with the digestion of the basal feeds.

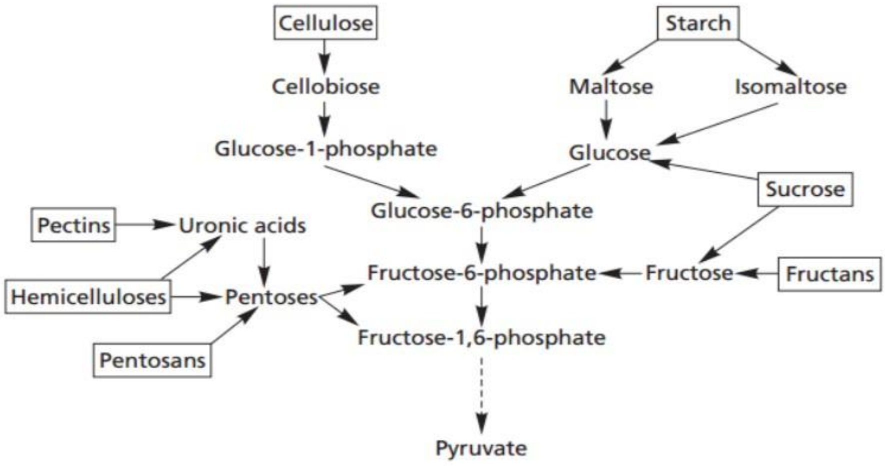
volatile Fatty Acids are absorbed through the walls of the rumen and are then transported in the blood to the liver. In the liver they are converted to other sources of energy.

ruminal absorption of volatile fatty acids (VFA) is quantitatively the most important nutrient flux in cattle. Historically, VFA absorption models have been derived primarily from ruminal variables such as chemical composition of the fluid, volume, and pH.

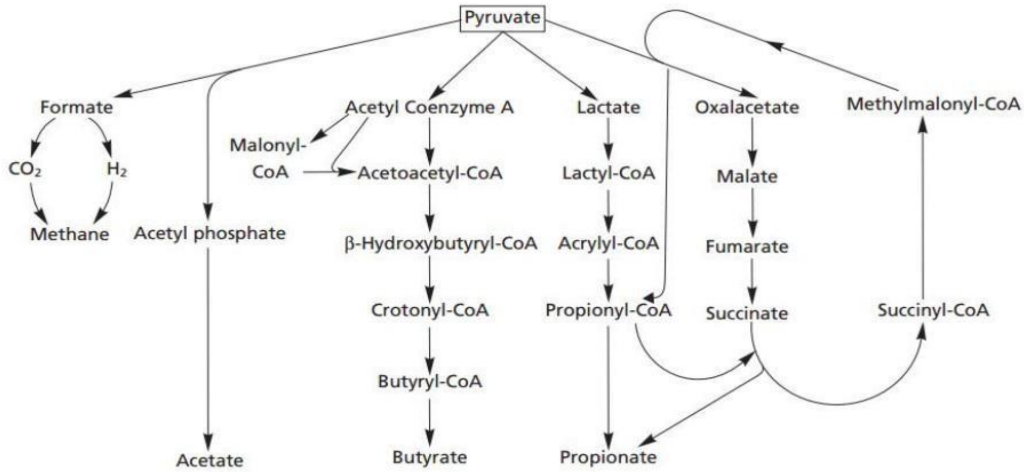
The consumption of fibrous foods, such as straw and hay, stimulates the enlargement of the reticulum. The fermentation of food by microbes in the rumen produces volatile fatty acids. (Weak organic acids with short chain lengths, most commonly acetic, propionic and butyric acids). These are monocarboxylic, alkanoic acids with the characteristics shown in the table.

	Molecular weight	Boiling point (°C)	pKa
Acetic	60	118	4.76
Propionic	74	141	4.87
Butyric	88	163.5	4.83

The NSP (non-starch polysaccharides) of foods may be degraded in the gut by microbial fermentation, yielding volatile fatty acids, which are absorbed and contribute to the energy supply. A further benefit relates to the volatile fatty acid butyric acid, which is reported to be an important source of energy for the growth of cells in the epithelium of the colon; thus, the presence of this acid will promote development of the cells and enhance absorption. More volatile fatty acids are produced from the finer particles as they have a larger surface area for attack by the bacteria. The digestion of cellulose and other higher polysaccharides is nevertheless small compared with that taking place in the horse and ruminants, which have digestive systems adapted to deal with fibrous foods. With conventional pig diets, microbial fermentation accounts for 8–16 per cent of the organic matter disappearing from the gastrointestinal tract. The products of microbial breakdown of polysaccharides are not sugars but are mainly the volatile fatty acids listed above. Lactic acid can be produced under some circumstances. The volatile fatty acids are absorbed and contribute to the energy supply of the pig.



