

# **Evaluation of tropical feed resources for ruminant livestock**

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## **Introduction**

The primary concern of this expert consultation is the assessment of the potential levels of animal production that can be achieved on feeds for ruminants that are available in the tropics.

The title suggests that there may be basic differences in evaluation methods for tropical feeds as compared to those available in the temperate countries. However, many feeds and feed ingredients are exported from their country of origin and the definition of tropical or temperate has little significance. For example a majority of poultry meats and eggs produced intensively and marketed in the tropics are produced from grains imported from temperate countries. Prices of surplus grain on world markets are likely to be subsidised to remain low despite the often high cost of pollution and loss of soil fertility accompanying mechanised production in the temperate countries.

Until recent times there has been a massive trade of protein meals from tropical developing countries to the temperate developed countries to support high levels of animal production in the latter areas (Borgstrom 1980).

The other contrast is that in ruminant production systems in temperate countries only or mainly high quality ingredients are used in compounding feeds. In turn this supports high production rates close to the genetic potential. Temperate countries in general must maximise production and therefore feed conversion efficiency through feeding and breeding in order to minimise the costs of feed, labour and capital depreciation which together are the largest proportion of their variable costs. Because of the high nutrient

densities of the feeds used to feed livestock in temperate countries the diets are rarely significantly deficient in any nutrients. This is not the case when agro-industrial byproducts, crop residues or tropical pastures are fed.

### **Differences between temperate and tropical countries**

Developing countries are mostly located in the tropical areas of the world, animals are often managed in small numbers, utilising the byproducts of agriculture, agro-industries or grazing pasture on land not easily farmed or too infertile for cropping. The cost of agricultural labour in these countries is relatively low or is not an issue such as the cost of family labour.

The basic differences are as follows:

- \* In the developed (temperate) countries in order to be profitable animal productivity needs to be maximised by meeting the animals' requirements for nutrients. To achieve this farmers generally use high quality energy dense feeds which are also high in protein. The nutritional research required in the temperate countries therefore is largely fine tuning of the nutrient balances arising for digestion and absorption from a diet.
- \* In the developing countries (tropical), land for ruminant feed such as pasture or crops specifically grown for forage is not generally available and the animal must depend on locally available byproducts of agriculture and industry which are often deficient in certain nutrients. In these countries there is a need to optimise production from the available resources by providing minimum amounts of the deficient nutrients. The level of production is even then often well below the animals genetic potential.

The major exception to these generalisations are in developed countries with low population densities and large tracts of land where labour costs are high and extensive grazing systems with low nutritional inputs persist because they best suit the short-term economic situation but perhaps are eventually non-sustainable as without inputs fertility of these rangelands decline.

These fundamental differences pose different criteria for feed

evaluation and indicate different sources of feeds for ruminants. For example straw is regarded as a major feed resource for ruminants in many developing countries whereas it is regarded as of little value in temperate developed countries and its disposal is now a major pollution problem. In those countries that have extensive grasslands the major resource is pasture usually from relatively infertile land and which rarely supports more than medium levels of production. Evaluation of pastures by chemical analysis is rarely relevant, as the intake of pasture and its composition is unknown and changes progressively with seasonal conditions.

In the following discussions feed evaluation is discussed in relation to optimising animal production from local resources rather than maximising animal production from high quality feed resources.

### **Local/imported feeds for livestock**

A presumption made here is that there are only a few basal feeds and options for feedstuffs in any single locality and therefore there are few feeds to evaluate. This then lends itself to evaluation of feeds in feeding trials with the target animals.

With limited chemical knowledge of the feeds and a few principles of ruminant nutrition the compilation of diets to optimise production from the least cost basal feed resource can be accomplished and local feeding trials can be used to determine the response to graded levels of supplement inputs. The data from these trials then becomes the basis for "rule of thumb" recommendation for widespread development of feeding systems. A response curve to any input then allows economic level of supplementation to be used.

This assertion often disappoints scientists who have mastered complex computer models or computerised least cost diet formulation. It also angers others from the temperate countries, presumably because they feel that perhaps the applicability of their science is being challenged. However, if the feed evaluation systems, as applied to temperate countries (e.g. the ARC system or Cornell Metabolisable Protein System) were applied literally in developing

countries most of the present ruminant feeds of the developing world would be rejected as being too low in digestible nutrient densities to be useful.

The standards of developed countries for feed quality based on any energy measurements for ruminant are clearly misleading when they are applied to poor quality forage or non-conventional feedstuffs (see Leng 1990). In at least two major developments in Asia involving millions of animals in each, high growth rates of cattle (Guo Tinsuang and Yang Zhenhai, 1994; Dolberg & Finlayson 1995) and high milk production in cows (NDDB - see Leng 1989) have been achieved on feeds that are rejected in developing countries as being of too poor quality, yet these systems have production outputs that come close to those of many developed country systems based on high quality pastures.

### **Primary consideration of feed resources**

The first approach to feeding must be to identify:

- \* the feed resources in ample supply and that are therefore available to provide the bulk of a ration for the local herd or flock.
- \* the supplements (usually high in minerals and/or non protein nitrogen and/or protein) needed to balance the animal's nutrition on the biomass resource.

The former resources are comprised largely of fibrous carbohydrates that require microbial fermentative activity for digestion and include:-

- \* biomass from grasslands, waste land, roadsides and bunds between crops,
- \* crop residues,
- \* agro-industrial byproducts high in cellulose,
- \* crops grown specially for feeding to ruminants (grasses, sugar cane and silages).

These are generally all bulky feeds that are not economically transportable any distance and must be fed to ruminants within a few kilometres of where they are harvested.

Molasses and sugar cane juice which contains sugar that can be

digested intestinally appears to be the only dense carbohydrate resources sufficiently available in the developing countries to be considered as a basal feed resource for ruminants. However, export to developed countries, industrial processing and the demand for other uses (e.g. alcohol production) makes it unlikely that they will be used extensively as a basal feed for ruminants in the future. Molasses remains an important resource as a concentrated multi mineral source particularly for ruminants.

