Chapter 3

Balancing nutrition to maximize forage utilization

3.1 Concepts of balanced nutrition

The basic concepts of ruminant nutrition reviewed in the last chapter are briefly revisited below.

To optimize the utilization of poor quality forages, the appropriate supplements are:—

- an array of macro- and microminerals and a source of ammonia to meet requirements of the rumen microbes for efficient growth
- a supply of protein containing a substantial proportion of bypass protein to augment the protein supply to the animal.

Further increases in ruminant production, once these two requirements are met are obtained by increasing the energy density of the basal feed resource consumed by:—

- treatments that improve digestibility of a forage
- supplementation with higher digestibility forages that increase overall digestibility
- addition of small quantities of readily digestible feeds with a low rumen load, e.g., molasses
- using feeding strategies that allow selection from a forage. In this case ruminants will select the most nutritionally available components and reject the least valued materials (Boodoo *et al.* 1988; Aboud *et al.* 1990). The strategy is to feed 150% the quantity of a forage that would have been consumed when no selection was possible.

3.2 Meeting nutritional requirements of ruminants with appropriate supplements

In most regions or localities it is not practical to identify the deficient micro- and macrominerals in pasture or other forages, as these will vary from site to site and year to year and also with the pattern of fertilizer application and weather conditions. The practical approach is one that uses 'rules of thumb' to supplement effectively, i.e., to provide a best bet or 'shot-gun mixture' of minerals and a source of ammonia nitrogen in the rumen as economically as possible. A concentrated plant extract such as molasses, or the concentrated residues after fermentation of sugar to alcohol provides such mixtures and can be fortified for specific areas where local knowledge points to specific deficiencies. In this respect, molasses distillers slops (the residues of molasses fermentation) offer a useful sources of these minerals. Molasses or slops are also palatable to livestock and are useful for disguising less palatable nutrient sources. An oilseed byproduct meal or wheat and rice bran or a tree forage or other green forages can also be used to provide the animal with minerals.

Mineral salt mixtures are commercially available. They usually have a high content of sodium chloride and added quantities of trace elements. In practice, fortified molasses or molasses blocks will be superior to these mixtures as they present a greater coverage of all the minerals required and they are also a valuable source of other nutrients (e.g., B vitamins) and a small amount of fermentable energy.

3.3 Supplying the rumen microbes with ammonia

The requirement for ammonia by rumen microbes may be met from urea, other nitrogenous components or soluble proteins. Urea is commonly administered to livestock on dry forages together with minerals, and its concentration in such mixtures is controlled by safety concerns and difficulty of incorporation. It therefore rarely exceeds 10–15% of such mixtures. However, this is usually sufficient to allow an intake of between 50 and 100 g of urea by cattle from a molasses-urea multinutrient block (MUMB) which is usually sufficient to provide the rumen microbiota with their requirements of ammonia on a low N pasture. The amount needed may be reduced where an animal is able to consume urea at regular intervals, which then maintains rumen ammonia high at all times throughout a day. It has been found to be quite safe to feed mixtures with up to 30% urea in Australia where livestock are accustomed to taking such a mixture and it is always continuously available.

Many leaf proteins and some seed proteins appear to be readily degraded in the rumen and are therefore an available source of ammonia for microbial growth. As both soluble protein and urea can supply the microbes with ammonia, the results of feeding urea to ruminants gives insights into the potential value of highly soluble leaf proteins. In this instance, if leaf foliage is supplying only minerals and ammonia to the rumen microbes, the response will be similar to that from multinutrient blocks containing urea, but if they impart additional benefits then the response per unit of N will be considerably higher for leaf meals than urea combined with minerals. There are numerous other sources of rumen ammonia, including chicken and pig fæces, which are regularly included in ruminant diets.

