PRINCIPLES OF RATION FORMULATION FOR RUMINANTS

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Abstract

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Feeding standards as practiced in developed countries could be misleading when non-conventional feed resources are used in formulating rations for ruminant livestock in developing countries. They tend to reject the poor quality feeds that are available in vast quantities. The non-availability of good quality forage throughout the year and the need to optimise the efficiency of utilisation of locally available feed resources have lead to the application of basic nutritional principles when considering ration formulation. The alternative approach to the use of feeding standards would be to ensure that the production system matches the available resources. The development of feed supplementation strategies based on locally available feed resources require the understanding of the relative roles and nutrient needs of the two-compartment system represented by the micro-organisms in the rumen and the host animal.

1. INTRODUCTION

The relevance of using feeding standards in the formulation of rations for ruminant livestock in developing countries of the tropics has been questioned for many years [1], especially after the publication in 1980 of "Who needs feeding standards?" by Prof. M.G. Jackson of the University of Pant Nagar, India [2]. Jackson argued that feeding standards as practiced in developed countries are misleading when non-conventional feed resources are used in formulating rations for ruminants in developing countries. He pointed out that the level of production achieved might be considerably less than what is being predicted by the feeding standard. More importantly, he emphasised that feeding standards lead to the rejection of many locally available feed resources which were apparently poor in supplying the digestible energy needed for production although they could be the main or the sole feed resources available at the smallholder level. Feeding standards also encouraged researchers in developing countries to copy feeding systems from the temperate countries, which required resources that were often inappropriate on socio-economic grounds. They also ignored the value of rumen non-degradable protein; in many instances although nutrient requirements were satisfied according to traditional standards the responses did not correspond to the predicted level of performance.

The smallholder farmers in developing countries have limited resources available for feeding to their ruminant livestock. They are unable to select the basal diet according to the requirement for production unlike their more fortunate counterparts in developed countries, but use whatever is available at no or low cost. Therefore, the strategy for improving production should be to optimise the efficiency of utilisation of the available feed resources, and thereby attempt to maximise animal production.

2. FEED RESOURCES AVAILABLE FOR RUMINANT LIVESTOCK

The availability of feed resources is determined by the land utilisation pattern. This reflects the demand of the human population and the nature of the ecosystem which in turn is a function of land and soil characteristics including terrain, availability of water, rainfall, soil fertility, etc. Due to the ever increasing human population and the consequent increase in demand for food, livestock feed tends to be derived from residues and by-products of the food industry.

The major problems with feeding of livestock occur in those areas subjected to long dry seasons, when there is insufficient plant biomass carried over from the wet season to support domestic livestock population. The situation becomes more acute as the dry season becomes established, when protein content of the natural grazing falls, often from 12–14% to about 6–8%. The fall in crude protein content is also accompanied by an increase in fibre content. Thus, the animal is faced with insufficient amounts of a low quality and relatively indigestible feed. The situation is intensified by drought.

In most developing countries, the major feed resource is natural grazing, often in communal ownership. Over the past 50 years a rapidly expanding human population has markedly increased pressure on land, causing arable land to encroach on the best of the grazing land. In some areas this has made zero grazing a necessity, especially for dairy cattle production, in place of the traditional grazing systems. Feed resources available for livestock production in the tropics can be categorized into four groups.

2.1. High fibre-low protein feeds

These include fibrous residues arising from crops grown for human consumption, such as straws and stovers from rice, millet, sorghum and maize, and sugarcane bagasse.

The production of crop residues and by-products can be estimated fairly accurately from estimates of the primary product (e.g. grain), using multipliers which assume grain:residue ratios. The uncertainty of such ratios can be judged by the different multipliers used by different people [3, 4]. Not withstanding such discrepancies in grain:residue ratios for estimating residue yields, it is quite evident that vast quantities of residues are produced as a result of crop cultivation. A conservative estimate would be over 5 billion tonnes of dry matter (DM) per year.

Crop residues are characterised by their high fibre content (>700 g of cell wall material/kg DM), low metabolizable energy (<7.5 MJ/kg dry matter), low levels of crude protein (20–60 g of crude protein/kg DM) and mineral nutrients and low to moderate digestibility (<30–45% organic matter digestibility). Their daily intakes are often limited to less than 20 g dry matter/kg live weight. Most residues are also deficient in fermentable carbohydrates, reflected by the relatively low organic matter digestibility.