The other group of feed resources are the supplements. These provide essential nutrients in high concentrations and therefore blend with complement and balance basal feed resources. These resources include concentrated sources of minerals (e.g. residue after fermentation of molasses); bypass proteins, (e.g. cottonseed meal); non protein nitrogen sources (e.g. urea and poultry manure) or their precursors in the rumen (e.g. fresh forage plant proteins); fat (e.g. from oilseed cakes) and vitamins (e.g. vitamin A - from green grass). Because these resources are to be used as a small proportion of a diet relative to the basal feed, they can often be transported economically. Where these supplements cannot be delivered economically then resources have to be produced and/or processed locally to provide the critical nutrients needed to balance low protein forage based diets, particularly with respect to the provision of a protein meals that escapes rumen degradation (see Leng *et al* 1977; Preston & Leng 1987; Leng, 1990; Leng, Choo and Arreaza, 1992).

### **Evaluation of basal feed resources**

In relation to tropical feeds for ruminant livestock the major resources that fall into this category are straws and stovers, pasture grasses and agro-industrial byproducts of sugar cane industry, that is bagasse and sugar cane tops. These are all categorised as poor quality forages which in general means that they are of low digestibility i.e. generally lower than 50% digestible and are low in protein and non protein nitrogen (NPN) (often less than 6% CP) and variably deficient in a number of minerals. Mineral components of such biomass obviously depends on growing conditions including soil

fertility, climate and stage of maturity of the plant at harvest. These forages will need to be supplemented to correct their nutrient deficiencies e.g. fermentable N, bypass protein and minerals. There appears to be therefore little point in measuring chemical entities on the forages per se without supplements, although they are often fed in developing countries alone. Knowledge of the potential deficiencies for the microbial system in the rumen is most important since this is often the limitation that determines the nutritional value of the feed. The first criteria in a feed evaluating system is to understand the likely order of deficient nutrients firstly for microbial growth in the rumen which determines the potential extraction of nutrients by the rumen microbiota (see later) and then for the animal.

### **Assessment of degradability of a feed in the rumen**

The balance of nutrients potentially made available from and the digestibility of the dry matter in the rumen are the most important criteria of the potential of a basal feed. Digestibility primarily establishes the intake of the basal feed once nutrient deficiencies for the rumen microbes have been corrected (Minson, 1982), however, intake is effected by climate and a range of other factors.

There are only a few methods available to assess digestibility these include *in vivo*, *in sacco* or *in vitro* methods. A number of chemical analysis can be used to predict digestibility but except for rapid screening processes these seem to be of little value against the more direct measures of digestibility determined *in vivo* or *in sacco*. Digestibility values are only valuable if they are determined with some accuracy in a well designed digestibility trial. *In vitro* digestibility is highly correlated with the *in vivo* potential digestibility but standardisation is necessary. The nylon bag technique (*in sacco* digestibility) provides valuable data on digestibility provided the technique is standardised and the curve of disappearance of dry matter from the dacron bag in the rumen is well defined using replicate samples taken over a time period. It is however, apparent that in most laboratories the nylon bag technique is rather crudely applied.

The disappearance curve for dry matter may be analysed to provide data on fractional digestibility rate and the potential dry matter digestibility. Ørskov *et al* (1988) have argued that the coefficients of the disappearance curve of dry matter loss with time from nylon bags in the rumen can be used as a primary measure of nutritional value of a forage and allow prediction of growth rate (see later).

A major point to be stressed here, however, is that the nutritional value of a forage alone is not always the important issue. The nutritional value of the diet containing the forage as a major component and balanced to achieve efficient microbial growth in the rumen and efficient partitioning of nutrients into tissue or milk synthesis is the most important issue and therefore knowledge is needed of:

- \* the level of production on the forage which is supplemented to ensure the diet meets the microbial growth requirements in the rumen.
- \* the response of relationships of production to level of the appropriate supplements.

It is thus relevant now to discuss methods for assessing the efficiency of the rumen and the composition (quality) of the appropriate supplements.

### **Defining the status of microbial growth on the rumen**

An approach to estimating the net efficiency of microbial growth in the rumen depends upon knowledge of rumen biochemistry - mainly the factors that are involved in the production of VFA in the fermentative processes relative to microbial growth in the rumen. Microbial protein synthesis relative to VFA production determines the protein to energy ratio (P/E ratio) in the nutrients absorbed. Maximisation of microbial growth on any carbohydrate resource requires all necessary microbial nutrients to be present and at optimum levels, this then leads to a maximisation of the P/E rates in the nutrients absorbed from the rumen (Leng 1982). The best estimate of rumen efficiency is microbial cells available. The main *in vivo* method to measure microbial cells produced in or leaving the

rumen appears to be in the quantity of purine excreted in the urine (Smith and McAllen 1971) purine excretion in g/d relative to digestible feed intake is an index of the efficiency of the rumen microbial ecosystem (Chen and Gomes 1992).

Other approaches to assessing the relative microbial growth include an *in sacco* method. In this method the digestibility and a, b, and c of the disappearance curve of a standard forage has been measured in an animal with an efficient rumen and then these same measurements are made in the rumen of an animal fed the basal feed resource (see later). This indicates whether microbial growth is sufficiently high to maximise digestibility but not necessarily microbial growth yield per unit of feed digested.

A further approach measures the relative rate of incorporation of a marker (usually  $^{35}\text{S}$ ) into microbes in rumen fluid from an animal on a diet and compares this with rumen fluid from another animal known to have a highly efficient rumen microbial ecosystem (Hendrickx & Martin 1963).

### **Evaluation of supplements**

Supplements needed to maximise production from the basal feed resource are obviously variable and at times include:-

- \* minerals - calcium, phosphorus, sulphur, magnesium, sodium and trace minerals etc. required by both the microbial ecosystem in the rumen and by the animal.
- \* calcium requirement in particular, as a deficiency of calcium in solution in the rumen specifically inhibits cellulase activity,  $\text{Ca}^{++}$  is a co-enzyme for the microbial cellulolytic enzymes (Walker & Leng, 1994).
- \* non-protein-nitrogen (mainly ammonia) and sulphur source for rumen microbial growth.
- \* a source of bypass protein to enhance the essential amino acid supply to the animal.
- \* supplements that improve the overall digestible energy density of a low digestible basal feed. Included in this group are high digestibility forages, molasses, sugar cane or its juice and fats.