3.4 Some examples of the value of multinutrients in cattle given forage based diets

The effects of correcting deficiencies of nutrients for rumen microbes in cattle given poor quality forage by supplementation with leaf foliage may be anticipated by examining the effects of multinutrient mixtures on production of ruminants on such diets. Thus an examination of the literature detailing responses of forage-fed ruminants fed molasses urea multinutrient blocks (MUMB) gives a good model to compare cattle responses to tree foliages. For this reason, data on the value of molasses/urea blocks as supplements to cattle and forage based diets are given below. From this point in the discussion, molasses-urea multinutrient blocks, which differ in composition depending on the country/place of manufacture, will be referred to as MUMB.

3.4.1 Effects of supplementation with urea/molasses/multinutrient blocks (MUMB) on cattle production

Only a few examples are given here as a more comprehensive review of this area is in preparation.

Table 3.1: *Effects of MUMB supplements on growth rate of Friesian Holstein steers, Ongole steers, sheep and goats fed cut/carry pasture in Indonesia (Hendratno* et al *1991). This study indicates the value of multiminerals included in the MUMB, as the cut-and-carry forage was green.*

Animals	N (g/d)	Growth rate (g) Nil	Growth rate (g) +MUMB	% Increase in production
FH Steers	156	210	560	166
	171	400	810	102
Ongole Steers	161	333	526	57
	204	478	465	-2.7
	291	388	822	111
	110	183	403	120
Sheep (Local)	30	36	67	86
	32	140	316	126
Goats (Does)	32	40	88	120
Goats (Kids)	52	91	105	15

3.4.2 Effects of multinutrient mixes on growth rates and milk yield of cattle

Growth Rates In research at the small farmer level in Indonesia with both growing and milking animals fed green grass/forage mixtures in a cut and carry system, responses to MUMB have been spectacular (Tables 3.1 on the page before, and 3.2 on page 34), but in this case the effects were due to both minerals and urea in the blocks. A probable explanation for the results in Table 3.1 on the page before is that microbial growth efficiency in the rumen was depressed by mineral deficiencies, particularly, for example, sulphur, phosphorus and trace minerals (these deficiencies are widespread in the tropics) the responses in this case being due to their correction. In other countries the responses to multinutrient blocks observed may also be due to correction of other macrominerals as well as trace mineral deficiencies.

In the results from Indonesia, *in vitro* studies using rumen fluid from unsupplemented and supplemented animals showed that without the multinutrient source, rumen microbial growth was undetectable using the incorporation of ^{35}S, but was improved to normal by the provision of multinutrients in the form of MUMB (Hendratno, C., personal communication[1]).

Trials, feeding molasses-urea mixtures to cattle on dry native pasture in Northern Australia over five years of experimentation are shown in Figure 3.1 on the following page. The effects illustrate the variable responses and the differing minimal requirements for urea under grazing systems. It also indicates that under some circumstances other mineral deficiencies quickly become a primary limiting nutrient for the growth of rumen microbes.

Milk Yield In recent studies in India, even where buffalo and cattle have been fed considerable amounts of a concentrate, green forage and millet straw that made up 60% of the diet, a molasses-urea-multinutrient block, improved milk yield by an average of 30% (Figure 3.2 on page 35).

Milk production from dairy cows on tropical pastures supplemented with or without MUMB in Cuba and The Dominican Republic is shown in Table 3.4 on page 35. These results are highly typical of results from various countries and show that these supplements have a marked effect on milk yield where cattle are fed tropical forages and crop residues under a wide variety of conditions.

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Figure 3.1: *Summary of liveweight responses of young* Bos indicus *cross cattle (initially 18–24 months of age) to various levels of urea fed through molasses/urea roller drums during the dry season in Northern Australia (Winks* et al. *1972; Winks* et al. *1979; summary by Dixon, 1995).*