Conversion of carbohydrates to pyruvate in the rumen. (Mc Donald et al 2010)



Conversion of pyruvate to volatile fatty acids in the rumen (Mc Donald et al 2010)

Ruminal Volatile fatty acid production and absorption

Volatile fatty acid production in rumen: The feeds, which is ingested by the animals broken down to volatile fatty acids like acetic, propionic and butyric acids via pyruvic acid. Higher fatty acids like valerie and isovaleric acid etc. are also formed in smaller amounts. With normal diets the predominant acid is acetic acid followed by propionic acid and butyric acid. Volatile fatty acids represent in the following proportions. 1. Acetic acid 60-70% 2. Propionic acid 15-20% 3. Butyric acid 10-15% 4 2021-2022 4. Valerie and isovaleric acid present in traces. On an exclusive roughage diet the production of acetic acid is highest. As the concentrates in the diet are increased, the production of acetic acid reduces and that of propionic acid increases. Lactic acid is also formed as an intermediate product but is fermented to acetic and propionic acid.

Mature fibrous forage give rise to VFA mixture with high proportion of Acetic acid (about 70%). Less mature forage tend to give a lower acetic acid and higher proportion of propionic acid. On concentrate feeding diet the acetic acid predominates if the rumen ciliate protozoa survive. The proportion of fatty acids production is changed under following condition: 1. High ratio of concentrates in the ration. 2. Fine ground forages, 3. Lack of physical fibrousness. 4. Green fodder low in fibre and high in soluble carbohydrates. 5. Pelleted concentrates. 6. Heated concentrates. 7. High starch diet.

This will bring relatively high ratio of propionic acid to acetic acid. The conversion of pyruvate into different volatile fatty acids is shown below. Short-chain fatty acids (acetate, propionate and butyrate) are the end products of anaerobic microbial fermentation of carbohydrates in ruminant gastrointestinal tract. They represent the most predominant anions in the ruminant forestomach and large intestine. They are readily absorbed into the blood stream and transported to body tissues where they are used for hepatic gluconeogenesis, lipogenesis in peripheral tissues and milk synthesis. The transport of short-chain monocarboxylates across the plasma membrane in most cells is largely dependent on monocarboxylate transporter family. There is a potential functional collaboration between MCT1 and MCT4; this may provide new insights into the mechanisms that mediate the transport of short-chain fatty acids and other monocarboxylates in the different segments of the ruminant gastrointestinal tract.