### **Assay of mineral supplements**

It must be stated at the outset that many potential supplements have multiple roles. For example, most protein meals are high in phosphorus and minerals, molasses and distillers slops because of their origin as a plant juice contain a fairly complete array of minerals including trace elements. Urea molasses multinutrient blocks (UMMB) are designed to provide urea, a complete mixture of minerals and some slowly degradable protein (see Sansoucy, Arts and Leng 1988)-

Mineral components of standard materials can generally be assumed from literature values and local knowledge. However, mineral components of unknown but potential sources may need to be measured in laboratories specialising in such analysis to pick up the most likely limiting minerals. The mineral content of some recently recognised potential sources depend very much on the growing conditions of the plants. For example duckweed is a variable source of N, P, S and K depending on the water concentration on which the duckweed is grown (Leng *et al.*, 1995). However, the level and number of minerals needed in a supplement are extremely difficult to assess and again only a 'rule of thumb' approach can be applied. Usually a "shot gun" mixture is the best option, particularly where molasses, poultry manure or distillers slops are available to provide such a mixture.

Local knowledge of supplements is often essential, for example, with molasses, the sulphur and calcium content depends on the method of clarification of the sugar-cane juice in the manufacture of sugar. The process may use sulphur dioxide (e.g. parts of China), bentonite (e.g. in Australia) or calcium hydroxide (e.g. in Cuba).

The most valuable sources of minerals include:

- \* Concentrated plant juices, which besides the minerals required by the plant to grow are often fortified in their processing or lend themselves to ease of fortification with minerals
- \* Dried faeces of chickens and pigs fed high quality diets.
- \* aquatic plants that concentrate minerals (e.g. duckweed and azolla).

- \* Distillers slops that arise from molasses fermentation to alcohol and are often discarded into the nearest water resource.
- \* Tree foliages and forage legumes can also be a very useful source of minerals. For example the response of small ruminants on poor quality forages to supplements of leucaena leaf meal has been shown to be due mainly to its mineral content (Goodchild and McMeniman 1994).

### **Fermentable N**

Urea or ammonia can be used directly in feed supplements. As most unprocessed proteins also provide fermentable N or ammonia in the rumen, an assessment of solubility of a protein source, or extent and rate of production of ammonia when incubated in rumen fluid are strong indicators of the fermentable N in a protein meal. The best option for assessing the availability of fermentable N is to measure the level of rumen ammonia in animals given the feed. The ammonia level should be at a minimum 100mg N/l but levels up to 200mg N/l are more efficiently used (Perdok and Leng 1990; Kanjanapruthipong & Leng, 1995). In order to be sure the technique above can be used to assess microbial growth efficiency it is necessary that an efficient rumen is achieved when sources of rumen ammonia are fed.

It is usually more economically important to protect such proteins from rumen degradation and in this way provide the animal with amino acids, augmenting those from the rumen microbes digested in the intestine and replace the low availability of ammonia from the protein by using urea.

Although there is some indication that amino acids are required by some rumen microbes for growth, particularly on starch and sugar based diets recent research indications are to the contrary for forage based diets (Maeng *et al* 1976; Leng, 1990; Kanjanapruthipong & Leng, 1995).

### **Bypass protein**

Productivity of ruminants under a wide variety of feeding systems is improved by supplementation with a protein meal that, because of its

physical and chemical characteristics, is not quickly degraded in the rumen and significant quantities escape to the intestines to be absorbed as amino acid (see Preston & Leng 1987). This has been recognised widely since the early 1970's but the end effect was recognised much earlier (Marston, 1932). The need for both a source of NPN and protein in roughage diets fed to ruminants was first extensively promoted by Leng *et al* 1977 and Preston & Leng 1987). Many feed evaluation systems now attempt to incorporate the need for fermentable N and bypass protein into their calculations. However, quite clearly, from applied research results supplementation of ruminants on poor quality forages with protein meals containing a high level of escape or bypass protein has shown up quite alarming discrepancies when productivity levels are compared with those calculated from the energy density of a feed (see Leng, 1990). Whereas standards based on the metabolisable energy density of a poor quality forage suggest negligible production on such feeds it is now demonstrated, on a massive scale, that growth and milk production of cattle can be promoted with bypass protein from a few grams per day to levels that would be highly applauded for cows fed on high quality fertilised and irrigated grasslands. Recently, McClennan *et al* (1994) claimed that bypass proteins have a major effect on productivity of cattle fed a medium quality hay but they suggested it could be accounted for by using the feeding standards based on metabolisable energy density of the feed. However, as will be demonstrated when their data is combined with experiments from the world literature a different interpretation is required.

The requirements of cattle for minerals, NPN and bypass protein are well exemplified by data from around the world on supplementation of cattle given straws and hays supplemented with cottonseed meal. Solvent extracted cotton seed meal protein appears to be about 75% protected from rumen degradation (Leng *et al* 1984). When fed to ruminants it increases the protein nutrition of the animal *per se*.

The response in growth rate of young cattle to incremental increases in cottonseed meal is shown in Figure 1 for eight studies from various countries. The response relationships has been fitted to

the equation:

$$\Delta\text{GR} = x + y (1 - e^{-zq}) \quad (1)$$

where  $\Delta\text{GR}$  = growth rate in kg/d;  $x$  is growth rate without cottonseed meal supplementation;  $y$  is the potential growth rate on such a diet and  $z$  is the fractional growth response to cottonseed meal supplement level ( $q$ ).

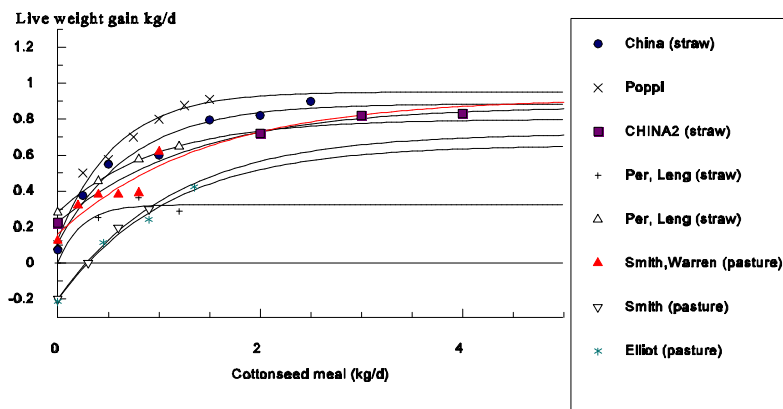
Whilst the shape of the response relationships appear to be similar, between experiments the potential growth rate without supplements and at optimum supplementation rate are quite variable between forages of different digestibilities. For example there is a large difference in cattle fed straws that are untreated or have been treated with ammonia to improve digestibility (see figure 1). Thus digestibility of forage or some description of the progress of digestion of straw are important in feed evaluation and determine both the growth rate when only the rumen is balanced to support efficient microbial growth or when both rumen and the animal is balanced for nutrients.