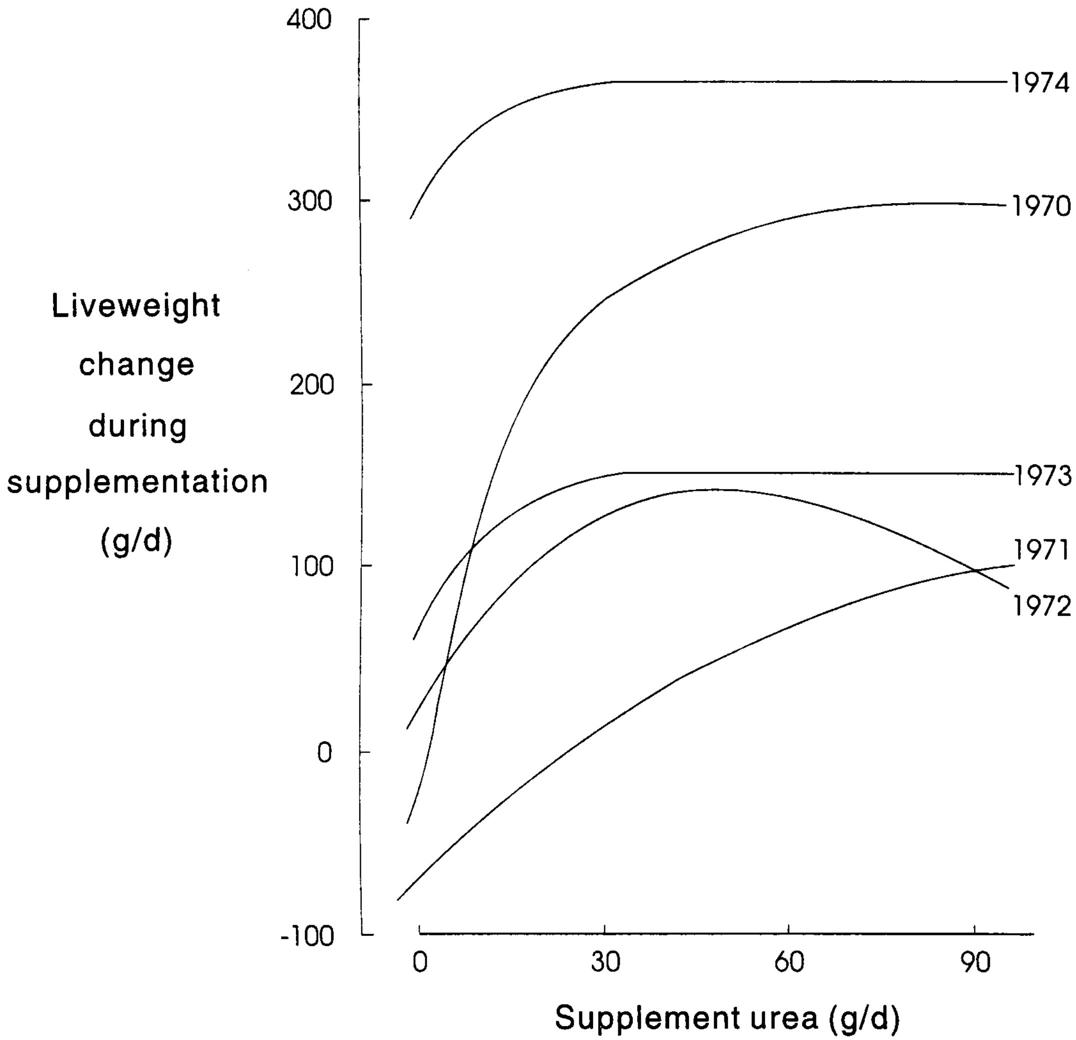


Table 3.2: *Effect of MUMB supplement on milk yields of Friesian-Holstein dairy cattle given cut and carry green forage in Indonesia (Hendratno* et al. *1991)*

		Milk yield (18 weeks, in litres)		
	N intake (g/d)	Nil	+MUMB	% increase
Lembang, West Java	297	1008	1019	1
Garut, West Java	197	900	1107	23
Mageland, Central Java	270	871	1119	28

