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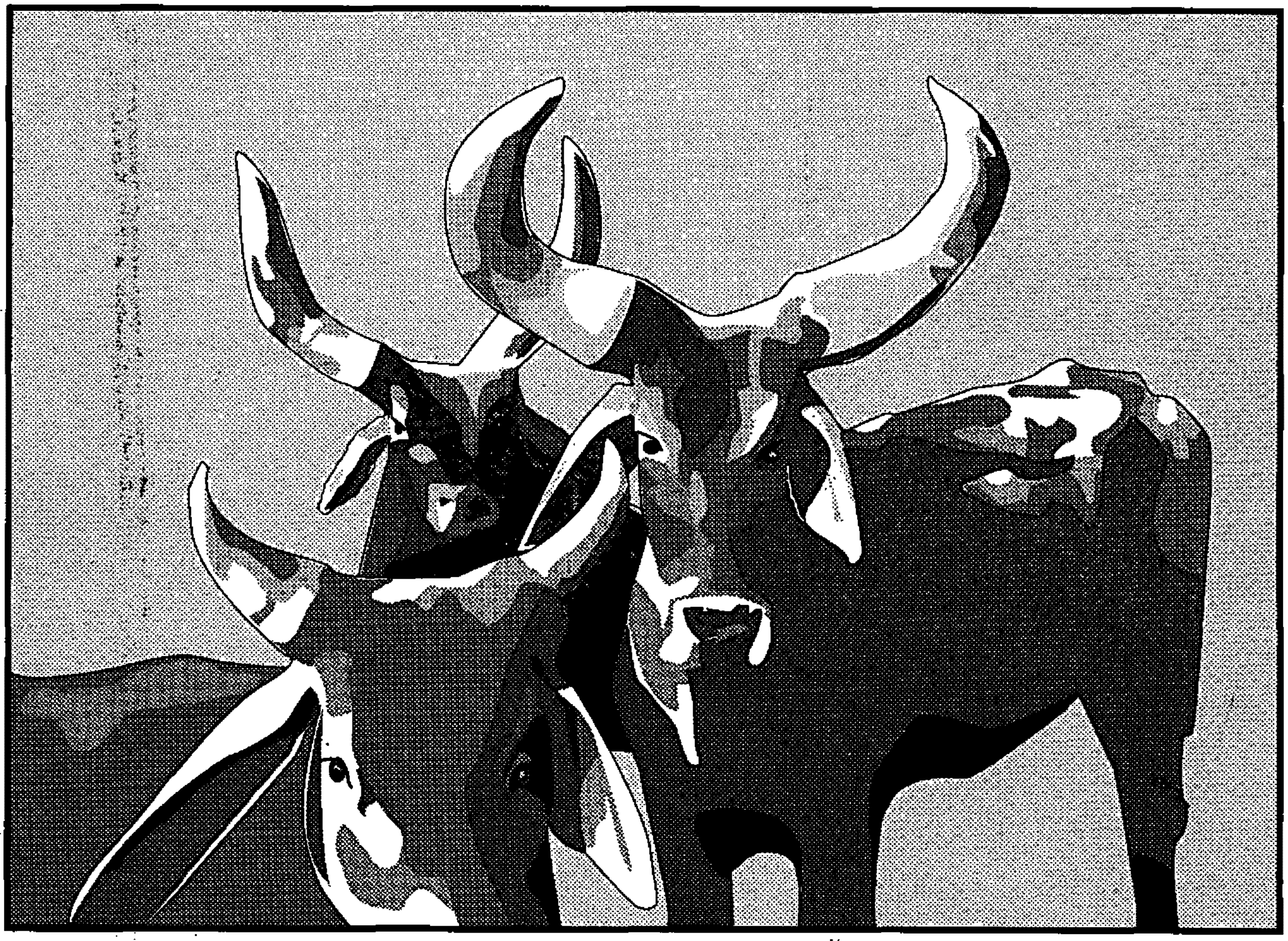
Improving Ruminant Production And Reducing Methane Emissions From Ruminants By Strategic Supplementation



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Improving Ruminant Production and Reducing Methane Emissions from Ruminants by Strategic Supplementation

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May 1991

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Part 1

Preface

The preparation of this report was funded by the U.S. Environmental Protection Agency (EPA). The purpose of the report is to summarize information regarding the potential to reduce methane emissions from ruminants through the use of strategic supplementation. This approach for reducing emissions was one of several promising approaches identified and discussed at an EPA-sponsored workshop in February 1989 and in a workshop conducted under the auspices of the Intergovernmental Panel on Climate Change (IPCC) in December 1989. Information regarding these workshops can be obtained from the following:

- U.S. EPA, *Reducing Methane Emissions from Livestock: Opportunities and Issues*, Office of Air and Radiation, EPA 400/1-89/002, August 1989;
- U.S. EPA, *Greenhouse Gas Emissions from Agricultural Systems*, Policy Planning and Evaluation, 20P-2005, September 1990.

This report has been prepared to further discussion and analysis of opportunities to reduce emissions of greenhouse gases from various sources. The U.S. Environmental Protection Agency does not endorse the performance, environmental acceptability, or commercial viability of any of the emissions reduction strategies discussed in this report.

Part 2

Executive summary

2.1 Introduction

It is well documented that the global atmospheric abundance of methane is increasing. Recent rates of increase are of the order of one percent per year. Based on analysis of ice core data, it has been estimated that the increase in methane concentrations began about 200 to 300 years ago. The major anthropogenic sources of methane emissions are: animals (primarily managed ruminant livestock); rice cultivation; biomass burning; oil and gas production and distribution; coal mining; landfills; and waste management.

The increased abundance of methane will have important impacts on: the stratospheric ozone layer; background levels of tropospheric (i.e., ground-level) ozone; global climate. Estimates are that methane will contribute about 20 percent of the expected global warming from the greenhouse effect, second only to carbon dioxide.

As part of international efforts to address global warming, emissions inventories are being prepared and opportunities for reducing methane emissions are being identified and evaluated by the U.S. Environmental Protection Agency and others. A recent workshop sponsored by the Intergovernmental Panel on Climate Change (IPCC) found that opportunities exist to reduce methane emissions from managed ruminant livestock. Achieving such reductions in concert with reductions from other key sources could help to stabilize global methane concentrations. Managed livestock, and in particular, large ruminant animals, are important contributors to the increasing abundance of atmospheric methane, accounting for on the order of 15 to 20 percent of annual methane emissions.

Of the approximately 1.5 billion large ruminant equivalents (i.e., cattle, buffalo, sheep and goats) in the world, the largest proportion of these are supported on relatively poor feeds particularly (but not only) in developing countries and therefore grow and produce at variable but relatively low rates. It is probable that 80% of the whole global herd could come into such a category.

Improved nutritional management of these ruminant animals, e.g., through supplementation, is expected to lead to increased productivity and will generally reduce methane emissions per unit of product. Provided that the markets for the products do not expand, improved animal productivity will lead to reductions in methane emmissions from these animals.

This report provides

- essential background information on the basic chemistry of fermentative digestion in the rumen
- the reasons for specifying supplementation as an important and practical means of reducing methane emissions from ruminant animals
- the likely reduction in methane from ruminants through supplementation
- the strategy needed for application in developing countries where large numbers of low producing animals are found
- a case study of application of supplementary feeding in India
- some issues required to obtain wide scale acceptance of the feeding practices in those countries where livestock population densities are high but at a subsistence level of production.

Application of strategic supplementation to cattle fed poor quality forage could reduce methane production per unit of product by 25–75%.

2.2 Methane production by ruminants

Ruminant animals (cattle, deer, goats and sheep) are estimated to produce 65–85 Tg of methane annually (1 Tg = 1 teragram = 10^{12} grams = 10^{9} kilograms = 10^{6} metric tons) or 15–25% of the estimated global methane production (400–600 Tg). Most of this is attributed to cattle, of which the vast majority are situated in developing countries.

The objectives for reduction of methane production, apparent when dealing with ruminants, are to:

- increase the efficiency of feed utilisation in fermentative digestion
- modify intestinally digestible feed components (protein and starch) to avoid fermentative digestion
- increase animal product turnoff and satisfy human demands for ruminant products from fewer animals (i.e., reduce the numbers of low producing animals, particularly in the heavily populated countries)
- supplement diets with natural products or chemicals that inhibit methanogenesis irrespective of whether this increases productivity and/or profitability

Other possibilities include the development of methane oxidising organisms or other hydrogen sinks in the rumen using genetic engineering.

The first three objectives are compatible and the first two automatically support the third. Manipulation of methanogenesis in the rumen may be more applicable in the developed countries with large automated feedlots.

The use of supplements and in particular molasses/urea multinutrient blocks in developing countries could form a vehicle for chemicals used for rumen manipulation. Where there is easy access to animals fed compounded rations the chemicals could be directly added to the diet.

Over the last 20 years, increases in animal products have been achieved in developing countries by increasing animal numbers rather than increasing the level of production per animal. These countries have over half the total world ruminants, and they are, in general, owned in small groups (i.e., 1–5 animals) by small farmers and are fed on forages which generally promote slow growth, poor reproductive performance and low milk production.

The pressure on land in most developing countries for food-crop production, suggest that it is not possible to alter the basal diets of these animals, which are generally fed on poor pasture and/or crop residues that are low in protein and digestibility. The feed resource is usually of poor quality for the majority of any feed year. Methane production by these animals may be as high as 15% of the digestible energy of feed since the diets are deficient in critical nutrients (in particular ammonia) for efficient microbial growth in the rumen.