### **Prediction of potential productivity of cattle on a basal forage Towards a measure of forage quality for feeding to ruminants.**

All nutritional evaluation standards are or were predicated on the premise that there are no nutrient deficiencies for optimum digestion of the feed substrate in the rumen. This alone makes them unusable in most feeding systems discussed in this presentation. However, deficiencies of specific nutrients are the primary cause of low productivity of cattle in the tropics and it is rather misleading to quote a standard feed evaluation for instance based on prediction of digestibility without knowing the need to correct the nutrient deficiencies.

**Figure 1.** Results from 8 studies of the effect of supplementing cottonseed meal to cattle (140-200kg LWt) fed poor quality forages. Basal forages including straw, ammoniate ensiled straw and pasture.

from Dolberg and Finlayson 1995, × McClennan *et al* (1994), Dolberg and Finlayson 1995, + Perdok & Leng (1990), Perdok & Leng(1990), ▲Smith and Warren (1986), Smith and Warren (1986), \* Elliot and O'Donovan (1971) .



When the rumen is made efficient with NPN and minerals the most important supplements to forage based diets are protein meals. Identifying the reasons for a response to any particular supplement, however, is not simple. For example, many vegetable protein meals contain a full complement of trace minerals and are rich in phosphorus. Thus protein meals could provide additional ammonia in the rumen and the limiting minerals in addition to intestinal amino acids for absorption.

Supplementation of cattle on low true protein forage based diets with protein meals has shown that levels of production from a feed under these conditions are considerably higher than predicted from the apparent digestible or metabolisable energy contents of the basal feed (see Webster 1989). For example the production responses of

cattle fed poor quality roughage and supplemented with deficient nutrients for rumen microbes (e.g. molasses urea blocks) and cottonseed meal are some times ten times more efficient in converting metabolisable energy to liveweight gain than predicted by the ARC-metabolisable energy system (see Leng, 1990).

The level of production in ruminants on a basal forage diet without supplements and the maximum response to supplementation appears to be controlled by the digestibility characteristics of the basal feed. The nutritional value of a forage is therefore highly dependant on the kind and level of supplementation.

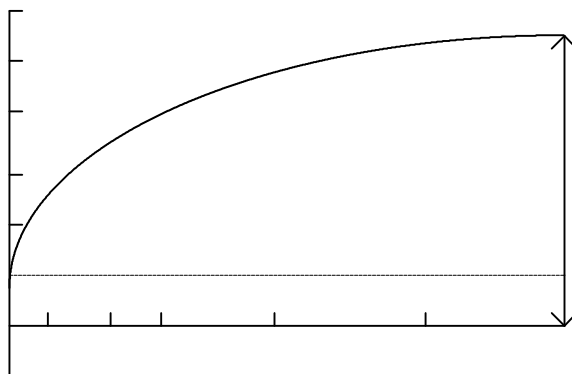
### **In search of a formula to describe nutritional quality of a forage based diet.**

Ørskov (1989) asserts that most analytical approaches to estimating the feeding value of forages are of little value. He has recently suggested an approach to estimating the feeding value of forages by using the characteristics of the time course of solubilisation of forage dry matter from nylon bags held in a functional rumen of an animal. Using feed ground to a standard size and incubated in the rumen in standardised nylon bags, the disappearance of dry matter with time is established. A typical curve is shown in Figure 2. The best description of the curve is given by the equation

$$p=a+b(1-e^{-ct}). \quad (2)$$

Where  $a$  is the solubility in water or dry matter disappearance at zero time,  $b$  the upper quantity that will potentially disappear (or maximum potential digestibility) and  $c$  is the fraction of non-soluble dry matter that disappears per hour ( $t$ ) (Ørskov & Mc Donald 1979).

**Figure 2.** Description of degradation characteristics of a typical fibrous residue using the expression  $p = a + b(1 - e^{-ct})$ . (Ørskov & McDonald 1979).



Ørskov and his colleagues have developed a number of such curves for different forages held in nylon bags in the rumen of sheep fed roughage diets balanced to give an efficient rumen. The intakes of straw and growth rates of cattle (200kg LWt) fed that straw *ad lib* fortified with minerals and with an additional supplementation of 1½kg concentrate per day was measured. These were then related to a, b and c generated using nylon bags of each forages/dry matter. Growth rate ( $\Delta GR$ ) was best described by the equation

$$\Delta GR = 0.0571a + 0.126b + 17.02c + K \quad (3)$$

where K is a constant equivalent to -1.261kg/day. This is the rate of weight loss when a, b and c are each zero and therefore is synonymous with weight loss in starvation. Unfortunately K is large relative to the low growth rates of cattle on straw based diets. The accuracy of the prediction of growth then depends heavily on the error around K. The latter constant has not yet been determined *in vivo* by starving animals for a period.

The data used by Ørskov (1989) to generate Equation 2 is shown

in Table 1. The percentage contribution of K to the predicted growth rate from equation 3 when the animal is fed straw plus 1½kg 16% crude protein concentrate (and nutrients to optimise rumen fermentation) is shown in the same Table. Although the prediction of growth rate depends on the accuracy of a, b or c and the error around K this may still be a useful guide we have to the value of a feed in supporting growth in an animal.

The accuracy of the estimation of K is an important consideration in estimating  $\Delta$ GR at zero supplementation since an error of  $\pm 150\%$  ( $0.064 \pm 0.108$  kg/d) change in the predicted growth rate at the lowest growth rate reported in the data set used by Ørskov (1989). On the other hand at the highest growth rate similar errors in K give an error  $\pm 16\%$  (i.e.  $0.783 \pm 0.127$  kg/d).

If prediction of growth rate at zero protein supplement intake by cattle on forage based diets could be predicted with some accuracy it should be possible to superimpose a response curve to a bypass protein starting with the former value as the initial growth rate without supplementation. It may, however, be more appropriate to carry out growth studies to determine the growth rate without protein meal supplementation in order to establish  $\Delta$ GR at zero supplement and then predict the response to proteins. This should be a major discussion point for by the expert panel. The response curve then has the equation.

$$\Delta\text{GR} = 0.051a + 0.126b + 17.02c - 1.261 + y(1 - e^{-qz}) \quad (3a)$$

### **Predicting responses to a bypass protein**

In Figure 1 the response of young cattle consuming a low quality forage to increasing quantities of cottonseed meal (a good bypass protein) are shown for various investigations in a number of countries. These response relationships were fitted to equation 1. The composite curve for all curves shown in Figure 1 are shown in Figure 3.