3.4.3 Effects of MUMB on reproduction of cattle, sheep and goats

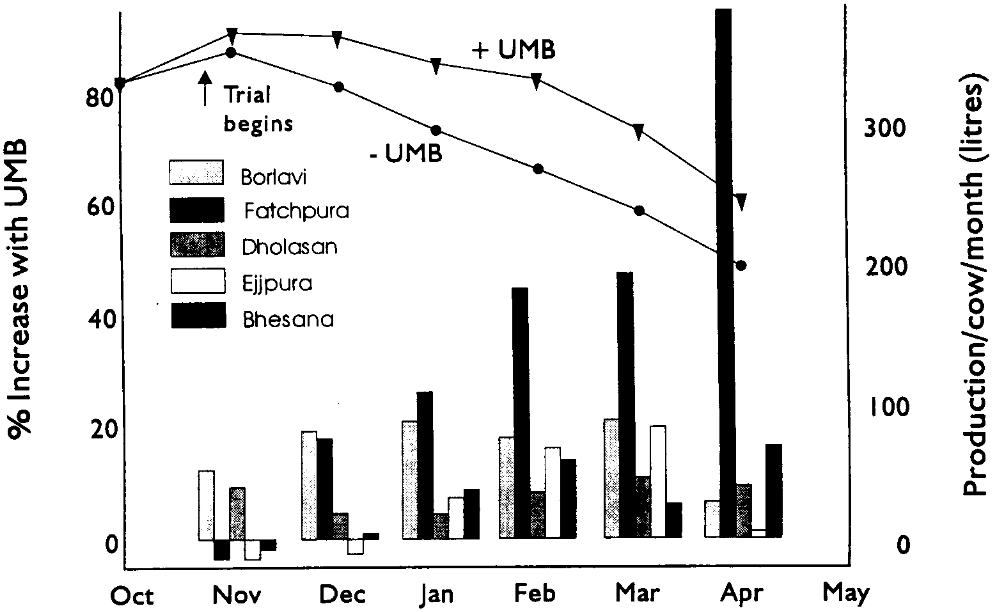
Reproductive rates of cattle/sheep have been strongly affected by supplementation to balance nutrition of ruminants fed low quality forage based diets. Australian researchers showed that where cattle and sheep have only poor quality forage during the last trimester of pregnancy, the birth weight of the calf or lamb is adversely affected unless the rumen is made efficient by the use of urea and mineral supplements (Table 3.3). The chances of survival of the lightweight offspring from unsupplemented cows or sheep are extremely low because of their low body weight.

Table 3.3: *Effects of urea/sulphur supplementation on birth weight of lambs and calves fed poor quality forages. Sources: Lindsay* et al. *(1982) and Stephenson* et al. *(1987).*

Animal	Supplement	Birth wt. (kg)
Sheep	+ urea/sulphur	3.2
	Nil	2.9
Cattle	+ urea/sulphur	22
	Nil	32

The effects of feeding MUMB on reproductive performance of African hair sheep are shown in Table 3.5 on page 36. The sheep were fed chopped cane tops supplemented with *Gliricidia* foliage (Vargas & Riviera, 1994).

Figure 3.2: *The pattern of milk production in several villages in India where similar cattle and buffalo were fed with or without MUMB. See Table 3.4 for diets. The overall averages from 77 animals in each group are shown (Manget-Ram* et al., *personal communication.*[3]*)*



3. A.K. Manget-Ram, A.K. Tripathi, A.S. Dave, A.K. Metha and M.P.G. Kurup, The National Dairy Development Board, Anand, India.

Table 3.4: *Effect of MUMB on milk yield of grazing cows in Cuba (Diaz* et al. *1994) and Dominican Republic (Prodeleste, 1991).*

	Nil	+ MUMB	Increase (%)
Cuba (litres/day)	3.1	4.3	39
Dominican Republic (bottles/day)	5.5	6.9	28

3.4.4 Conclusions on reproductive efficiency

It appears that, provided the rumen microbial ecosystem is efficient (i.e., microbial growth is optimized) even on low digestibility forages ruminants will reproduce at normal rates and produce offspring of an adequate size with nutrient reserves to ensure their viability following birth. However, this is not true in cattle with high genetic capacity for milk yield which require much higher protein levels; these levels can only be achieved with bypass protein in addition to a MUMB.