2.3 Methane production by cattle fed poor quality forage

Data developed from extensive work in India and other countries indicate that strategic supplementation of the diet to promote efficient fermentative digestion of forages will decrease methane generation per unit of digested feed by some 30–50% (15% of digestible energy (DE) to 7% of DE).

These data also show that in addition to ensuring an efficient fermentative digestion in these ruminants, judicious supplementation with protein, in a form that is directly available to the animal, reduces the time for an animal to reach slaughter weight or puberty by up to three years (from a "normal" 5–6 years down to 2–3 years) and reduces the amount of forage required to grow an animal to slaughter weight or to a breeding size by 4 to 5-fold. Over a 12 month period (1989) close to 50,000,000 extra litres of milk have been produced in Kiara, as against 1988 and 1987, when traditional supplementation was used. Methane production per unit of meat produced is reduced to about 0.2 of that produced in the unsupplemented animal. For milk production, the amount of methane produced can be lowered from about 250 g methane/litre to 40–80 g methane/litre of milk.

Other methods for improving animal nutrition, e.g. increasing the digestibility of the forage (with alkali treatments) in combination with such supplementation, can further reduce the age of slaughter and feed required per unit of meat or milk production.

2.4 Effects of supplementation on breeding herds

As already pointed out, in most developing countries, the animals owned by small farmers mature at a late age (puberty at 4 years) and often breed irregularly (one calf every 2 years). It is suggested that the strategies outlined, in the main text have the capability of reducing the age of first calving from 5 years to 2–3 years and the intercalving interval from 24 months to 15–12 months. This diminishes the numbers of breeding cows required for meat production and/or providing replacement draft animals by at least 50%. With the dairy industry it can more than double milk production by increasing the number of cows in the National Herd actually in milk at any one time.

Widespread application of these nutritional strategies coupled with good health care and management can have a huge impact on animal production. Animal production in developing countries can be improved between 2 and 4 fold by the nutritional strategies outlined provided they can be widely applied.

The eventual overall effects on methane emission will depend on the control of animal numbers within a country. This in turn will depend on market demand for meat and milk and other products (including draft power). However, market forces will surely reduce animal numbers as production per animal increases; this has already occurred in the USA in dairying where cow numbers have decreased linearly with increases in milk yield per animal. The increased production has been achieved through better feeding and breeding.

Meeting the market demands for ruminant products through a higher efficiency of feed utilization and animal production, together with the reduced requirements for numbers of breeding cows will also reduce or remove the incentives to create vast ranches from tropical rainforests.

The supplementary feeding strategies, but not the treatment of straw are being widely advocated for cows and buffaloes in villages throughout India by the National Dairy Development Board. Their policy is to turn over all their feed mills to producing protein meals which are prepared so that the protein escapes fermentation and is used directly by the animal. They have in place, or have planned, some 50 factories to produce molasses/urea multinutrient blocks. The use of these two supplements can achieve the increases in production sufficient to reduce methane emmissions significantly.

It is possible that within five years, six million animals will be being fed by these strategies in India alone. The wider scale application in other developing countries of these feeding strategies depends on political will, socio-economic factors and perhaps pressure from Aid Agencies.

2.5 The role of improved animal genotype

More scientific feeding of ruminants allows the use of improved genotypes for the particularly productive system. In India, for example, introduced cattle for crossbreeding purposes (such as Friesian-Holstein or Jersey with high genetic merit) have milk yields in their first lactation of 4000–6000 litres/305 days without resorting to grain based concentrates.

The projected requirements for milk and draft power in India could be met by 27 x 10^6 cows/buffaloes producing 3000 litres milk/year, breeding every 12 months. The male calves would provide 10 x 10^6 replacement bullocks needed annually for animal draft power. The net effect could be a reduction in cattle/buffalo numbers from over 300 x 10^6 to about 120 x 10^6 (which includes 75 x 10^6 draft animals).

2.6 Improved animal production and methane production

The effects of supplementation and of treatment of straw on the generation of methane per unit of feed intake and per unit of live-weight gain on milk production are shown in the Figures 1, 2 and 3 at the end of this Section. This indicates that a very large decrease in methane production from ruminants in developing countries can be achieved provided that animal numbers are decreased as productivity per animal is increased (see p. 20 **Socioeconomic considerations (a cautionary note)**). It also presupposes that disease/parasitism are not constraints or are controlled by good animal health management.

The new feeding systems, when applied in tropical countries, have given some remarkable responses. In general, the metabolisable energy content of a diet fails to predict liveweight gain of cattle on straw based diets that are supplemented with critical nutrients. This is shown in Figure 4 at the end of this Section.

At the same time, cattle on "poor quality forages" that are supplemented with critical nutrients, grow much more efficiently than predicted by feeding standards. They also produce only the same methane per kg liveweight gain as animals on high quality feeds (e.g. barley concentrate mix). This occurs despite considerable differences in growth rates which may be twice as fast on the high quality feed vs. the poor quality forage with supplements (Figure 5, end of this Section).

The foregoing discussion of the potential of supplements to increase methane is based on scientific principles, particularly the effects of improving microbial growth efficiency by supplementation. Whilst there is considerable data which supports the general thesis, there is no work that has set out to measure changes in methane production with improving microbial growth efficiencies. Research is needed in this area.

2.7 Strategic supplementation and the target groups

A total supplementation package consisting of a multinutrient block plus a by-pass protein feed needs to be applied to ruminants fed relatively poor quality forages/pastures.

The target groups of large ruminants for this strategy include the following:

1. Cattle/buffalo in developing countries:
   - fed crop residues or cut/carry grass and agro-industrial byproducts
   - grazing in areas with monsoonal climates in the tropics, particularly in the dry season
   - grazing tropical grasslands on infertile soils (e.g. Los Llanos, Colombia; Brazil and the pampas, Argentina)
2. Cattle in the developed or industrialised countries:
   - fed agro-industrial byproducts (e.g. molasses, sugar beet pulp or pineapple waste)
   - fed relatively low-protein grain based diets in feed lots (e.g. sorghum and whole maize cobs)
   - grazing relatively poor pastures in semi arid grazing areas (e.g. parts of the Southern United States and Northern Australia)

2.8 Requirements for success of strategic supplementation

The development of these feeding systems in India has clearly shown the applicability of this strategy. It cannot be assumed that methods used to obtain acceptance by farmers will be viable in other developing countries.

The essential ingredients for success with such strategies are:

- identification of local resources to provide the supplements
- developing raw ingredients where resources are not available locally
- placing priority on the use of these resources locally
- where necessary, establishing appropriate manufacturing capabilities to protect proteins from degradation in the rumen
- ensuring that the supplements are available to small farmers through an appropriate marketing system
- ensuring markets for meat/milk etc. and therefore profit motive to farmers
- facilitating purchase of supplements—particularly where the returns for their use are some time in the future—e.g. subsidies, low or zero interest rates, perhaps with a tax on the commodities when sold
- facilitating the use of potentially high producing genotypes by making germ plasm available, and insurance of the animals against death
- education on the benefits of such supplementary feeding strategies through all levels of the community
- ensuring that good disease/parasite control is associated with the feeding strategies

2.9 The Indian experience

The patterns of supplement purchase, milk sold and the ratio of supplement purchased/milk sold in the Kiara district of India are shown in Figure 6 at the end of this Section. The new feeding strategy was implemented in December 1988. Clearly, the advantages of the strategies are increased milk production (approximately 30% more than in the previous 2 years) and decreased supplement production coupled with increased efficiency of supplement use. The increased milk production per cow reduces methane production/unit of milk. The decrease in quantities of supplement used to feed milch animals in the villages will result in considerable fossil fuel savings in manufacture, transport and storage processes.

2.10 Socioeconomic considerations (a cautionary note)

These strategies do not take into account socio-economic aspects. Almost every rural household in India owns a milch animal and often depend on these for the day to day cash flow and for high quality nutrients for their family diet. Milk is important, as it supplements an often vegetarian diet which is often imbalanced for amino acids. Reduction in milch animal numbers would inevitably be at the expense of the rural poor—the tendancy, with ownership of "high yielding" animals will be for these to be owned in larger herds in the hands of "rich" farmers.

Additionally, in developed countries with market economies, improvements in animal performance have led to reductions in overall animal numbers. If socioeconomic considerations prevent similar shifts in animal numbers from occurring in cases where supplementation is implemented, the full potential to reduce methane emissions and increase productivity may not be realized. It is expected, however, that constraints on feed supplies will, over the long term, is likely to force shifts in animal numbers that are consistent with the experience of market economies.

Thus any suggestion of reduction of numbers of milch animals may reduce the standard of living of the rural poor in India (and other developing countries); alternative sources of income would need to be provided along with the development strategies envisaged. India already has a policy of decentralisation of industry to rural areas with large incentives such as suspension of taxation of profits.

2.11 Tables and Figures

Figure 1: This appears later as Figure 5.3

(A) The effects of improving the efficiency of rumen fermentative activity on methane production per kg of digestible energy consumed.

