Nutrient requirements of ruminants for different physiological stages (cattle, buffaloes, sheep and goats)

In order that responses in animal productivity to supplements can be predicted accurately on a particular diet, it is necessary to take account of the constraints to metabolism. These relate specifically to the relative amounts of amino acids, glucogenic energy, VFA energy and long chain fatty acid energy in the end products of fermentative and intestinal digestion, since this is what determines the animal's productivity. Productivity of ruminants is influenced primarily by feed intake which, in turn, is determined by feed digestibility and the capacity of the diet to supply the correct balance of nutrients required by animals in different productive states. Therefore the two major variables that need to be considered are:

- The amounts and balance of nutrients required.
- The quantitative availability of nutrients from the diet.

The balance of nutrients required depends upon:

- The amounts of dietary components unchanged by rumen fermentation that are absorbed (amino acids, glucose and long chain fatty acids).
- The rates of production of the end products of fermentative digestion (which can be highly variable).
- The productive functions (pregnancy, lactation. growth, work, maintenance, depletion or repletion of bodyweight).
- The environmental factors (disease, parasitism, temperature and humidity, and other sources of stress).

The availability of nutrients from a diet is highly dependant on:

- The microbial ecosystem in the rumen which influences the availability of microbial protein, VFA energy and glucogenic energy.
- The chemical composition and physical form of the diet which influence the amounts of protein, starch and long chain fatty acids which escape the rumen fermentation.

At the present time, it is not possible to predict the nutrients required by ruminant livestock and to match these with nutrients available from digestion, because of the many interactions between the animal, its rumen microbial ecosystem and the diet. The most widely available low-cost feeds for ruminants in the majority of developing countries are usually native pastures, crop residues and to a lesser extent agro-industrial by-products. The expensive, and often unavailable (or exported), feeds are the protein meals, derived from oilseed residues and the processing of animals, fish and cereal grains.

Generally, energy (the basic feed resource) and fermentable nitrogen (urea) are relatively inexpensive ingredients, while the sources of amino acids and glucogenic compounds (the protein meals, cereal grains and cereal by-products) are very expensive. Since it is fermentation of carbohydrate which provides the energy for microbial growth, and as the feed is often low in digestibility, it is generally desirable to supply fermentable energy on an *ad libitum* basis. The basal diet should not therefore be restricted.

As a rule of thumb, 3 g of fermentable N per 100 g of fermentable organic matter are required to meet the needs for efficient microbial growth. It is not always necessary to provide this amount since some feed protein will be fermented to ammonia and some urea-N may enter the rumen in saliva. These processes reduce the amount of non-protein nitrogen needed. In addition there is evidence that the rumen microbes need small amounts of amino acids and other nutrients for efficient microbial growth. The potential of the diet to satisfy the requirements of the animal for amino acids, glucogenic precursors and long chain fatty acids depends on the pattern of fermentation and on the dietary protein, lipids (or their constituent fatty acids) and starch that escape fermentation and are digested in the intestines.

The extent to which the protein in a supplement escapes the rumen is partly a function of its rate of degradation (solubility) in the rumen. It is likely to be influenced greatly by the rate of flow of fluid and small particles out of the rumen. This latter characteristic will be influenced by processing of the feed (by physical or chemical means), the presence of some green forage, the amount of protein reaching the duodenum and external factors such as temperature and exercise/work.

The same factors will influence the supply of glucose and glucogenic precursors in terms of the likely by-pass of starch to the duodenum. However, the nature of rumen fermentation will have a major influence in terms of the supply of propionic acid for glucose synthesis.

Relating nutrient supply to productive state

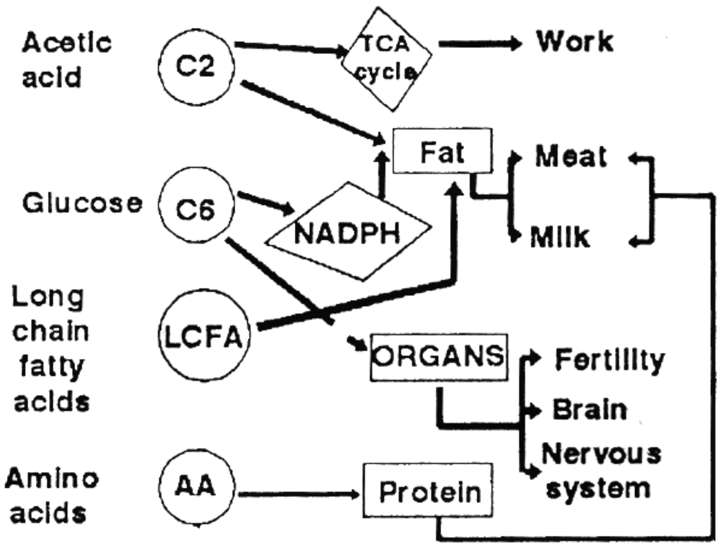
There is insufficient information available to permit the precise quantification of the proportions of the different nutrients required for different productive states. Nevertheless, an approximation of the needs of animals can be attempted. The suggested scheme attaches relative priorities to the groups of nutrients according to the physiological and biochemical processes underlying the expression of the particular productive state (see Figure 5.3).