Table 3.5: *Effect of MUMB on performance of African hair sheep (Vargus & Riviera, 1995).*

	Nil	+ MUMB
Liveweight at weaning (kg)		
ewes	32	34
lambs	12	14
% ewes pregnant at 150 d *post partum*	56	85
Mortality rate (%)		
maiden ewes	20	6
lambs to weaning	32	8

3.5 Conclusions on the use of supplements that provide critically deficient nutrients

The overall conclusion from a wide variety of studies throughout the world is that the value of supplements that are aimed at correcting deficiencies of microbial nutrients in the rumen in cattle given poor quality forage based diets are:—

- increased weight gain
- increased milk yield
- increased conception rate
- increased survival of mature animals
- increased survival of offspring

The operative question here is whether these nutrients, required for efficient microbial growth, can be adequately supplied to ruminants by tree foliages.

3.6 Crude protein requirements of ruminants

Up until some 20 years ago the protein requirements of ruminants were defined in terms of crude protein (N x 6.25) in the diet. It is now recognized that crude protein in the diet may contribute a significant amount of the ammonia utilized for microbial growth in the rumen. However, some protein meals, because of various physical and chemical properties or as a result of processing, have properties that slow their rate of degradation in the rumen: protein escapes to the intestines and augments the total amino acid supply to the animal. Microbial protein and dietary escape or bypass protein provide the essential amino acid requirements of the animal and also supply glycogenic substrate.

Table 3.6: *Results of strategic supplementation to balance nutrition of cattle consuming poor quality roughage supplemented with bypass protein. In most cases the basal diets received MUMB or some other form of urea and minerals in addition to 0.5-1.0 kg/day of a bypass protein meal such as cottonseed meal.*

* Improved feed intake (in tropics/subtropics)
* Improved efficiency of feed utilization
* Improved productivity

• growth rates of grazing cattle	from -330 g to + 300 g/d
• body condition of pregnant cattle over last third of pregnancy improved	from 850g/d to + 750 g/d
• milk yield, beef & dairy animals	2–3 litres milk/kg supplement
• age at first calving decreased	from 4–5 years to 2 years
• calving rates of cattle improve	50% to 85–95%
• birthweight of calves increased	from 22 kg to 32 kg
• survival of young animals increased	from < 30% to > 80%
• intercalving interval of cattle reduced	from 2 years to 12–15 months

Some protein meals when added to poor quality feeds increase productivity of ruminants to a greater extent than can be attributable to an enhanced rumen function. It became a major issue when the unexpectedly large responses to bypass protein of ruminants on poor quality forages were recognized. A general description of response to a bypass protein are shown in Table 3.6 on the page before and this area has been reviewed by Leng *et al.* 1977, Preston & Leng, 1986 and Leng, 1990).

Undoubtedly the level of bypass protein in a diet of poor quality forage is critical. The responses of ruminants on low protein forages to bypass protein meals are, therefore, a model to test whether such protein sources as tree foliages provide bypass protein.

3.7 Application of the new feeding strategies based on balancing nutrients

Even though the principles of balancing the rumen and feeding bypass protein to improve productivity of ruminants on poor quality forages have been known for many years, uptake and application has been slow and unspectacular in many developing countries. In the developed countries the compounding feed industries have quickly recognized the value of bypass protein. Industrial processing has been developed to produce bypass protein from vegetable proteins, particularly for the dairy industry.