(B) The production of methane per kg gain in supplemented cattle (feed conversion efficiency (FCR) 9:1) or unsupplemented cattle (FCR=40:1) fed straw based diets (after Saadullah, 1984)

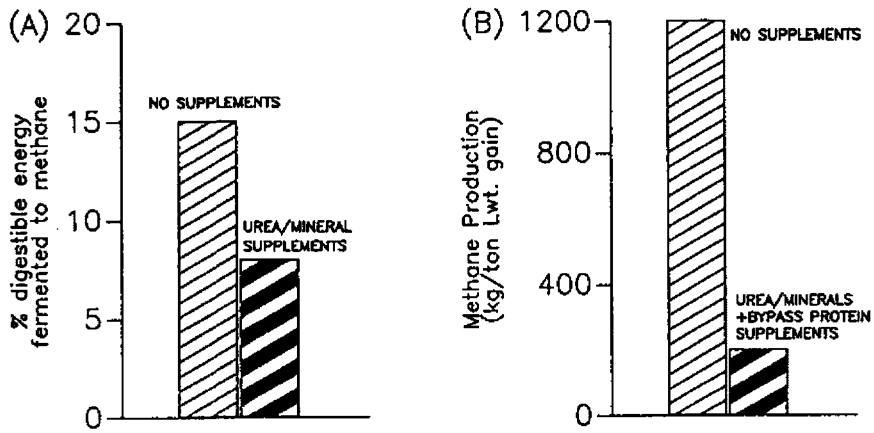


Figure 2: This appears later as Figure 5.4

Effects of supplementation and straw treatment on the kg methane produced for each kg gain in cattle fed straw that was untreated or treated with ammonia to improve its digestibility. The results are from experiments published by Perdok et al., *1988*

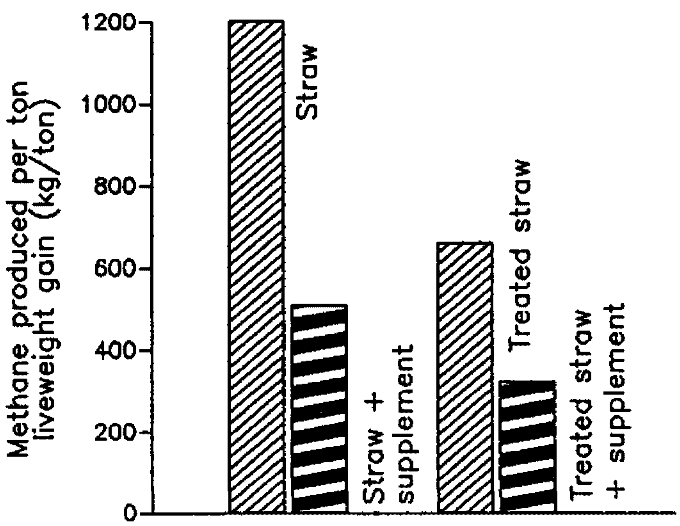


Figure 3: This appears later as Figure 5.6

Calculated amounts of methane produced per unit of milk production in unsupplemented (fed traditionally) or supplemented (new feeding systems) cows in India with moderate levels of production. The methane generated (g) per kg milk is also shown for high yielding cows in developed countries (fed traditionally) or high yielding cows in India fed tropical forage with molasses urea block (MUB) + 350 g/d bypass protein per liter of milk production.

The values represent the methane generated from feed consumed during the lifetime of the cow in relation to the lifetime's milk yield. The assumptions associated with this figure are tabulated.

	Case Study			
	1	2	3	4
Mature weight (kg)	400	400	600	600
Time of first calf (years)	5	3	2	2
Intercalving interval (years)	2	1.5	1	1
FCR* (kg/kg LWt gain)	30:1	15:1	8:1	8:1
Forage consumption (% LWt)	2.5	3	4	4
Digestibility of feed (%)	50	50	65	65
Methane (% Dig. Energy)	15	11	11	11
Life span (years)	13	13	5	8
Number of lactations	4	6	3	6
Lactation yield (tons/year)	1	2.5	6	6

*FCR = Feed conversion ratio (from weaning to first calf)

Case studies:

1. Traditional feeding with native cattle/buffalo in India.
2. New feeding system using MUB/bypass protein with native buffalo in India.
3. Friesian-Holstein fed high quality forage/concentrate in developed countries.
4. Friesian-Holstein fed tropical forage/MUB/bypass protein in India.

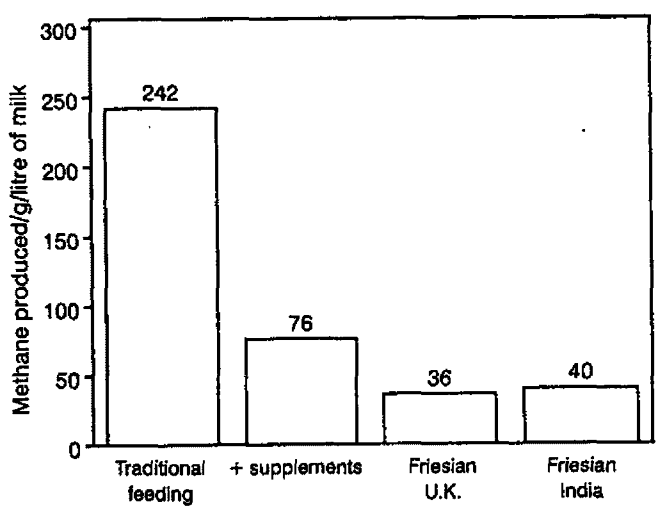


Figure 4: this appears later as Figure 5.2
Schematic relationship between diet quality (metabolisable energy MJ/kg dry matter) and food conversion efficiency (g liveweight gain/MJ ME) (- - -) (from Webster, 1989). The relationships found in practice with cattle fed on straw or ammoniated straw or poor quality hay with increasing level of supplementation of protein meals that pypass rumen fermentation. Australia (◇, ○, •) (Perdok et al., *1988); (□, △) (Hennessy* et al. *(1983); Hennessy* et al.,*1989), Thailand (△) (Wanapat* et al., *1986) and Bangladesh (□) (Saadullah, 1984) This illustrates the marked differences that result when supplements high in protein are given to cattle on diets of low ME/kg DM*

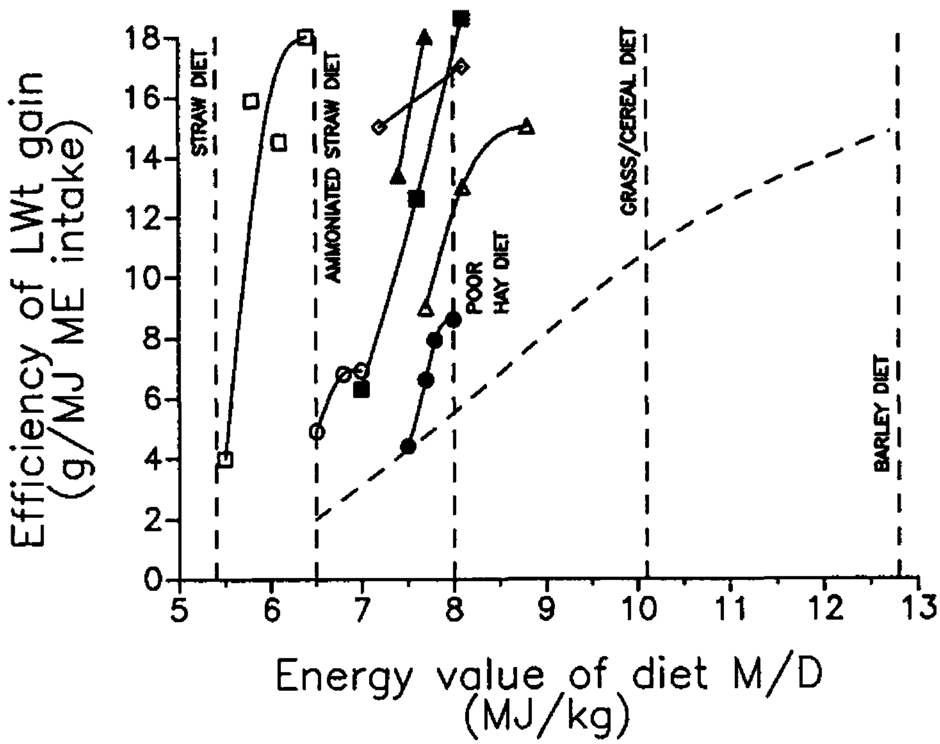


Figure 5: this appears later as Figure 5.5
Relationship between the metabolizable energy content of a feed (M/D, MJ/kg) and the theoretical methane produced per kg gain. The relationship shown by a broken line is based on the metabolizable energy system in practice in UK (Webster, 1989). The relationship indicated are results from the studies of Perdok et al., *1988 (◇, ○, ●); Hennessy* et al., *1983, Hennessy* et al., *1989 (□); Saadullah, 1984 (□) and Wanapat* et al., *1986 (△) in which cattle fed straw, straw treated to improve its digestibility or poor quality hay were supplemented with increasing levels of bypass protein. (The data are calculated from Figure 4.) Methane produced per unit of gain was lowest when the efficiency of liveweight gain had been stimulated by feeding bypass protein.*