The groups of nutrients to be varied for different productive states are:

- VFA energy.
- Glucogenic energy.

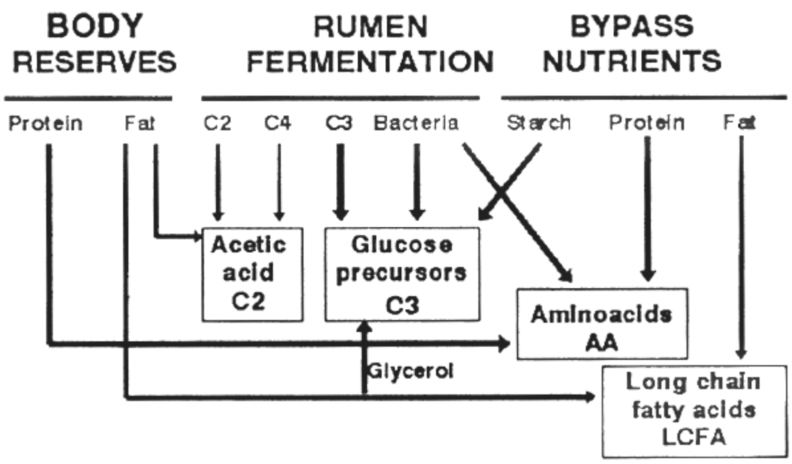
- Amino acids.
- Long chain fatty acids (LCFA).

Metabolic substrates and productive function



- The sources of these nutrients are summarized in Figure 5.4. VFA energy arises from the rumen fermentation of all types of organic matter principally carbohydrates. The principal way of increasing VFA energy in a particular feed is to increase intake (e.g., by selection through high offer level), to increase the rumen degradability (urea supplement), to supplement with by-pass protein or to treat with alkai (ammoniation).

Sources of nutrients for metabolism



Manipulation of the rumen to provide extra protein and glucogenic precursors is still at the experimental stage. Dietary supplementation is the most obvious way of manipulating the supply of absorbed amino acids, glucose and glucose precursors.

Most supplements are expensive and their use in ruminant nutrition competes with monogastric animal and human nutrition. As a rule of thumb, the role of the supplement ceases to be “catalytic” when it exceeds about 30% of the diet dry matter. Beyond this point it assumes a major role and substitution occurs. The productive functions and the need for supplementary nutrients are discussed in order of the least to the most demanding.

Work

Work requires ATP (adenosine triphosphate) generated from the oxidation of long-chain fatty acids, with obligatory requirements for glucogenie compounds and for amino acids (to repair the wear and tear of tissues and replace protein secretions). The working animal can often obtain sufficient nutrients from a nitrogen-deficient diet so long as it balances the protein:energy ratio needed for tissue turnover by “burning” off acetate which is in excess of requirements.

The mature, unproductive ruminant does not appear to require nutrients over and above those provided by an efficient fermentative digestion. Since the heavily working animal uses largely long chain fatty acids and glucose, the supplements used should contain or provide these substrates. This is particularly important in the case of long chain fatty acids, since their absorption and use for fat deposition or mobilization and for work will be much more efficient and will require less glucose oxidation than fat synthesis from acetate and subsequent utilization in muscle metabolism.

Maintenance

Maintenance alone obviously requires less energy expenditure than work so there is a proportionately higher demand for amino acids (relative to energy) than in the working animal. This will always be provided by a rumen system which is adequate in fermentable nitrogen. Animals in negative energy balance for an extended period on low-nitrogen roughage-based diets extract more digestible energy from the basal diet when this is supplemented with fermentable nitrogen.

Live weight change of pregnant cows and calf birth weights in response to supplements providing fermentable nitrogen and sulphur alone or with by-pass protein

	Hay intake (kg DM/d)	Live weight change (kg/d)	Birth weight of calf (kg)
Spear grass	4.2	-0.81	22
Spear grass+urea+S	6.2	-0.31	31
Spear grass+urea/S+			
by-pass protein*	8.1	+0.75	32

* 1 kg/d of protein pellet (80% cottonseed meal, 10% fish meal, 10% meat meal

Growth

Growing animals have a very high requirement for amino acids for tissue synthesis and glucose for oxidation in specific tissues (e.g., brain). In addition, considerable amounts of glucose must be oxidized to provide the NADPH required to synthesise fat from acetate. It is imperative to recognize that high growth rates cannot be supported on the products of fermentative digestion and that by-pass protein supplements are essential to take advantage of the VFA energy absorbed. Many factors influence the level of protein supplementation to be used. Response relationships must be established which relate protein supply to animal productivity for each basal (carbohydrate) resource and for the available protein sources.