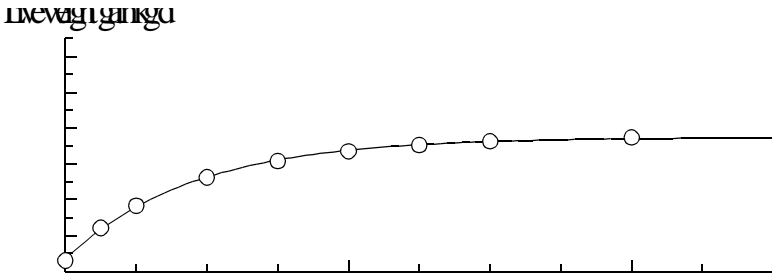
Table 1 Relationships of fermentative digestion characteristics a (g/100g), b (g/100g), c (fraction/h) for straws ( $\pm$  ammonia) in dacron bags in the rumen and growth rate of cattle (from Ørskov 1989)

Forage + ammoniation	Contribution to calculated growth rate (kg/d)									Growth rate (kg/d)*		
	a	b	c	a	b	c	k	c	k	$\frac{k}{a+b+c}$	predicted	actual
1. Winter Barley -	6.0	32.9	0.0337	0.342	0.415	0.574	1.267	0.95	0.64	.106		
+	7.9	54.4	0.0258	0.450	0.685	0.440	"	0.80	.208	.359		
2. Winter Barley -	5.1	38.2	0.0391	0.291	0.481	0.665	"	0.88	.170	.126		
+	7.9	45.2	0.0351	0.451	0.570	0.597	"	0.82	.351	.332		
1. Spring Barley -	3.4	48.7	0.0483	0.200	0.614	0.822	"	0.77	.369	.400		
+	0.4	60.4	0.0457	0.365	0.761	0.778	"	0.67	.637	.608		
2 Spring Barley -	7.5	48.0	0.0303	0.428	0.605	0.516	"	0.81	.182	.198		
+	9.3	52.1	0.0376	0.531	0.656	0.640	"	0.69	.560	.602		
Winter Wheat -	7.7	40.9	0.0343	0.440	0.515	0.445	"	0.91	.233	.273		
+	9.0	51.9	0.0364	0.513	0.654	0.883	"	0.61	.783	.516		

\* Actual growth rate here is growth on the basal feed with urea plus 1.5kg/day concentrate

**Figure 3** Composite curve developed from the responses of cattle fed low quality forage and levels of cottonseed meal (the data is the average of the fitted equations shown in Figure 1) The composite curve has the equation

$$\Delta GR = 0.069 + 0.679(1 - e^{-1.12q}) \quad (4)$$



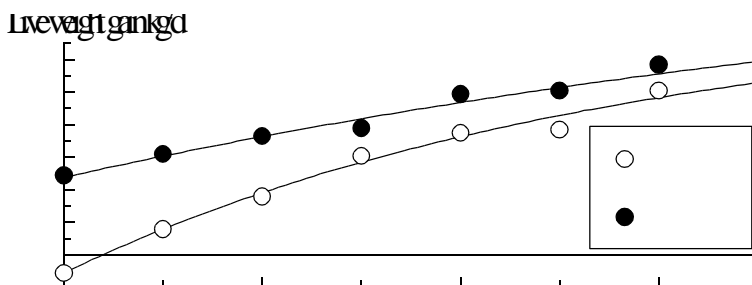
### Predicting the extent of bypass protein in a protein meal

The best option here would be to examine growth response curves to protein meals on the same feed, comparing in particular  $y$  and  $z$  in Equation 1.

Leng *et al* (1984) used in increased wool growth for sheep fed a low protein basal diet. Almost all the major protein meals available in any locality in Australia were assayed in two trials. In the research it is assumed that formaldehyde treated casein was 100% protected so a bypass protein index compared all other protein meals to the response to this supplement.

A further easier approach is to grade protein meals according to the rate and extent of degradation to ammonia in rumen fluid, again standardised against one protein meal of known bypass characteristics. Where proteins are shown to be highly degraded or degradable in the rumen, some form of protection of the protein needs to be carried out.

**Figure 4** Growth response to cattle fed untreated (○) and ammoniated straw (●) and supplemented with 0.7 kg/d molasses and graded amounts of a concentrate (16%CP) (Creek *et al* 1983).



#### A comparison of the nutritional value of a concentrate mixture and cottonseed meal

As an exercise to further examine the usefulness of an approach to basal feed evaluation and supplement quality, the growth response in cattle given ammoniated or untreated straw with 0.7kg molasses and 6 levels of a 16% concentrate mixture (1 to 6kg/d) (Creek *et al* 1983) are shown in Figure 4. The growth rate at zero concentrate intake was again calculated by fitting a curve.

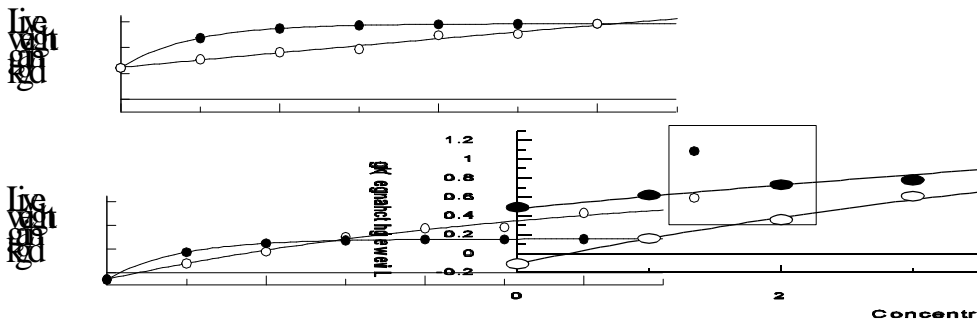
$$\Delta GR = x + y(1 - e^{-zc}) \quad (5)$$

where  $c$  in this case is the quantity of concentrate fed.

The growth rate at zero concentrate intake was predicted. Taking this as growth rate at zero supplementation the theoretical response to increasing increments of cottonseed meal to these straws were fitted to illustrate the dissimilarity in response relationships to a "balanced concentrate with 16% CP" and a bypass protein of 40-45% protein in cattle fed treated and untreated straws (Figure 5).