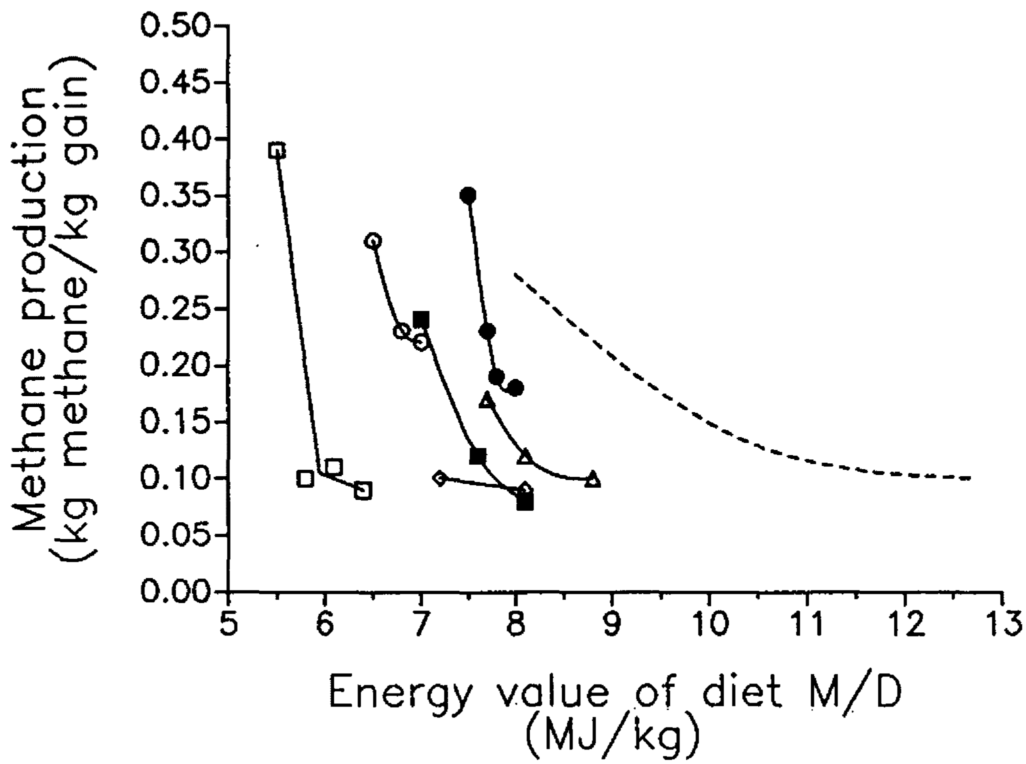


Figure 6: this appears later as Figure 6.6

A case study of the implementation of feeding strategies for large ruminants based on bypass protein (commencing Dec 1st, 1988) (NDDB records). In the Kiara district, Anand, India, there are some 18,000 crossbred cows (70% in milk), 55,000 indigenous cows (55% in milk) and 350,000 buffaloes (40% in milk) (Kunju, 1989).

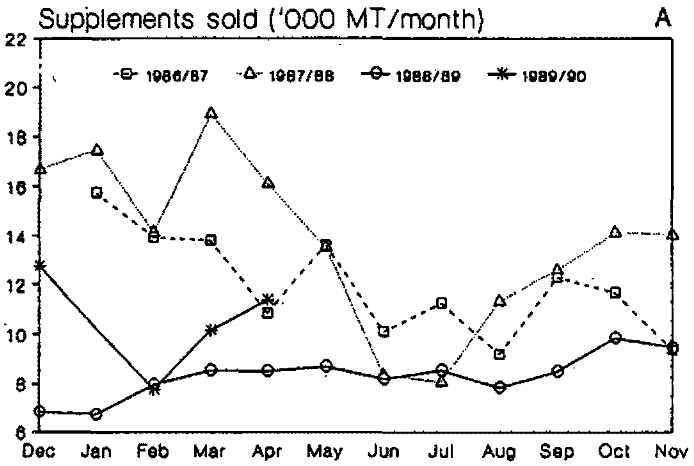
(A) shows the sales of a supplement-feed in the district from the Amul Feed Mill when a so-called balanced concentrate was available (1987/88) and after the change (1st Dec, 1988) to a 30% protein meal (bypass protein). In the latter system, the recommendations are to feed a molasses/urea block and half the previous quantity of supplement. Initially, there was some stockpiling of the original feed and there was marked resistance by farmers to the new feed. This resistance subsided.

(B) shows the milk procurement at the Amul Dairy Factory over the same three years.

(C) shows that farmers have faithfully followed instructions and that the rate of supplement (high protein feed) used, has dropped to about 350 g/litre of milk as compared to 700–800 g/litre of milk on the traditional concentrate. Milk yield has increased from 1.25 l/kg (old supplement) to 2.8 l/kg (new supplement).

(D) shows the thermal humidity index for Bombay. This is an index of the relative heat stress. Above 72 milk production is adversely affected in cattle fed on high quality feeds.

See next page.


Supplements sold ('000 MT/month)
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1986/87
1987/88
1988/89
1989/90
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18
16
14
12
10
8
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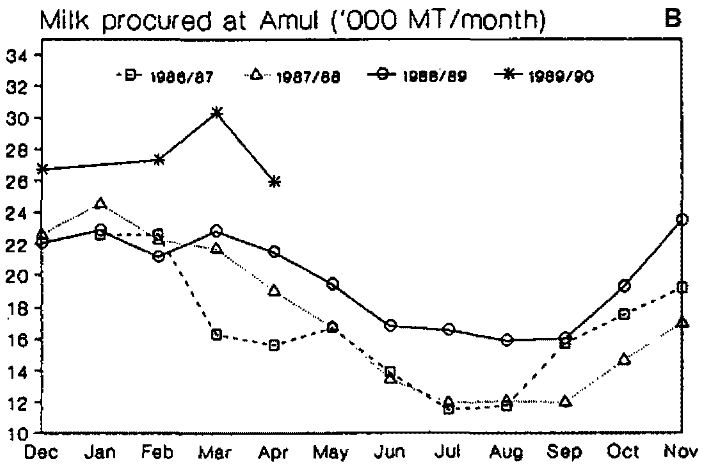
Milk procured at Amul ('000 MT/month)
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1986/87
1987/88
1988/89
1989/90
34
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28
26
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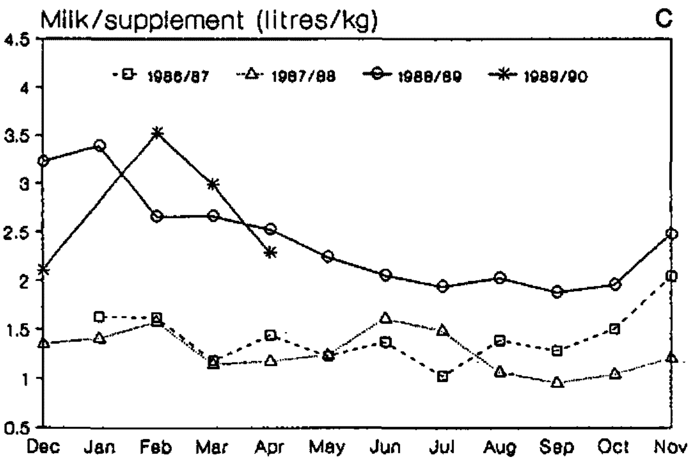
Milk/supplement (litres/kg)
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1987/88
1988/89
1989/90
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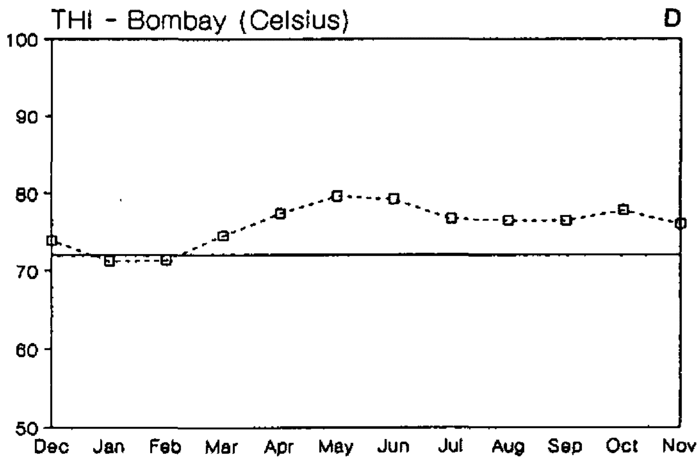
THI - Bombay (Celsius)
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Part 3

Introduction

Part 3 outline: Information is given which relates to the roles of livestock and the systems of livestock production practised in developing countries and in India in particular.

The problems of low productivity of ruminants and its consequences for methane generation are discussed. Strategies for improving productivity from the available feed resource are outlined.

The future possibilities for integrated farming are discussed in general terms. The overall strategy for limiting methane generation through strategic management is outlined.

3.1 The problem

The level of methane in the Earth's atmosphere is defined by emissions, from natural and anthropogenic sources, and natural destruction processes. It is well documented that the atmospheric abundance of methane is currently increasing at a rate of about one percent per year. Based on analyses of air trapped in the ice sheets of Greenland and Antarctica, long term methane trends have been established. The data indicate that the abundance of atmospheric methane has increased primarily in the last 200 or 300 years, with relatively stable levels prior to that time at about one-half the current levels.

The observed increase in the atmospheric abundance of methane must be caused by an imbalance in the sources (i.e., emissions) and sinks (i.e., destruction and uptake) of methane. The mechanisms leading to these observed increases in methane are believed to be: (1) increases in emissions; and (2) possibly decreases in its rate of destruction. The major anthropogenic sources of methane emissions are: animals (primarily managed ruminant livestock); rice cultivation; biomass burning; oil and gas production and distribution; coal mining; landfills; and waste management. Emissions from each of these sources have increased substantially in the last two or three centuries.

The increased abundance of methane will have important impacts on: the stratospheric ozone layer; background levels of tropospheric (i.e., ground-level) ozone; global climate. Estimates are that methane will contribute about 20 percent of the expected global warming from the greenhouse effect, second only to carbon dioxide.

To address the increasing concentrations of methane and other trace gases, international efforts have begun to identify opportunities for reducing anthropogenic emissions. A recent workshop sponsored by the Intergovernmental Panel on Climate Change (IPCC) found that opportunities exist to reduce methane emissions from managed ruminant livestock. Achieving such reductions in concert with reductions from other key sources will help to stabilize global methane concentrations. Although there is uncertainty in the level of emissions from various individual sources, it is believed that a combined reduction of about 10 to 20 percent in anthropogenic emissions will be sufficient to stop the increase in methane concentrations.

Ruminants produce 15–20% of the total methane generated; of the enteric source of methane, cattle contribute nearly 70%. The methane is generated largely in the fermentative digestive system (the rumen).