The uptake and application of such strategies by scientists and farmers alike in most tropical countries has been slowed by:—

- the dependency of many scientists trained in the traditional temperate country institutions on the feeding standards that apply to those countries
- the inability of research scientists to communicate with and have their suggestions accepted by applied technologists and those who apply agricultural policies
- the often unavailability of protein, minerals, and non protein nitrogen in the areas with large populations of ruminants and therefore the heavy cost of delivering these to the animal
- the controversies surrounding the principal mechanisms of action of protein supplementation which cloud the major issue. The major issue is that poor quality feeds can be turned into feeds of good quality by strategic supplementation

- the availability on international markets of inexpensive grains which have usually been heavily subsidized and are relatively easy to feed. However, movements in fuel prices, competition from pig and poultry production and general removal of protective trade barriers has seen the prices of these surplus grains increase recently. Any dependency on feed resources that are also used by humans could be calamitous for developing countries if supply decreases and/or the price rises.

The operative question now is whether tree foliages can be sources of bypass proteins or nutrients specifically needed in the rumen or both. A second major question is how to develop these as combination sources of each nutrient.

3.7.1 Major applications of balanced nutrition in developing animal production systems

Extensive application of the use of supplements of multinutrient blocks and bypass protein has occurred in India through the initiatives of The National Dairy Development Board of India (NDDB). For the reasons given above, progress was initially slow (the development started in 1980) but it is now accelerating at a pace which should see most of their feed mills dedicated to the production of bypass protein supplements within the next five years. At the present time between 200,000–300,000 MT of bypass protein are being fed annually to around 500,000 dairy animals sustained on poor quality feeds and owned by village farmers in the central parts of India. In many situations, this is coupled with the use of molasses urea blocks compounded to provide a spectrum of nutrients for the rumen microbes (NDDB, 1989).

Monthly milk collections are shown in Figure 3.3 on page 42, for a major dairy co-operative in the Kedah district of India that changed from feeding a traditional concentrate to a new supplement containing 30% of a protein meal with a high level of bypass protein. In this figure, the quantities of milk collected from villages in the area are shown for the previous five years and for the twenty-six months since conversion to the new feeding system. Whilst a number of changes have occurred in the area which could contribute to the increased quantity of milk collected, local research confirms that the responses in milk production to the new supplements (Leng & Kunju, 1988) are in agreement with observed increases in milk collected. A large proportion of the increased milk collected appears to be a result of more animals in the milking herd due to increased reproductive efficiency (i.e., a reduced intercalving interval).

The effects of the change to balanced feeding strategies based on supplementing with nutrients for the microbial ecosystem and bypass protein appear to be a 30–50% increase in milk collection from 1st December, 1988 to 1st December, 1989. A further similar increase in production is apparent in 1989–1990 (unpublished observation). This increase probably represents a flow-on effect that would come from increased reproductive efficiency and the increased proportion and number of cows in milk resulting from the improved feeding strategies.

In China, a major cattle production development based on the same principles and sponsored by FAO has had a very high level of success. It is estimated that around 3.3 million small farmers are presently fattening cattle on straw treated with ammonia to improve digestibility and supplemented with a bypass protein meal (cottonseed meal). The growth response of young cattle given straw or straw treated to improve its digestibility and supplemented with cottonseed meal is shown in Figure 3.4, page 43. A number of similar studies carried out in other countries are also shown in the same figure. China has a policy to increase beef production using this strategy to 10 million tons by the year 2000.

3.8 Availability of bypass protein meals

In many regions or countries, there is often little information on locally available protein sources, particularly the level of protection of these protein meals from degradation in the rumen. As a 'rule-of-thumb', solvent extracted oilseed cakes, fish meals that have been flame dried (but not sundried fish meal or fish silage) and protein sources that have been heat treated, have some protection from rumen degradation. The degree of protection is enhanced by pelleting the protein meal in the presence of free glucose or fructose (as occurs in molasses), when a mild Browning reaction tends to occur (unpublished observations). Recently xylose—a pentose sugar readily produced from bagasse has been added to soluble protein meals to provide a protected protein (Lewis *et al.* 1988). Although tannins in tree foliages may insolubilize constitutive proteins, it is unclear whether these proteins bypass the rumen and whether they are digestible in the intestine.