The predicted pattern of responses to supplements of cottonseed meal fed to cattle on a rice straw diet shown are completely different to that from more conventional concentrates presumably because the cottonseed meal improves efficiency of feed utilisation and a grain based concentrate generally substitutes more for the basal diet.

**Figure 5** *The relationship of growth rate and supplement intake (concentrate (o); cottonseed meal (●)) of cattle fed untreated straw and straw treated with ammonia to improve digestibility. (Creek et al 1983)*



It should be clearly noted that forage substitution by concentrate occurs, whereas a bypass protein tends to maintain or increase intake of the basal forage (see Leng 1990)

## **Supplements to increase productivity once the utilisation of the basal feed resources has been optimised**

### **High digestibility forage**

Figure 1 shows that supplements to basal feeds to optimise productivity at a final level set by the initial growth rate where only the rumen is efficient. At the upper level of response to supplement the only methods for increasing productivity further is to replace the basal feed resource with a more digestible feed that does not exhibit negative associative effects on the digestibility of the basal feed. The addition of a high digestibility forage to a low digestibility forage often stimulates digestibility of the basal feed as well as increasing the digestibility of the total feed (Ndlovu & Buchanan 1985). The response curve should be the same shape but starting at a higher growth rate at zero supplementation

### **Sugars and Grains**

Grain generally interacts with forages depressing the forage utilisation. This may be due to limited ammonia availability but also by other influences. On the other hand, at times addition of sugars can stimulate the overall total energy intake without depressing digestibility of forage so long as the amounts and availability of ammonia (and in all probability minerals) are increased commensurately.

Complex interactions occur within the rumen when sugars/starches are mixed with fibre with quite marked changes in the microbial ecosystem particularly with respect to protozoa and fungal densities. An increase in protozoa often lowers P/E ratio from the rumen because protozoa predate bacteria (Bird & Leng 1978). The response to feeding sugars (molasses) which stimulate at times protozoal densities in the rumen can often be unpredictable, at least with the level of knowledge we presently have. The alteration in P/E may change efficiency of feed utilisation by ruminants and produc-

tion improves without increases in feed intake. In general, however, these feeds should be used sparingly if at all in increase digestibility of a feed.

### **Fat**

Fats have been regarded as both beneficial and detrimental feed ingredients for ruminants depending on the level of inclusion (see Palmquist, 1988). Fat analysis is relatively easily undertaken by using an ether extract but this does not recognise the presence of insoluble soaps. In general fats are regarded as nutritionally beneficial up to 4-5% of a diet. Fats are absorbed extremely efficiently after hydrolysis to long chain fatty acids in the rumen (Thornton and Tume 1987) and deposited extremely efficiently in adipose tissue provided they are also given a bypass protein supplement (Van Houtert & Leng 1993). Above 5% or so the fats become detrimental because of a depressing effect on digestibility of the forage component of a diet. Recent studies have demonstrated that it is the concentration of long chain fatty acids in the rumen that effect digestibility. The mechanism of action on cellulolysis appear to be through reduction of free calcium ions in solution ( $\text{Ca}^{++}$ ), through the formation of calcium soaps of fatty acids. It is the low  $\text{Ca}^{++}$  that apparently suppresses microbial cellulase activity (Walker and Leng, 1994 unpublished). Increasing calcium intake progressively, results in elevated free calcium ions, and the effects of long chain fatty acids on forage digestibility are removed. Thus the level of calcium (in available form) in the diet is extremely important in deciding the nutritional value of high fat diets. The research that has shown that calcium can remove the detrimental effects of fat now paves the way for strategic supplementation with high fat diets that can be used to increase the energy density of low digestibility roughage.

### **Vitamin**

The most likely deficiency of a vitamin in a roughage diet fed to ruminants is Vitamin A. Often the supplementary feeding value of

a green forage source far exceeds the potential value on the basis of its protein and energy and at these times it is possibly a result of the additional Vitamin A which can be deficient when crop residues are fed over a prolonged period.

### **Climate influence on predicability of the nutritional value of feed**

Ruminants are extremely well adapted to cool environments but appear to have poor adaptation to hot conditions (Blaxter, 1962). A number of studies have demonstrated that animals selected for short shiny hair-coats consistently out-produce similar breeds with rough-hairy coats. This may be related to a low density of sweat glands. Buffaloes have no sweat glands.

As animals progress from cold to hot conditions their needs for protein relative to fat or fatty acid precursors change as follows:-

- \* under cold conditions the requirements for oxidisable substrate such as fat and short chain volatile fatty acids is increased totally and relative to the requirements for amino acids for tissue synthesis i.e. the P/E ratio in the nutrients required by the animal is decreased.
- \* under hot humid conditions the need for oxidisable substrate for heat production may be close to zero and the P/E ratio in the nutrients required by the animal is increased although total nutrient requirements may be decreased.
- \* Animals at the upper level of their ability to control their body temperature in a hot environment, may be heat stressed by the extra heat produced in an inefficient rumen microbial ecosystem or where acetate burn-off is required because of the imbalanced nature of the nutrients absorbed (see Leng *et al* 1993).

Heat stress in ruminants, which is indicated by excessive respiration rates in general reduce feed intake. This in turn would reduce the heat increment associated with fermentative digestion and also the heat released in fertile cycles of metabolism or in synthesis (of milk or tissue).

### Sources of heat for inducement of heat stress in ruminants

Heat is absorbed directly from the environment e.g:

- \* air surrounding the animal
- \* contact of the animal with hotter bodies
- \* irradiation heat from the sun.

Heat is also produced in:-

- \* microbial digestion of feed in the rumen (the more efficient the rumen the lower the heat)
- \* maintenance of the tissues dynamic state
- \* essential function - maintenance of cell homeostatic, conversion of absorbed products into tissue synthesis or reserve energy sources (largely fat and glycogen).
- \* oxidation of compounds that are constrained from synthetic processes because of imbalanced availability of nutrients and must be oxidised in futile metabolic cycles.

The animal may control to some extent its environmental heat load by changes in their behaviour e.g. seeking shade, standing in water and varying their feeding periods. All these may reduce feeding time and therefore overall feed intake.

The animal may control to some extent its metabolic heat load by reducing its workload in movement, changing its selection of feed components with lowest heat increment. For example at high environmental temperatures and humidities cows in India reduce their forage intake but consumed a bypass protein supplement extensively (Kurup, N.P.G. 1994).