Most of the world's cattle and buffaloes (Table 3.1) are in the developing countries in Africa and Asia where they are largely fed on poor pastures, crop residues and agro-industrial byproducts.

The large populations of cattle in South America, parts of the USA, Australia and New Zealand are largely supported on pasture land not easily farmed or of inherent low fertility. These systems use only low inputs and usually little or no

Table 3.1: *FAO statistics for livestock populations in Asia/Pacific region as of 1986. (Values in the table are in thousands.)*

	Cattle	Buffaloes	Pigs	Sheep	Goats
World	1,271,810	138,352	822,443	1,145,690	492,192
Asia/Pacific	395,472	133,495	407,221	457,690	244,913
India	200,000	75,010	8,700	54,560	102,870
Pakistan	16,479	13,384	—	25,826	30,785
Bangladesh	23,200	1,860	—	1,110	10,772
China	66,925	20,038	338,074	94,210	61,901

fertiliser, which, with certain exceptions (temperate pasture lands), leads to poor nutritional value of the pasture (Walker, 1987). The animals under these grazing systems have similar nutritional problems to those of cattle fed crop residues.

3.2 Overview of animal production in developing countries

The majority of large ruminants in the world are in developing countries and are owned by smallholders (in groups of 1–5 animals). They often have multipurpose roles; they provide draft power, milk, meat, hides, and manure for fuel and fertiliser. The reason for cattle ownership varies from country to country.

In India, with its large vegetarian population, the emphasis is traditionally on milk production, draft power and production of dung for fuel, whereas in many African countries large ruminants are kept for meat and draft power with milk and dung as byproducts.

In the rural areas (particularly Africa), cattle are often an important source of cash income and provide financial security for their owners. They are a capital reserve in societies where grazing land is communally owned.

A proportion of the people in any developing country have equivalent purchasing power to that of the middle class in industrialised countries. This represents, for example, some 80 million people in India who can afford to purchase primary products and are increasingly demanding meat as well as milk.

It can be expected that, with improving standards of living and also with population density increases, the demand for meat and milk per capita in developing countries will increase, particularly as most developing countries have large and increasing populations.

Where institutional credit is restricted, livestock are often a key element in any critical increase in the cash flow of most small farmers. The sale of livestock products, in particular milk and meat, provides a major source of disposable funds for agricultural development (e.g. for purchase of improved seeds and fertilisers) particularly in India. The first step in improving the standard of living of smallholder farmers is frequently through an increase in animal productivity.

Milk is often the main source of a number of essential amino acids that are at times in low supply in the diet of the rural poor, who are often vegetarian from choice or because they are too poor to purchase animal products. Development strategies to improve the standard of living of the rural poor must aim at increasing the productivity of animals from the available feed resources. This must be considered when discussing the potential for reducing methane emissions from cattle in developing countries.

3.3 Livestock production systems: comparison between industrialised and developing countries

The high levels of individual animal productivity in the industrialised countries have been achieved through a disproportionate use of the world's resources (Borgstrom, 1980), especially fossil fuels, marine fisheries and the protein rich

Table 3.2: *Average meat production (kg) per animal of total population of cattle/buffaloes in Europe (representative of the concentrate/forage feeding systems) and in Asia/Pacific (1986)*

	Cattle	Buffalo
Europe	68	50
Asia/Pacific	5	7

meals. Even if this could be repeated in the developing countries, it would be a short-sighted one to adopt, since fossil fuels must increase in relative cost as world reserves become depleted and the environmental crisis increases (Porter, 1983).

The industrialised countries are, for the most part, situated in regions with temperate climates conducive to the growing of cereals and high protein, high quality forages. In contrast, the developing countries, are mainly tropical and in general produce cereals only for human consumption. They have, in the past, exported protein meals arising from oilseed crops in order to earn foreign exchange; the availability of protein meals is now known to hold the key to improved productivity of livestock fed on the available forage resources (this is discussed extensively by Preston & Leng, 1987). These protein meals are now less in demand with the development of soyabean production in Europe and, because their export is decreasing, there is an increasing availability at local outlets in India.

3.4 Ruminant feed resources in Asia

Ruminants in Asia are mainly supported on byproducts of agriculture and their growth and production rates are low (Tables 3.2, 3.3 and 3.4) compared to the averages in developed-temperate countries where improved pastures, grain based concentrates and high protein forages are fed (e.g. USA, Canada and Europe).

Table 3.3: *Average carcass weight (kg) per animal slaughtered (Jasiorowski, 1989) (1986 statistics)*

	Cattle	Buffalo
Europe	185	206
Asia/Pacific	120	161

Table 3.4: *Average milk produced (litres/lactation) per total population or per animal milked (Jasiorowski, 1989) (1986 statistics)*

	Cattle	Buffalo
Europe	860 (2335)*	586 (1043)*
Asia/Pacific	82 (865)*	254 (707)*

* milk production per animal milked.

Comparisons of productivity rates for Europe and Asia/Pacific are shown in Tables 3.2, 3.3 and 3.4, and clearly illustrate the low productivity of large ruminants in the Asia/Pacific region.

There are a number of ways to reduce enteric methane generation, but an obvious method is to increase animal productivity per animal to such an extent that the services and products provided by ruminants can be achieved by a much reduced number of animals.

3.5 Improving ruminant production in developing countries

Livestock-keeping in the Indian sub-continent and within Africa is dominated by the need for draft power. The majority of agricultural land (approx. 90%) is still worked with bullocks. Most farmers in India keep cows in order to produce male offspring to be reared as draft bullocks (Kurup, 1989).

However, with the inception of the milk co-operatives in India, specialised milk production with high yielding crossbred cows and selected buffaloes is increasing.

Buffaloes, on the other hand, are kept largely for milk production and manure generation for fuel purposes. Buffaloes are rarely used for draft power except in wet rice production and most males are allowed to die in the first few weeks of life (Kurup, 1989).

There are some 75 million bullocks (bovine) in India with an annual replacement rate of 10 million. These replacements are produced by some 40 million nondescript cows, which probably calve once every two years and average 500 to 600 kg milk per lactation.

There are strong reasons for arguing that the most economic way of meeting the increasing demand for milk, meat and draft animals is through improvement of traditional livestock production systems based on multipurpose animals, rather than through development of specialised milk, meat and draft animals (see Preston & Leng, 1987).

The bases for this argument are as follows:

- The growing need for larger numbers of draft animals in some developing countries makes it increasingly necessary to use milch animals for draft. Also, decreasing farm size in some countries, notably Bangladesh, is forcing farmers to use cows for work. Draft animals will often increase farm output several fold by increasing the area that can be put under crops and farmed by a family.

- Feed required for high levels of milk production using temperate countries' feeding systems (over 8000 litres per lactation) is in competition with food for humans and feed for pigs, poultry and fish. New methods of feeding are, however, overcoming this and with byproduct protein meals and molasses/urea blocks, milk yields from Friesian cows and their crosses with local breeds may approach 5–7,000 litres/305 days lactation.

- High levels of milk production from the specialised dairy breeds require much higher levels of management in the humid tropics than in temperate countries. Without appropriate feeding strategies and disease control, temperate dairy animals, when introduced into the tropics, often fail to produce and often have quite short lives.

  Milk production in India based on cows with high genetic potential would need a massive breeding programme and importation strategy to achieve the numbers needed to supply the milk requirements of a country. However, using artificial insemination with semen from bulls with high genetic potential, crossbreeding for milk production is a viable option and the resultant male offspring may be used as draft animals.

  The progeny of such crossbreeding have excellent dual purpose characteristics so long as they are given high protein supplements (i.e., balanced diets) in early life. Cows yield 1500–2000 litres of milk with selected animals often reaching 4000–5000 litres of milk per lactation, which can be supported on locally available basal feeds such as straw/protein meals and their meat production potential is comparable to that of the specialised beef breeds.

Poor nutrition, disease and parasites usually exert a major limiting influence on animals of high genetic potential and this highlights the importance of combining appropriate genotypes with relevant management and nutritional strategies in developing livestock systems suited to given situations.

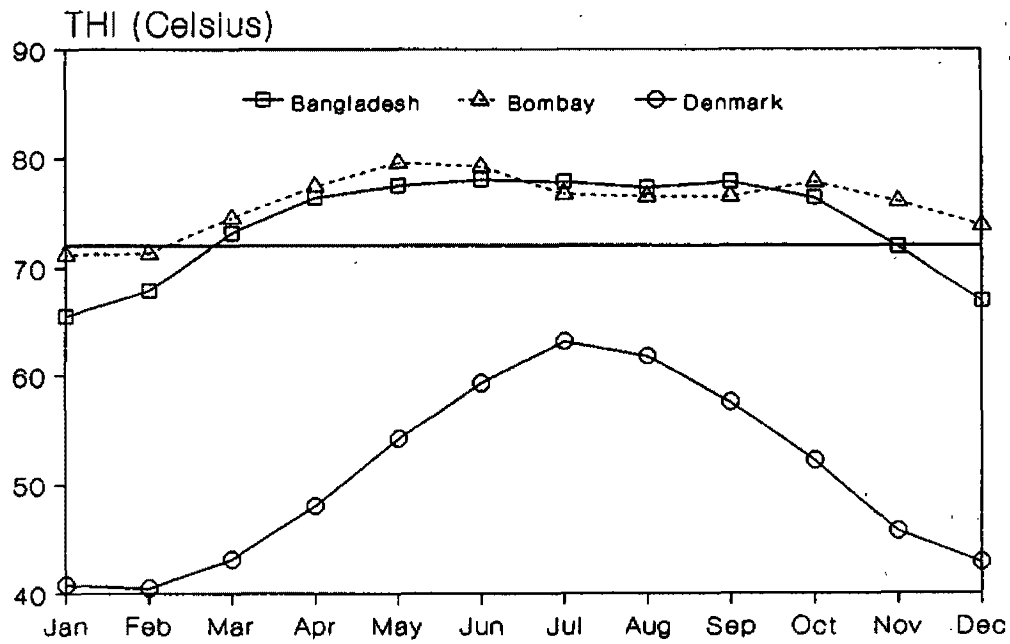
3.5.1 Impact of climate on production of ruminants