Chemical treatment increases the potential feeding value of crop residues. Alkali treatment of fibrous residues has been well researched and the possibility of using urea as a source of ammonia led to the expectations of rapid adoption of the technology in developing countries. However, for various reasons this has not been realised [5].

2.2. High fibre-high protein feeds

By-products derived from crop production (tops and haulms from ground nut, sweet potato vine, cassava leaves, bean straw) and industrial processing (bran from cereal milling — rice, wheat and maize bran, brewer’s grain), fall into this category of feeds. They are generally less fibrous (below 700 but above 400 g of cell wall material/kg of DM) than those in the first category but have relatively high amounts of crude protein (> 60 g/kg DM). Leaves from tree legumes and browse plants such as *Glyricidia, Leucaena* and *Erythrina*, that have around 250–350 g/kg of crude protein in DM, can also be considered in this category.

2.3. Low fibre-low protein feeds

These include feed resources derived from crops grown for renewable energy such as sugarcane by-products and root crops. They are generally rich in energy and low in protein content. Examples of this category would be molasses, oil palm juice and waste material arising from the fruit processing industry (citrus pulp, pineapple waste) and root crops (cassava waste).

2.4. Low fibre-high protein feeds

These are the feeds traditionally called *concentrates* and include oilseed meals and cakes (coconut cake, soybean meal, cotton seed cake, groundnut meal/cake) and animal by-products (fishmeal, blood meal, feather meal). They are valuable sources of good quality protein for both ruminant and non-ruminant animals.

Oil seed meals and cakes may contain variable amounts of crude protein: coconut meal contains around 200 g crude protein/kg of dry matter while decorticated oil seed meals such as groundnut meal, and cotton seed meal (or cake) may contain as much as 400–500 g of crude protein/kg of dry matter. The amount of oil contained in the by-product may affect the keeping quality of the feed. It varies according to the method of extraction of the oil; solvent extracted meals or cakes will contain less oil than expeller extracted meals or cakes.

Animal by-products are very good sources of high quality protein and can improve the nutritive value of low quality forage based diets for ruminants. Fishmeal is often used for balancing the amino acid content in monogastric feeds. Even for ruminants, fishmeal can provide a high proportion of rumen non-degradable protein acting as a reservoir of amino acids for high levels of production.

Natural pastures fall into the first and/or the second category depending on time of harvesting, the nature of the pasture species, climatic conditions, etc.

The proximate composition of some common feeds found in developing countries and classified according to the above criteria are shown in Table 1.

3. RATION FORMULATION FOR RUMINANTS — AN ALTERNATIVE APPROACH

If one considers that the use of traditional feeding standards as practiced in developed countries are inappropriate for developing countries with limited resources, then there must be an alternative approach when formulating rations for ruminants. This alternative approach would require that the livestock production system is matched with the resources available and optimises the utilisation of locally available feed resources. Such an alternative approach for formulating rations for ruminants should consider that:

- the efficiency of the rumen ecosystem cannot be characterised by any form of feed analysis currently in use. This raises the question: can the feed support optimum rumen function? What are the nature, amount and proportion of end products of fermentative digestion?
- feed intake on some diets bear no relationship to digestibility of the feed
- feed intake is often influenced by supplementation
- the availability of amino acids cannot be inferred from the crude protein content of the diet. This reflects the potential escape of nutrients from the rumen and their digestibility in the small intestine

- the energy value of a diet and the efficiency of its utilisation are largely determined by the relative balances of glucogenic energy, long chain fatty acids and essential amino acids absorbed by the animal

Therefore, as described by Leng and Preston [6] and Preston and Leng [7], when considering ways to optimise the utilisation of feed resources for ruminants it is necessary to apply two basic concepts.

a) ensure optimum conditions for microbial growth in the rumen to make the digestive system of the animal as efficient as possible
b) supply deficient nutrients to balance the products of digestion to requirements, optimising production
c) any further increases in production should be by the use of supplements of protein, starch and lipids.

This entails that the ruminant animal must be considered as a two-compartment system having a digestive system with an efficient rumen fermentation optimising microbial growth. This implies a requirement of nutrients for the microbes. The animal ought to rely on the products of fermentation of those feed components that escape rumen fermentation but are digested in the intestines for the supply nutrients for maintenance and production purposes.

The two systems are mutually supportive. Efficient rumen fermentation ensures that the host animal receives the maximum amount of digestible nutrients from a given feed. The rumen microbes need protein (amino acids, peptides), glucose and minerals, in particular sulphur, potassium and phosphorous, as pre-cursors.