Cattle on ammoniated (urea-treated) rice straw, when supplemented with only 50 g/d soybean meal, increased their live weight gain threefold. On a molasses-based diet of higher energetic potential, 450 g/d of soybean meal were needed to raise live weight gain from 300 to 900 g/day.

Reproduction

Improvements in fertility brought about through nutrition are usually attributed to increased energy intake. There is, however, information to show that the supply of glucogenic precursors relative to total energy is an important feature of the improved energy status which results in increased fertility.

Conception and puberty

Recent studies have demonstrated that even when the protein supply is adequate, the “quality” of the energy can also be a limiting factor. At the same metabolizable energy intake (the basal diet was low-N Coastal Bermuda grass pasture), puberty was reached at lower liveweights when glucose availability in the animal was enhanced by supplementation with monensin. This is not a recommended practice but serves to demonstrate the concept. There are, of course, ways of increasing the glucogenic potential of the absorbed nutrients without recourse to chemical additives (e.g., by the use of by-pass protein).

Growth of the fetus

The growth of the conceptus has little effect on the protein and energy demand of ruminants until the last third of gestation when most of the foetal tissues are deposited. Because of the time course of growth of the conceptus which increases the daily need for nutrient to only a small extent, it appears that rumen function even on diets of low digestibility can support the birth of a viable offspring of normal weight. This was shown in studies in which urea was included in the drinking water of ewes on nitrogen deficient pasture.

Increases in calf birth weight were recorded when pregnant cattle, given a basal diet of hay of low digestibility (45%), were supplemented with urea. However, to prevent bodyweight loss and/or promote weight gain of the dam through pregnancy, it was necessary to provide additional by-pass protein. It appears that urea supplementation enhances milk production to a level that ensures survival of the offspring. But to allow the young animal to grow, milk yield must be further stimulated by feeding a by-pass protein meal.

Male reproduction

Male reproduction has been enhanced under grazing conditions by supplementary feeding. Bulls can be maintained in good condition on poorly digestible, low-nitrogen spear grass pasture by providing 1 kg daily of a protein supplement.

More importantly, the circumference of the scrotum decreased consider-ably when no supplement was fed; and it is known that a bull with a lower scrotal circumference is less fertile and has a lower libido. This shows quite clearly that protein nutrition influences male fertility. As with female fertility, there appears to be evidence for beneficial responses to manipulating propionate production in the rumen. At the same feed intake, bulls reached puberty earlier and, at puberty, had a greater scrotal circumference and larger testicles.

Milk production

The major constraint to milk production on diets based on crop residues and agro-industrial by-products appears to be the availability of glucogenic compounds to provide the glucose for lactose synthesis and for oxidation to provide the NADPH for synthesis of fatty acids. There is good evidence that, in large ruminants, about 50% of the fatty acids of milk arise from dietary fat.

A dietary source of lipid can thus reduce considerably and imbalance caused by relative deficiencies of glucogenic energy and amino acids in the end products of rumen digestion. For many feeding systems in the tropics the level of fat in the diet could be a primary constraint to milk production. This could be particularly important in diets based on molasses or sugar-cane. Supplementation of lactating animals, particularly on diets based on tropical pastures, crop residues and sugar-rich agro-industrial by-products, should aim to correct the imbalances of nutrients for milk production. By-pass protein usually increases feed intake and as a consequence promotes milk production.

But to balance energy quality, fat must be mobilized and glucose diverted from oxidation and tissue synthesis to lactose production. In these circumstances, animals tend to lose body weight. Dietary fat may reduce this effect. Adding a source of by-pass starch in such a diet balances the ratio of glucogenic precursors to protein and energy and will tend to prevent body fat mobilization. The points to be stressed are that:

- By-pass protein because of its effects on feed intake almost always stimulates milk production and depending on the imbalance in nutrients (fermentation pattern) may cause animals to mobilize body reserves. This may be prevented by the use of high-fat, high-protein meals that supply both protein and long chain fatty acids for digestion post ruminally.
- By-pass starch or manipulation of the rumen to give higher propionate production, because it balances nutrients for milk production, may prevent mobilization of body reserves without large effects on feed intake and therefore on milk production. But because it balances the nutrients for milk production, efficiency of energy utilization is increased and body weight is often increased.

Wool and hair production

The effect of nutrition on wool production appears to be dependent almost entirely on the quantity, and quality, of the balance of amino acids absorbed. Therefore, feed intake is the primary limitation to wool or fibre growth although at any one feed intake, wool growth can be stimulated by altering the balance of protein relative to energy in the products of fermentative digestion (e.g., removing protozoa from the rumen). Thus on diets that require fermentative digestion, including those based on sugars or fibre, a by-pass protein supplement will increase wool growth.