In the humid tropics where night temperatures often remain above 30°C, it is difficult for ruminants to lose the heat produced when on the feeding levels required for extremely high yielding cows in temperate climates (that is above 35

Figure 3.1: *Graphs illustrating the relatively stressful heat conditions throughout the year for the tropical and temperate areas. THI 72 is believed to be the point above which milk production is severely effected (Johnson, 1987).*

Climatic conditions are indicated by Temperature—Humidity Index (THI) where:

$$THI(^\circ C) = Temp.(dry\ bulb) + 0.36\ Temp.(dew\ point) + 41.2^\circ C.$$



litres/day). Average milk yields of up to 25 litres/day are, however, possible even in the humid tropics with the appropriate feeding strategies discussed here. (The Temperature Humidity Index (THI), above which milk production tends to be depressed is illustrated in Figure 3.1, together with those for Bombay (India), Chittagong (Bangladesh) and Copenhagen (Denmark)). In most developing countries the development of specialised milking herds is counter-indicated as it is much more rational and more simple to introduce crossbreeding. When compared to the specialized non-native milking herds, the crossbreds usually have greater resistance to disease and other environmental constraints. The appropriate strategy for each country, however, should be adjusted according to the available feed and technological resource.

3.5.2 Specialised beef cattle production

Unlike specialised dairy cows, specialised beef cows are inefficient, especially when the feed offered could support more productive systems. This is because their productivity is governed by their reproductive rate, which is always less than one offspring per year and considerably inferior to that of other meat-producing species such as pigs, poultry, sheep, goats and rabbits.

Highly specialised ruminant production systems that produce only meat (and hides) have developed largely in countries where population densities are low and land areas are large. In developing countries specialist beef herds are largely confined to government stations and large commercial ranches. Specialised goat and sheep production can be very important in the Moslem countries.

3.6 Strategies for improving animal production/reducing greenhouse gas emissions

Any strategy for improving livestock production must fit within a country's development-framework and now must consider the implications for global warming (i.e., the Greenhouse Effect). A best bet approach for most countries will be realised through an integrated approach that employs multipurpose crops, multipurpose animals, with residues and byproducts useable as feed or fuel or capable of being recycled back to the land. Inevitably such developments will lead to increased production per animal per life time and reduction in overall animal numbers as the market requirements become saturated.

3.6.1 Management to increase ruminant productivity

For most systems, improved reproduction rates of cattle (which are extremely low on pasture or crop residue based feeding systems) will be the critical issue. Improvement in a feeding strategy will improve reproduction. Improved nutrition and reproduction rates are compatible with improvements in the genetic base.

In terms of management the most critical areas to improve production rate of cattle are:

- improved nutrition;
- disease and parasite control;
- improved animal genotype to take advantage of the improved management;
- improved animal growth leading to larger animals with greater draft capabilities;
- improved implements for draft animals, reducing the numbers of draft animals required.

3.6.2 Integrated farming systems

As fuel requirements are often difficult to meet in many developing countries even for household needs, the use of feces directly as fuel or to generate biogas is a useful and important factor in any strategy—particularly in India, Africa and other parts of Asia where the availability of fuel is a major problem (MacNamara, 1985). Integrated farming systems may have a major role to play in the future in decreasing emissions of carbon dioxide and methane and therefore mention is made of it here.

The principles for achieving optimum resource use include:

- development of livestock production systems that match available resources and thus use these resources efficiently
- selection of crops and cropping systems that maximise biomass production and therefore carbon dioxide and nitrogen fixation

- generation of biogas from animal feces and urine
- recycling of inorganic wastes from livestock to minimise fertiliser requirements
- more efficient use of agricultural by-products and crop residues as sources of ruminant feeds, or directly for fuel
- use of multipurpose animals such as cattle and buffaloes that work and provide milk and meat and also breed to provide suitable draft animals, in addition to supplying fuel and fertilizer from their excreta
- incorporation into the production system of appropriate non-ruminant species that are well adapted to tropical feed resources, by-products and wastes (e.g. ducks, rabbits and fish) and which can use biomass with minimum methane production (e.g. pigs fed sugarcane juice).

3.6.3 Integration of livestock with crops/fuel production

The integration of livestock with crop production is a means of establishing sustainable farming systems that aim to optimise resource use and in addition it will reduce carbon dioxide and methane generation in agricultural systems. The realisation of such aims will maximise the degree of self-reliance of the system, since a variety of products will be obtained with minimum inputs to maintain soil fertility.

The integration of livestock into agricultural systems based on food crops calls for efficient use of crop residues and agro-industrial byproducts by the ruminant. As is discussed later, the by-products from such crops are inefficiently used at present, with consequences for environmental pollution.

3.6.4 Integrating ruminant production with biogas production

In the industrialised countries, feedlots are planned in order to maximise animal productivity and minimise operational costs. This has led to the use of feed resources with high energy and protein content (i.e., grains and oilseed meals). These feeds are usually compounded using modern equipment that facilitates mechanised feeding. The heavy capital investment in machinery has necessitated the establishment of large units with high animal densities.

Waste disposal in these enterprises has become a major problem. The accumulation of wastes, the cost of their disposal and pollution of the environment are serious consequences of the intensification of livestock enterprises in developed countries.

By contrast, the wastes from crop and livestock production in the developing countries are valuable sources of fuel and fertilizer. Fuel (methane) can be produced conveniently and efficiently from animal waste by anaerobic digestion. Recycling liquified excreta through biodigestors to irrigation systems avoids the loss of nitrogen and other plant nutrients which occurs when dried dung is burned for cooking and reduces the need for further dependence on fossil fuels.

The major constraint to widespread acceptance of biogas technology has been the high cost of the early digestors, which were built of concrete and steel. Simpler designs are now available which use plastic film (see Preston, 1989). These are easier to construct and install and are especially suitable to small farmers who have few animals.

3.7 Trends in livestock production in India

All developing countries require increased amounts of animal products. India, for example, produces at the present time about 163 g milk/capita and has set its goal at 200 g daily per capita. This requires a doubling of total milk production because of projected population increases. Jackson (1981) has pointed out that, with the 'feed base' of India, increased milk production to 1981 has been through increased animal numbers rather than increased milk production per animal. This is the opposite of what has happened in developed countries, where the numbers of dairy animals have decreased and production per animal has improved to provide the milk requirements of a country.

Operation Flood, a development project in India managed by the National Dairy Development Board, has been responsible for implementing policies resulting in large increases in milk production per animal through better feeding and breeding. By providing the infrastructure for marketing milk and milk products, it has set the example for the way forward for most developing countries.

The large increase over the last 10 years in importation of animal products into the underdeveloped sections of Africa has resulted from increasing demand. There is therefore the stimulus for these countries to increase production per animal as they cannot afford these imports. Imports of meat and milk into Africa have risen seven fold on a per caput basis, and in 1979 cost close to $US5 billion per year (Brumby, P., ILCA statistics). On the other hand India needs only to import milk products when drought conditions effect large tracts of country

In the future there must be large increases in the demand for animal products in all developing countries. If this is achieved by increasing animal numbers, rather than increasing individual animal productivity then large ruminants will continue to contribute significantly to the global methane emissions. It is essential that the increased demand for primary products be met from increased animal productivity without utilising resources directly usable by the human population. The demand must also be met from fewer animals growing and reproducing at much higher rates than presently attained.

3.8 The overall strategy

The bottom line is that strategies must be developed that maximise animal production from the available resources and minimise the numbers of ruminants needed to meet a country's need for:

- milk, meat and other animal products
- draft power.

Improved production per animal (see later) will reduce methane production per kilogram of meat or milk produced. Improved rates of production by individual animals could lead to a large reduction in cattle numbers once national requirements are met. This would have a multiplier effect on the decrease in methane production from better feeding of livestock.

No consideration is taken here of the sociological effects that this could have on the standard of living and the populations of small farmers in developing countries, nor how a decrease in animal numbers could be managed particularly in Africa and India. The application of improved feeding and breeding strategies must take into consideration political, economic, biological and sociological aspects. Many of these aspects are not predictable, particularly sociological and political aspects, and are not considered further in this presentation.

Nevertheless, the importance of these factors should not be minimized because they will have a significant impact on the ability to realize reductions in methane emissions in many countries.

Part 4

Digestive physiology of ruminants: implications for improving animal production from poor quality forages

Part 4 outline: The information given in this chapter is fundamental to understanding the strategies for limiting methane production from ruminants. Aspects covered include anatomy of the ruminant, the microbiology of the rumen, the requirements of rumen microorganisms for nutrients and the stoichiometry of rumen fermentative digestion of feed and the balances of nutrients available to the animal. Applied significance of the balances of protein to energy in the products of digestion that are absorbed is discussed.

4.1 Introduction

An understanding of the digestive physiology and metabolism of ruminants is the foundation for developing appropriate strategies that best utilise available feed resources and which at the same time minimise enteric methane production.