Heat production in fermentative digestion in the rumen is variable and dependant on the efficiency of microbial growth in the rumen. Heat increment in the animal is largely a function of the balance of nutrients absorbed in particular there is evidence that the amino acids absorbed from microbial cells plus bypass protein controls relative metabolic heat production (see Leng *et al* 1993).

Thus an animal unsupplemented and fed on a poor quality forage could have considerable metabolic heat generation, which if the animal was cold could be put to good use in keeping the animal warm. On the contrary the heat production might exacerbate a heat



stress in an animal in a hot/humid environment which would largely result in reduced overall feed intake.

### **Interactions of climate/diet**

Animals that are in a hot climate can therefore be expected to have a lower intake of an unbalanced diet than animals in cool/cold climate. In general on a poor quality roughage diet if the rumen of an animal in a hot/humid environment is deficient, in say fermentable N and/or sulphur and/or phosphorus then this will:-

- \* reduce digestibility - by as much as 5 to 10 units
- \* reduce efficiency of microbial cell growth per unit of organic matter digested and therefore lower P/E ratio in the nutrients absorbed.
- \* reduce feed intake both because of the lower digestibility and also because the extra heat from the rumen and the animal.

Correcting the rumen deficiencies will:

- \* increase digestibility
- \* increase P/E ratio in nutrients from microbial digestion in the rumen, this in turn will decrease overall heat load from heat of fermentation and metabolic heat
- \* the increased digestibility together with the decreased heat production will allow an increased feed intake that will vary according to the environment of the animal and its ability to lose heat.

If the extra metabolic heat resulting from imbalanced nutrients has a major control over appetite then large responses in feed intake will occur when bypass protein are introduced into the diet.

### **Overview**

The nutritional value of a forage therefore depends on the environment of the animal and the access the animal has to supplements. A clear demonstration of the responses is shown in data by Lindsay and Loxton 1981. Their research was carried out with cattle supple-

mented in mid summer in the dry tropics of Australia. Feed intake in cattle given poor quality hay was improved by feeding urea/sulphur but further improved when bypass protein was also given. This same discussion has been used to rationalise the results from different research institutions where results of supplementation of cattle on poor pasture or poor quality forages have given different effects (see Leng, 1990).

The research in this area is still limited by the endless discussions about whether the differences, observed between researchers at different sites are real. If the explanation for the differences is in the differences in climate, then a poor quality forage can be considered to have a different nutritional value depending on the climate and the supplements used. The responses to supplementation of cattle aimed at balancing the nutrients available to nutrient requirements will have greater effects on production rates in the tropics as compared to cool or cold regions. Not only the climate of the tropics will be implicated but the animals insulation (hair, coat), its ability to dissipate heat or to modify its behaviour to minimise heat stress will also change the nutritional value of the feed.

## **Conclusion**

There can be no confidence in using digestibility or chemical analysis of feeds to predict the likely productivity of ruminants from the feed resources that are generally available in tropical countries. The only realistic approach appears to be based on feeding trials with ruminants on basal feed resources with access to multivitamin blocks and then to categorise response curves to bypass protein inputs. Improving nutritive value then requires progressive supplementation of the basal feed with small quantities of a higher digestibility feeds to determine the responses to these inputs at optimum supplementation levels.

There appears to be little chemical analysis needed. The major approach is to gain experience with the few feeds that have to be assessed and measure responses to the two categories of supplements discussed in the body of this document.

**The bottom line - the challenge**

It may surprise the reader that no references are made in this document to NDF, ADF or lignin or any other methods of chemical analysis. It is this writer's personal opinion that these are useful techniques for investigating feed utilisation but have little to offer feed evaluation. A common problem with research methodology is that quite often applied research in which the main approach is the feeding trial, often quote the detergent analysis, seldom do these receive more than a passing reference in the discussion and it is seldom that they (chemical analysis) contribute anything to explaining the applied production responses but nevertheless they seem to be mandatory for acceptance for publication. The present writer has had a paper turned down because the feed given to cattle, which was straw, was not analysed. It is now time to challenge the chemical approaches to describing feed since it often ties up competent technical staff, delays publication and therefore knowledge transfer to the end user and emphasises the evaluation of the feed and not the response of the animal to that feed. The expert consultation should consider recommending a cessation of the use of such chemical analysis.

Publications are now starting to appear in which a,b,c of nylon bag degradation pattern of a forage are reported again without using them to predict growth rate and without discussion.

It is suggested that few feeds are available in quantity in any one locality and therefore the best options may be to do the necessary feeding trials to assess their value.

**References**

- ARC (1980). The nutrient requirements of Farm Livestock 2. Ruminants Agricultural Research and Council, London, England.
- Bird S.H. and Leng, R.A. (1978) *Br. J. Nutrition* 40, 163-167
- Blaxter, K.L. (1962) *The energy metabolism of ruminants*, Hutchinson, London
- Borgstrom, G. (1980) The need for appropriate animal production systems for the tropics In: "Animal Production Systems for the Tropics Pub. No. 8 IFS Stockholm
- Chen, X.B. and Gomes, T.Y.J. (1992) Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives. Occasional Publication International Feed Resources Unit, Rowett Research Institute Aberdeen.
- Creek, M.J., Barker, T.J. & Hargus, W.A. (1983) An evaluation of the use of anhydrous ammonia to treat rice straw UNDP/FAO Beef Industry Development Project EGY/82/007. Field document No.8 FAO Rome.
- Dolberg, F. and Finlayson (1995) Treated straw for beef production in China: *World Animal Review* (FAO) N° 82 pp 14-24.
- Elliott, R.C. and O'Donovan M.W. (1971) In "Report of the Henderson Research Station, Harere Zimbabwe
- Goodchild, A.V. and McMeniman, N.P. (1994) Intake and digestibility of low quality roughage when supplemented with leguminous browse *J. Ag. Sci.* 122 151-160
- Guo Tinsuang and Yang Zhenhai (1994) Beef fattening with treated straw in China In: "Sustainable Animal Production and the Environment - Symposium on Improving Animal Production Systems Based on Local Feed Resources 7th AAAP Animal Science Congress Bali Indonesia July 11-16 1994.
- Hendrickx, H. and Martin, J. (1963). In: *In vitro study of the nitrogen metabolism in the rumen. Rech.Inst.Tech. Sci. Ind. Agric. Bruxelles* 31:7-10.
- Kanjanapruthipong, J. and Leng, R.A., (1995) (unpublished observations)