Maximum efficiency will occur when a continuous supply of fermentable carbohydrate is matched with the correct amount of ammonia and amino acids so that microbial protein is formed without waste of the major substrates (microbial cells contain 40 to 60 percent protein on a dry matter basis).

3.1. Feeding the rumen microbes

The two compartments system requires that the rumen microbes are adequately fed so that they could perform at their optimum level. When feeding the rumen microbes the following are important.

- free choice of basal diet to ensure maximum intake. Ideally, offer the animal over and above its requirement — offer ENOUGH — to facilitate selection by the animal of more digestible components.
- the need for ammonia is in excess of 200–250 mg per litre of rumen fluid to maximise digestibility as well as intake. This is especially important when considering fibrous crop residues and by-product feeds. It can easily be achieved by allowing access to a highly soluble source of nitrogen such as urea in urea-molasses multinutrient blocks.
- macro and micro minerals. Macro minerals phosphorus and sulphur and the micro mineral cobalt are considered essential for optimum microbial growth. They can be supplied through multinutrient blocks and/or mineral supplements or small amounts of green forage.
- macro nutrients such as peptides and amino acids come from rumen degradable proteins given in the basal diet.
- an optimum ecosystem that will promote the rapid colonisation of the basal diet. When possible, provision of a small quantity of highly digestible green forage (say 2 kg of fresh material/100 kg live-weight) is the best way of supplying this.

TABLE I. PROXIMATE COMPOSITION OF SOME COMMON FEEDSTUFFS FOUND IN DEVELOPING COUNTRIES IN AFRICA AND ASIA (g/kg DRY MATTER)

Feed Resource	Ash	Crude Protein	Crude Fibre	Neutral detergent fibre	Digestibility
			(range — g/kg dry matter)		(%)
High fibre-low protein	low to moderate	low	high	high	low to moderate
Cereal straw/stover	40–120	20–60	>300	>800	30–45
Bagasse	30–40	<30	>450	>800	20–30
Sugarcane tops	50–60	50–70	>300	>700	
Corn cobs	15–20	30–40	>300	>800	
Cottonseed, groundnut hulls	30–60	40–60	>300		
High fibre-high protein	low to moderate	moderate to high	moderate to high	moderate to high	moderate to high
Leguminous tree leaves (meal) *(Gliricidia, Leucaena, Erythrina)*	10–15	100–300	100–150		60–70
Haulms and tops (bean, ground nut, soybean, sweet potato vine)	60–150	60–195	120–300	>600	50–65
Cassava leaf meal	70	120–250	150		
Brewers grain	30–40	200–250	150–210		50–70
Cassava peels	70–120	50–120	100–300		
Low fibre-low protein	low to moderate	low	low	low	low to moderate
Molasses	70–100	<60	-		
Citrus pulp	30–120	<60	120–200		40–60
Low fibre-high protein	low to moderate	moderate to high	low to moderate	low to moderate	moderate to high
Oil seed cakes (coconut cake, groundnut cake, cottonseed cake, sun flower cake, soybean meal)	50–80	250–500	30–300		60–70
Brans (rice, wheat, maize)	20–90	80–160	70–180		70–80
Animal by-products (blood meal, fishmeal)	20–160	>600			
Poultry waste (offal, hatchery waste, feather meal)	50–200				
Cage layer manure	120–250	200–400	170–300		

3.2. Feeding the host animal

When feeding the host animal the aim should be to increase the protein:energy ratio in the nutrients absorbed. This is generally achieved by:

- increasing the efficiency of rumen fermentation to maximise microbial protein production
- supplying rumen non-degradable protein (e.g. from cotton seed meal, sun flower meal) to meet the deficit protein between that is synthesised in the rumen and that is required by the host for a given level of production.

While the first above can be achieved by way of the basal diet supplying adequate nutrients for optimum functioning of the rumen microbes the latter needs to be addressed by way of supplementation.

When considering supplementation a number of factors have to be born in mind. The purpose of supplementation would be to provide nutrients that are deficient in the basal diet and additional nutrients needed for production. The selected supplements should not reduce intake and utilisation of the basal diet but instead have the potential for enhancing them. The ideal supplement will facilitate maximum utilisation of the basal diet and will be of limited value as a feed for man or other monogastric species. The supplements should also be easily available, cheap and require minimum labour for storing and feeding. At the same time they should improve animal productivity, compatible with on-farm feeding practices and offer minimum chances of poisoning or ill health to the animal.

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