Digestion in the ruminant is different from that in monogastric animals (e.g. humans and pigs) because of the fermentation of feed in the rumen prior to acid and alkaline digestion in the intestines. Fermentative digestion results in major alterations in the type and balance of nutrients available to the animal when compared to that contained in the feed. Plant cell-wall materials (largely indigestible by monogastric animal species) can be digested through microbial fermentation in the rumen and therefore ruminants are often the main source of animal protein in countries with large resources of crop residues and poor quality pasture (i.e., from pastoral areas unsuitable for cropping).

4.2 The rumen

The dominant feature of the digestive tract of cattle is the rumen, which maintains an environment capable of supporting dense and varied populations of micro-organisms. These organisms ferment carbohydrates and other plant materials to produce mainly short-chain organic acids or volatile fatty acids (VFAs), methane and carbon dioxide and the process provides ATP (energy) for the growth of micro-organisms.

The microbial system in the rumen is anaerobic and includes bacteria, protozoa and fungi. Over 200 species and strains of organisms have been identified to date, although on individual diets a smaller number dominate. The complex rumen ecology includes both competition and cooperation among these organisms which ferment the primary feed constituents (fibre, sugars, and starches) into secondary products that can be catabolized further and subsequently used by the animal.

Rumen methanogenic bacteria are the source of methane produced in ruminants. Although these bacteria are a small fraction of the total population of microorganisms in the rumen, they play an important role in the complex rumen ecology. While methanogens can convert acetate (a fermentation product produced in the rumen) to methane and carbon dioxide, this pathway for methane production in the rumen is of minor importance. Instead, the conversion of hydrogen or formate and bicarbonate from the fluid medium is the primary mechanism by which methanogenic bacteria produce methane in the rumen.

The bacteria are the principal organisms that ferment plant cell-wall carbohydrates (Hungate, 1966) but the anaerobic phycomycetous fungi may at times be extremely important (see Bauchop, 1981).

Protozoa on the other hand are now recognised as having a negative effect in the rumen, particularly where ruminants are fed on diets low in true-protein (Bird & Leng, 1984). Protozoa ingest and digest bacteria and reduce the bacterial biomass in the rumen (Hungate, 1966; Coleman, 1976). They decrease the protein to energy ratio in the nutrients absorbed (see later) and in this way increase the requirement of animals for true protein and conversely they decrease the efficiency of utilisation of feed for growth and milk production (see Bird & Leng, 1984).

The presence of protozoa in the rumen may also reduce the rate at which bacteria colonise and degrade the ingested feed particles. In studies with sheep fed straw based diets, it has been found that the apparent digestibility of dry matter was increased by 18% after protozoa had been removed from the rumen (i.e., defaunated) (Soetanto, 1985; Bird & Leng, 1984), suggesting that large increases in productivity may be achieved with ruminants fed fibrous diets, particularly those low in true protein. These changes in digestibility have not been observed on diets based on straw and grain and in some instances removal of protozoa from the rumen has led to decreased digestibility of mixed diets (Jouany, 1989).

Rumen methanogenic bacteria are the source of methane produced in ruminants. Although these bacteria are a very small fraction of the total population of microorganisms in the rumen, they play an important role in the complex rumen ecology. While methanogens can convert acetate (a fermentation product produced in the rumen) to methane and carbon dioxide, this pathway for methane production in the rumen is of minor importance. Instead, the conversion of hydrogen or formate and bicarbonate from the fluid medium by the primary mechanism by which methanogenic bacteria produce methane in the rumen.

4.3 Fermentative efficiency in the rumen

A deficiency of a nutrient needed by the micro-organisms in the rumen will, in general, reduce the microbial biomass and therefore reduce digestibility and feed intake, particularly of fibrous feeds. The first priority for feeding ruminants on any diet must be to ensure the availability of essential nutrients for microbial growth in the rumen. The efficiency of microbial growth (that is, the amount of microbial biomass available for digestion in the intestines per unit of digestible carbohydrate entering the rumen) largely determines the proportion of digested energy that is lost as methane.

Methane production accompanies the formation of acetate or butyrate, whereas the conditions that promote the synthesis of microbial cells and propionate production also lead to reduced methane production.

4.3.1 Meeting the requirements for efficient microbial growth in the rumen

On most diets based on crop residues and low-digestibility forages, the primary limitation to the growth of rumen micro-organisms is probably the concentration of ammonia in rumen fluid (with secondary considerations for deficiency of minerals, particularly sulfur, phosphorus and certain trace minerals). Ammonia must be above a critical level for a considerable period of the day to ensure a high rate of microbial growth, rate of digestion and feed intake. The level of ammonia that supports the optimal population of micro-organisms in the rumen, and therefore maximum digestion, will vary among diets. In general the ammonia level should be above 200 mg nitrogen/litre (Perdok *et al.*, 1988).

It must be stressed, however, that any nutrient required in the growth of microorganisms that is deficient in a diet will result in low microbial cell yield relative to VFA and this will increase methane generation per unit of feed consumed.

Deficiencies of ammonia and a number of trace and macrominerals in the rumen of animals on poor quality forage based diets can be corrected under applied conditions by using a molasses/urea multinutrient block lick (referred to as MUB) (see Leng & Preston, 1984; Leng & Kunju, 1989). Under tropical conditions, sodium, sulfur, magnesium, phosphorus and a number of trace minerals (copper, cobalt, zinc etc.) are the most likely limiting nutrients.

4.4 Consequences of the ruminant mode of digestion

One of the costs of the ruminant mode of digestion is that fermentation of the readily digestible feeds results in up to 20% of the digestible energy in the feed consumed being lost as heat and methane. A second major disadvantage is that proteins that are fermented in the rumen are lost as sources of amino acids. Skillful balancing of the nutrients for the rumen and the animal can have very large effects on animal production through effects on the efficiency of all important functions.

In general, where a ruminant is fed a forage based diet typical of that available in tropical developing countries, small amounts of extra nutrients are needed to increase the efficiency of digestion and also the efficiency of anabolism of the absorbed nutrients in growth, pregnancy, lactation or work.

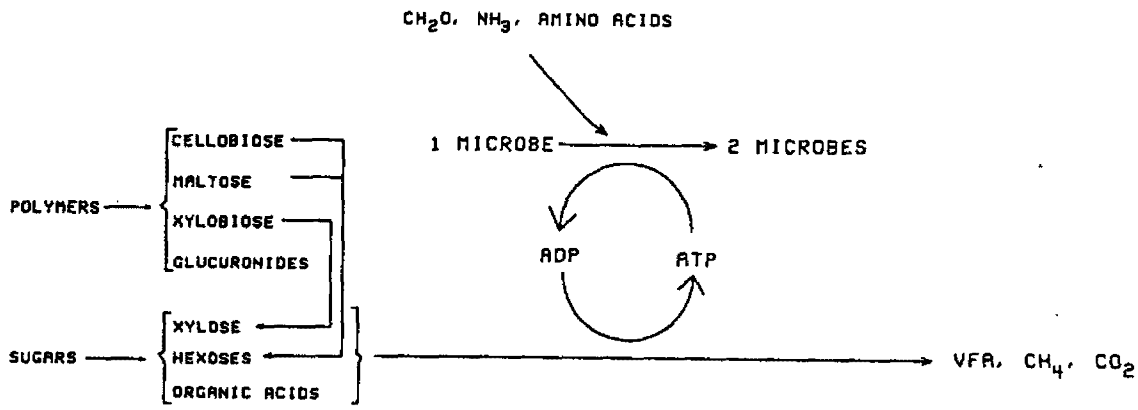
4.5 Quantitative aspects of fermentative digestion in the rumen

The end products of rumen fermentation are governed by the feed, the rate of consumption of feed, the balance of nutrients in the feed for microbial growth and the balance of microorganisms that develop (bacteria, protozoa and fungi) which largely depend on the chemical composition of the diet.

In general, a proportion of the digestible feed dry matter is converted to volatile fatty acids (VFA), methane and carbon dioxide and the balance is assimilated into microbial cells. The pathways of these reactions are well known (see Baldwin, 1970; Leng, 1970) and a schematic outline is shown in Figure 4.1.

Microbial cells, that are synthesised using the ATP generated in the formation of VFA, are lost from the microbial biomass pool either by passage out of the rumen to be digested in the intestine or by death and breakdown within the rumen (with formation of VFA, CO_2 and methane).

Figure 4.1: *Relationship between carbohydrate (polymers) fermentation and the production of VFA, methane and carbon dioxide and microbial cell synthesis*



Because microbial cells are more reduced than the substrate fermented, the quantity of microbial cells leaving the rumen per unit of carbohydrate consumed has a large effect on the overall methane production (Table 4.1; Figure 4.2).

4.6 A model of fermentation in the rumen

For the purposes of the present discussion, a model for a 200 kg steer will be used to illustrate the quantitative availability of nutrients from rumen fermentation. The steer consumes 4 kg which represents 25M anhydroglucose of organic matter which is completely fermented in the rumen.