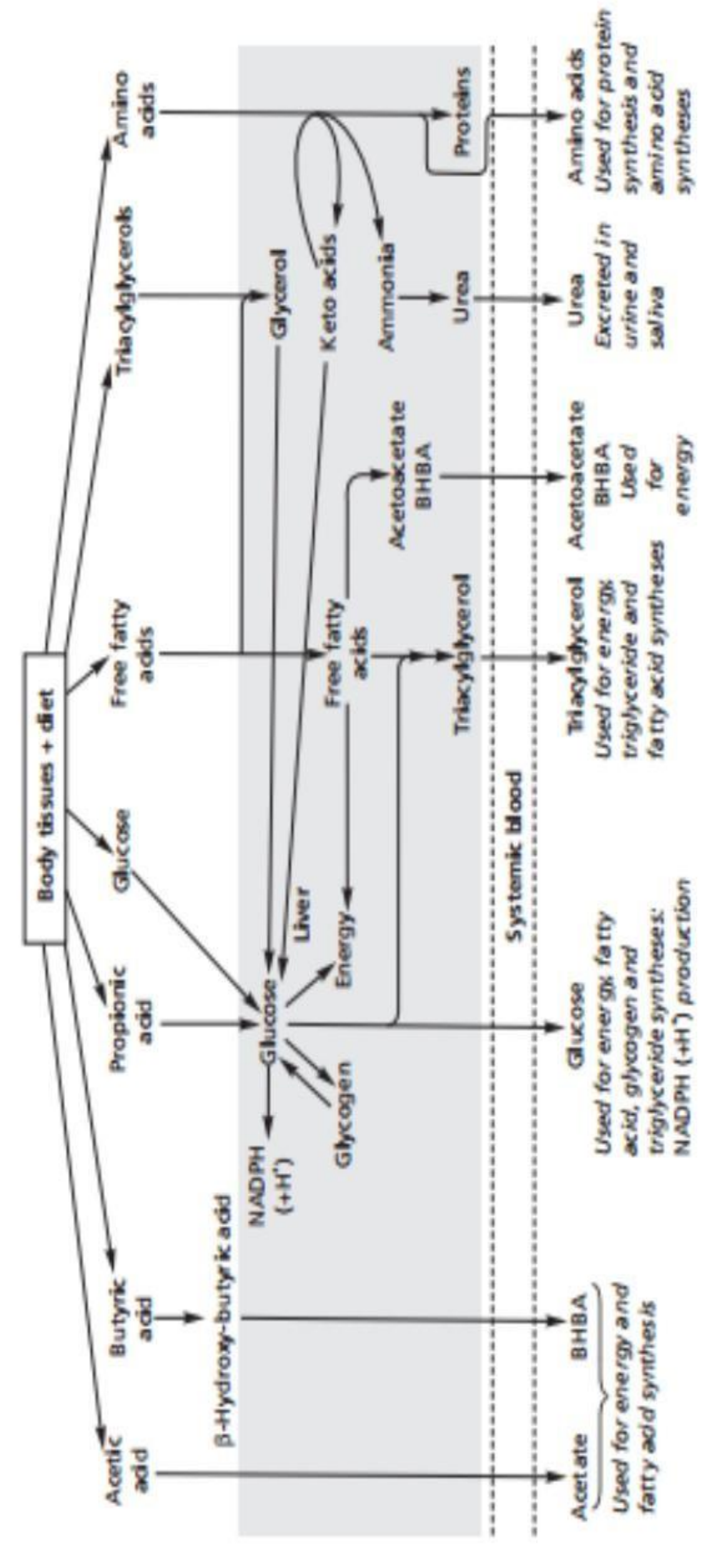


Fig. 9.1 Sources and fates of major body metabolites.
BHBA – β-hydroxybutyric acid; NADPH (+H+) = reduced nicotinamide adenine dinucleotide phosphate.

(Mc Donald et al 2010)

Rumen papillae (sheep)

The rumen is lined with stratified squamous epithelium similar to skin, which is generally not noted for efficient absorption. Nonetheless, this squamous epithelium has a structure which functions similarly to the columnar epithelium in the small gut and performs efficient absorption of VFA, as well as lactic acid, electrolytes and water. Recall also, that the epithelial surface is expanded greatly by formation of well-vascularized papillae.

It is of considerable practical importance that the size and length of ruminal papillae respond to concentrations of VFA in the rumen. Animals that have been on a high plane of nutrition, with abundant VFA production, have long, luxuriant papillae well suited to promote absorption. In contrast, animals which have been under nutritional deprivation have small, blunted papillae, and require time on a high quality diet to allow for development of their papillae and absorptive capacity.

All the VFA appear to be absorbed by the same mechanism, which is diffusion through the epithelium, down a concentration gradient. As they pass through the epithelium, the different VFA undergo different degrees of metabolism. Acetate and proprionate pass through the epithelium largely unchanged, but almost all of the butyric acid is metabolized in the epithelium to beta-hydroxybutyric acid, a type of ketone body.

The three major VFA absorbed from the rumen have somewhat distinctive metabolic fates:

- Acetic acid is utilized minimally in the liver, and is oxidized throughout most of the body to generate ATP. Another important use of acetate is as the major source of acetyl CoA for synthesis of lipids.
- Proprionic acid is almost completely removed from portal blood by the liver. Within the liver, proprionate serves as a major substrate for gluconeogenesis, which is absolutely critical to the ruminant because almost no glucose reaches the small intestine for absorption.
- Butyric acid, most of which comes out of the rumen as the ketone beta-hydroxybutyric acid, is oxidized in many tissues for energy production.