3.9 Identification of bypass protein sources

Some countries are fortunate in having large amounts of crop residues high in protein, most of which have a high degree of protection brought about by processing methods (e.g., solvent extracted sesame, linseed and cottonseed meal). These materials are convenient for use directly by the farmer or may be processed through existing feed mills for the production of a supplement which can be fortified with minerals and non-protein nitrogen. The most valuable and important source of bypass protein is probably solvent extracted cottonseed meal and where development programmes have been successful in promoting animal production, it is often been where cottonseed meal is readily available. It has been found that a number of oilseed byproducts contain soluble proteins and therefore it is has been necessary to protect, for instance, soyabean meal with xylose; in N. America and Europe and in Australia, canola, sunflower and safflower seed meal are also being protected in commercial factories with formaldehyde prior to feeding to ruminants as a bypass protein source.

In many countries, particularly with monocultures of cereals, sugar cane or extensive grasslands or savannahs, protein sources may not be readily available, or the sources not so obvious or easily obtainable. Most fresh legume forages, legume seeds, edible tree leaves, seed pods and seeds that are available in these areas, probably contain highly soluble protein which is easily fermented in the rumen. These, when used as supplements, provide a valuable source of rumen ammonia and minerals and appear to have a synergistic effect in lifting the digestibility of the basal diet (Ndlovu & Buchanan, 1985); they then increase feed intake and so increase production of cattle on a basal diet of low protein roughage. When fed as a small proportion of the diet, however, they provide little bypass protein, as the protein degrades rapidly in the rumen. It is important to know whether such supplements are as efficiently used for these purposes as MUMB supplements.

In the following chapters the potential use of fodder trees to provide ruminants with the nutrients critically deficient in poor quality forages are discussed.

Figure 3.3: *Milk collection records and the sale of supplements in a milk co-operative in the Kedah district of India when supplements were compounded on traditional concepts (1985–1987) then replaced (1st December, 1988) with a 30% C.P. bypass protein pellet (records provided by the NDDB of India).*