- Kurup, N.P.G., (1993) - NDDDB India (unpublished)
- Leng, R.A., (1982) Modification of rumen fermentation. In: Nutritional Limits to Animal Production from Pastures. (Ed. J.B. Hacker). CAB, Farnham Royal, U.K. pp 427-453.
- Leng, R.A., (1989) Recent advances in applied aspects of ruminant physiology and nutrition. Ruminant physiology and nutrition in Asia (edited by Devendra, C.; Imaizumi, E.). 1989, 1-26; 49 ref. Ottawa, Canada; International Development Research Centre (IDRC).
- Leng, R.A. (1990) Factors affecting the utilization of 'poor quality' forages by ruminants particularly under tropical conditions. *Nutr. Res. Reviews* 3: 277-303
- Leng R A, Stambolie J H and Bell R, 1995. Duckweed - a potential high-protein feed resource for domestic animals and fish. *Livestock Research for Rural Development*, 7: 1 Paper 3.
- Leng, R.A. and Kunju, P.J.G. (1988) A new approach on protein nutrition for ruminants. Report published by the NDDDB (Anand, India)
- Leng, R.A., Nolan, J.V. and Kempton, T.J. (1977). Non-protein nitrogen and bypass proteins in ruminant diets. *A.M.R.C. Review* No. 33 pp 1-21.
- Leng, R.A., Davis, J. and Hill, M.K. (1984) Estimation of bypass protein based on wool growth. *Proc. Aust. Soc. Animal Prod.* 15 431-433.
- Leng, R.A., Jessop, N.J. and Kanjanapruthipong, J. (1993). Control of feed intake and the efficiency of utilisation of feed by ruminants. In: *Recent Advances in Animal Nutrition in Australia 1993*. (Ed: D.J. Farrell). Published by the Department of Biochemistry, Microbiology and Nutrition, University of New England, Armidale, Australia. pp.70-88.
- Leng, R.A., Choo, B.S., and Arreaza, C. (1992). Practical technologies to optimise feed utilisation by ruminants. In: *Legume Trees and Other Fodder Trees as Protein Sources for Livestock*. FAO Animal Production and Health Paper 102. FAO. Rome. pp. 75-

- Lindsay, J.A. and Loxton, I.D. (1981). Supplementation of tropical forage diets with protected proteins. In: Recent advances in animal nutrition in Australia. (Ed: D.J. Farrell). University of New England, Armidale, Australia. p. 1A (abstract).
- Maeng, W.J., van Nevel C.J., Baldwin, R.L. & Morris, J.G. (1976) Rumen microbial growth rates and yields effects of amino acids and protein *Journal of Dairy Science* 59 68-79.
- McClennan, S.R., Poppi, D.P. and Connell (1994) Effects of previous nutrition on the response to protein supplementation by weaner steers *Recent Advances in Animal Nutrition* (1993)
- Marston, H.R., (1932) Studies in the supplementary feeding of Merino sheep for wool production. 1. The effect of supplementary ration of blood meal on the growth rate and wool production of Merino sheep on central Queensland pastures. *Bulletin for the Council for Science and Industrial Research (Australia)* Vol. 7. *Bulletin* 61: 5-31.
- Minson, D.J. (1982) Effects of chemical and physical composition of herbage upon intake In: "Nutritional Limits to Animal Production from Pastures (JAB. Hacker ed) CAB Farnham Royal U.K. 167-182.
- Ndlovu, L.R. and Buchanan-Smith, J.G. (1985) Utilization of poor quality roughages by sheep: effects of alfalfa supplementation on ruminal parameters fibre digestion and rate of passage from the rumen *Can J. An. Sci.* 65 693-703.
- Ørskov, E.R., Reid, G.W., and Kay, M. (1988) Prediction of intake by cattle from degradation characteristics of roughages, *Animal Production* 46 1. 29-34.
- Ørskov, E.R. (1989) Recent Advances in evaluation of roughages as feeds for ruminants *Recent Advances in Animal Nutrition in Australia 1989* p102-108
- Ørskov, E.R. & McDonald (1979) The estimation of protein degradability in the rumen *J. agric. Sci. Comb.* 96 251-252
- Palmquist, D.L. (1988) The feeding value of fats. In *Feed Science* pp 293-311 (Ørskov, E.R. editor) Amsterdam, Elsevier Scientific Pub. Company.

- Perdok, H.B. and Leng, R.A. (1990). Effect of supplementation with protein meal on the growth of cattle given a basal diet of untreated or ammoniated rice straw. *Asian-Australasian J. of Agric. Sci.* **3**: 269-279.
- Preston, T.R. and Leng, R.A. (1987). Matching ruminant production systems with available resources in the tropics and subtropics. Penambul Books, Armidale.
- Sansoucy, R., Aarts, G. and Leng, R.A. (1988). Molasses-urea blocks as a multnutrient supplement for ruminants. In: *Sugarcane as Feed (Vol. 2)*. (Eds: R. Sansoucy, G. Aarts and T.R. Preston). Proc. of an FAO Expert Consultation held in Santo Domingo, 7-11 July, 1986. pp. 263-278.
- Smith, R.H. and McAllen A.B. (1971) Nucleic acid metabolism in the ruminant 3. Amount of nucleic acids and total ammonia nitrogen in digesta from the rumen duodenum ot ileum of calves, *Br. J. Nutr.* **25** 181-190.
- Smith, G. and Warren, B. (1986a) Supplementation to improve production of yearling steers grazing poor quality forage 1. The effect of forage type and cottonseed meal supplements *Aust. J. Exp. Ag.* 261-266
- Smith, G. & Warren, B. (1986b) Supplementation to improve production of yearling steers grazing poor quality forage 2. The effect of oats, supplemental nitrogen, lupins and cottonseed meal *Aust. J. Exp. Ag.* 26 7-212
- Thornton, R.F. and Tume, R.K. (1987) Factors controlling fat deposition in ruminants In *Recent Advances in Animal Nutrition in Australia 1987* p 28-49.
- van Houtert, M.F.J. and Leng, R.A. (1993). Protein, acetate and propionate for roughage-fed lambs. 2. Nutrient kinetics. *Animal Production.* 56:3
- Walker, G. and Leng, R.A. (1994) (unpublished) University of New England
- Webster, A.J.F. (1989) Bioenergetics, bioengineering and growth *Animal Production* **48** 249-269