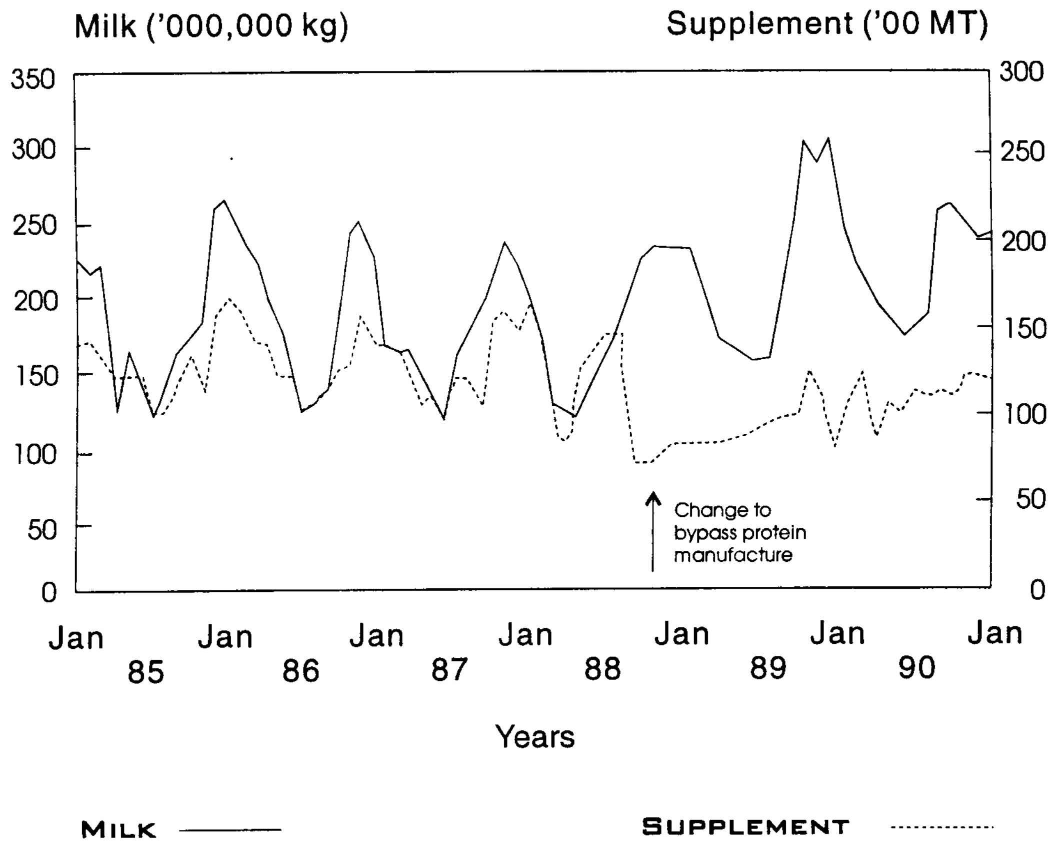
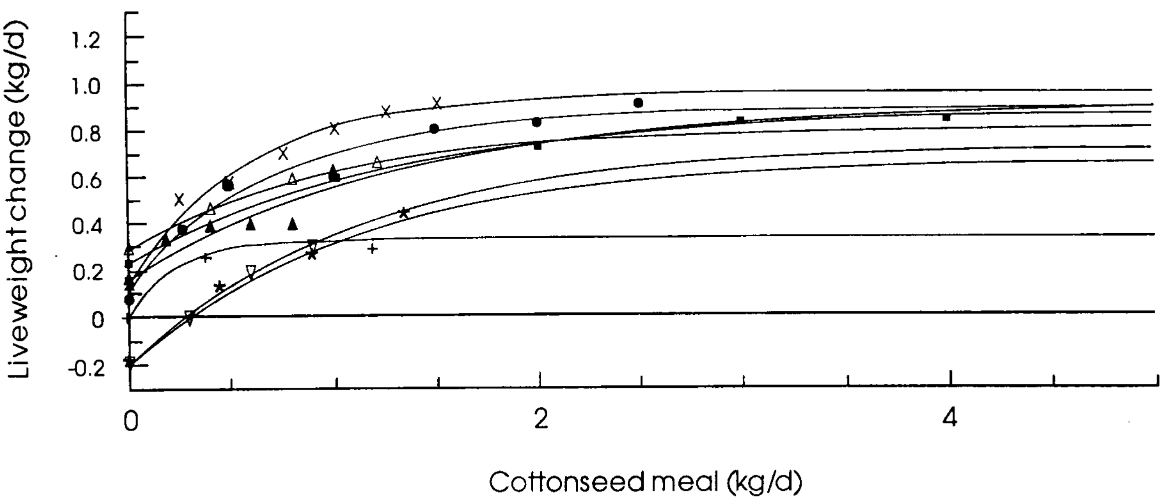


Figure 3.4: *The response in liveweight gain of cattle fed basal poor quality forage supplemented with cottonseed meal (after Leng, 1995).*



x cattle (145 kg LWt) fed Rhodes grass hays (McLennon *et al.* 1994)

● cattle (200 kg LWt) fed ammoniated straw (see Dolberg & Finlayson 1995 for review)

■ cattle (200 kg LWt) fed ammoniated straw (see Dolberg & Finlayson 1995 for review)

+ cattle (275 kg LWt) fed rice straw unbeaten (Perdok & Leng, 1990)

Δ cattle (275 kg LWt) fed ammoniated rice straw (Perdok & Leng (1995)

▲ cattle (yearlings) grazing oat straw after harvest of the grain (Smith & Warren, 1986*a*)

∇ cattle (yearlings) grazing dry winter pastures in Australia (Smith & Warren, 1986*b*)

* cattle (200 kg LWt) grazing dry pastures in Zimbabwe (Elliot & O'Donovan, 1971)