It is assumed:

- that the fermentation of 1 mole of carbohydrate from forage gives rise to either 2 mole acetate, 2 mole of propionate or 1 mole of butyrate, according to the following stoichiometry:

$$
\begin{array}{lcl}
\text{Hexose} & \longrightarrow & \text{Pyruvate} + 2\text{ATP} + H_2 \\
2\ \text{Pyruvate} + 2H_2O & \longrightarrow & 2\text{HAc} + 2CO_2 + 2H_2 + 2\text{ATP} \\
2\ \text{Pyruvate} + 8[H] & \longrightarrow & 2\text{HPro} + 2H_2O + 2\text{ATP} \\
2\ \text{Pyruvate} + 4[H] & \longrightarrow & \text{HBu} + 2H_2 + 2CO_2 + 2\text{ATP} \\
CO_2 + H_2 & \longrightarrow & CH_4 + 2H_2O + 2\text{ATP}
\end{array}
$$

Figure 4.2: *Relationship between the production of microbial cells (Cell DM) and volatile fatty acids (VFA) and methane (CH_4) in fermentative digestion in ruminants. The relative efficiency of the system (indicated as Y_{ATP}) is governed largely by the availability of essential nutrients for microorganisms (after Leng, 1982). The ranges of Y_{ATP} are shown for:*

A. a relatively inefficient rumen (i.e., ammonia deficient)
B. a 'normal' rumen with no deficient nutrient for microbial growth
C. a rumen free of protozoa with no deficient nutrient for microbial growth
D. the theoretical optimum microbial growth efficiency

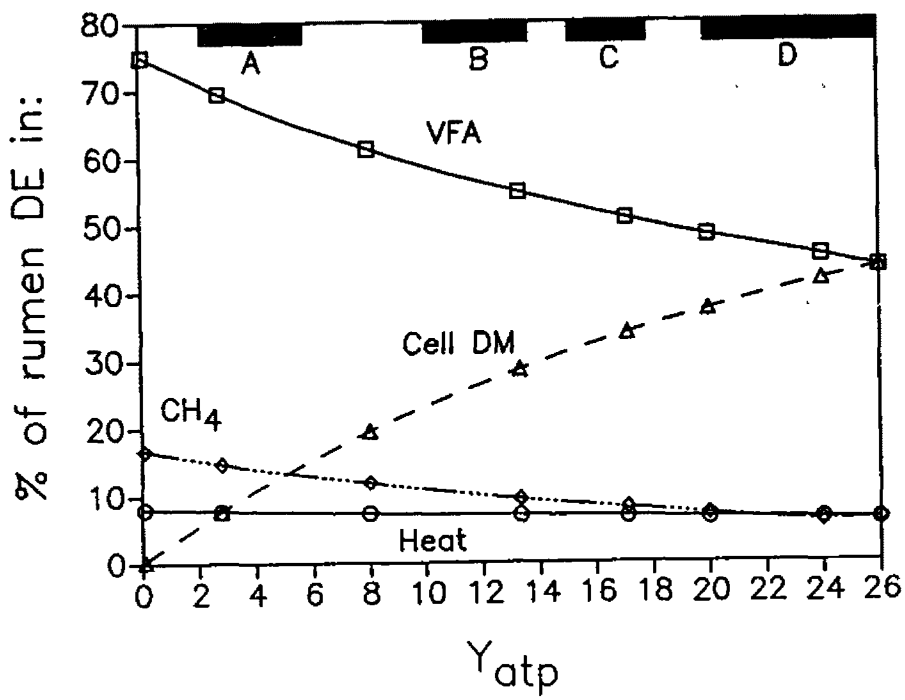


Table 4.1: *The effect of different efficiencies of microbial growth on ratio of protein to VFA energy available to ruminants*

Y_{ATP}	Microbial protein (g)	VFA energy (MJ)	Methane energy (MJ)	Heat energy (MJ)	Protein / VFA energy (g protein/MJ)
8	498	55.5	9.4	6.4	9
14	798	46.8	8.5	5.1	17
19	1008	40.8	8.0	4.3	24
25	1212	34.9	7.6	3.1	34

Example is for a steer consuming 4 kg fermented organic matter (Leng, 1982*a*)

In the stoichiometry, H_2 indicates reduced co-enzymes, HAc is acetic acid. HPro is propionic acid and HBu is butyric acid

- that the production rates of individual volatile fatty acids are proportional to their concentrations (Leng & Brett, 1966)
- that one-third of the organic matter fermented is converted to microbial cells
- that the moles ATP generated per mole of end-product are for acetate 2, butyrate 3, propionate 3, and methane 1 (Isaacson *et al.*, 1975).

The equation relating substrate and products for fermentation of 4 kg of carbohydrate is as follows:

$$16.7\text{CHO} \longrightarrow 21\text{HAc} + 6\text{HPro} + 3\text{HBu} + 7.5\text{CH}_4 + 78\text{ATP}$$

$$8.3\text{CHO} \longrightarrow 1.4 \text{ polysaccharide} + 13.8 \text{ pyruvate} + 2\text{CH}_4 + 17\text{ATP}$$

Overall:

$$25\text{CHO} \longrightarrow 21\text{HAc} + 6\text{Pro} + 3\text{HBu} + 9.5\text{CH}_4 + 1300 \text{ g dry cells}$$

In the example, one-third of the carbohydrate provides the precursor for microbial cells, 1300 g dry microbial cells are produced at a Y_{ATP} of about 14.5. (Y_{ATP} is a measure of the efficiency of utilisation of ATP generated in fermentation of carbohydrates to VFA; it is defined as the g dry cells produced per mole ATP available. The relationship between cell synthesis and organic production is shown in Figure 4.1.)

The upper level of efficiency (or the theoretical highest level of cell production) has a Y_{ATP} of 26. On the other hand the lowest efficiency of a microbial growth in the rumen that is deficient in, say, ammonia, is probably below a Y_{ATP} of 4.

Based on this model, but assuming a varying efficiency, the microbial cells produced relative to VFA and methane production change as shown in Table 4.1. The main point to emphasise is that, depending on the efficiency of utilization of ATP for microbial cell synthesis, the amount of carbohydrate converted to microbial cells can be highly variable and it is this that controls the amount of methane and VFA produced (see Figure 4.2).

4.7 Protein utilisation by ruminants

Protein that is fermented in the rumen is largely wasted as a source of amino acids to the animal because:

- dietary protein is degraded and essential amino acids are deaminated to form ammonia and VFA
- fermentation of 1 g of protein generates only half the ATP that would be produced from 1 g of carbohydrate.

This means that only 30 to 60 g of microbial protein becomes available to the animal for digestion for every kilogram of dietary protein that is fermented in the rumen. The fermentation of protein is associated with only small amounts of methane produced; on the other hand methane generation from protein if this bypasses the rumen is zero.Protein that is insoluble or has a high component of disulphide bonds tends to bypass rumen fermentation but is digested in the intestines and in this way it alters the ratio of protein to energy (P/E) in the nutrients absorbed. The better the balance of nutrients for microbial growth the higher the ratio of P/E of the nutrients absorbed.

4.8 Applied significance of P/E ratio

The amino acid supply to an animal effects a large number of biological functions within the animal. Obviously where end-products containing protein are the objective of the feeding system the amount of amino acids absorbed relative to VFA will be highly correlated with the productive level achieved. For example, wool growth, milk production and growth in young animals all increase with the increase in the P/E ratios in the nutrients available to the animal. The higher the P/E ratio in the nutrients absorbed, the more efficient the animal becomes in utilising the available nutrients for milk production, liveweight gain and other production functions.

4.9 Significance of protein in the diet

Considerable research has demonstrated that, in ruminants fed poor quality forages, supplementation with a source of rumen ammonia (or molasses/urea multinutrient blocks) stimulates rumen function, which stimulates food intake. On all diets that are low in protein, supplementation with bypass protein stimulates the efficiency of feed utilisation and/or feed intake. This principle appears to hold for a wide variety of diets from fibrous cereal crop residues through to diets based on starches (barley) and sugars (molasses) (Preston & Leng, 1987) and is discussed extensively in Part 3.

Part 5

Modifying methane production

Part 5 outline: Two factors affect methane production per unit of digestible feed; these are microbial growth efficiency and the formation of propionate in the rumen. Higher production of either cells or propionate reduces methane production per unit of organic matter digested in the rumen.

Microbial growth efficiency is inefficient in animals fed on forage based diets, typical of those fed to ruminants in developing countries, and can be stimulated by nutrient supplementation. This reduces methane generation markedly.

Factors that limit the efficiency of microbial growth in the rumen are discussed. Ruminants fed low digestibility forages use this more efficiently when their protein status is improved by supplementation with a bypass protein.

Methane production per unit of production, therefore, can be ameliorated in practice by balancing the nutrient available from rumen fermentation with dietary protein that avoids fermentation.

The implications for the rates of methane production per animal or per unit of product of improving both feed conversion efficiency and growth rate are outlined.

Basically there are three approaches to increasing animal productivity from poor quality forages these include:

- ***supplementation to improve the animal's feed conversion efficiency***
- ***chemical treatment to increase digestibility of the basal forage***
- ***treatment plus supplementation.***

The theoretical effects of stimulating production of ruminants and methane production per unit of product are discussed in quantitative terms.

5.1 Stimulating rumen fermentative efficiency

5.1.1 Chemical manipulation

Manipulation of the rumen by the use of specific chemical additives to increase propionate production or microbial cell yield relative to acetate production, has generally resulted in relatively small responses in animal production but large decreases in methanogenesis (from 10–80%) (see Chalupa, 1980). Often there has been an increase in efficiency of feed utilisation rather than an actual increase in productivity. Depending on level of application, the chemical additives have tended to reduce rumen fermentation rates, at times allowing a greater proportion of the diet to pass to the lower digestive tract. Digested feed as against feed fermented does not give rise to methane. This is beneficial when the diet contains starch, but may be detrimental if the diet consists of refractory plant cell wall materials. In the latter case, increased methane production in the lower digestive tract will result in a higher proportion of the digested feed being converted to methane, because the microbial cells produced in the lower intestines are largely lost in feces.

Table 5.1: *Effects of ionophores (feed additives) on cattle performance in the USA (Chalupa, 1988)*

			Performance (% of control)		
Ionophore	Diet	trials	Intake	Gain	Intake/Gain
Monensin	Feedlot	19	94	102	92
	Feedlot	6	95	99	95
	Pasture	12	-	117	-
	Greenchop	3	98	123	85
	High forage	12	97	114	91
Lasalocid	Feedlot	16	96	103	94
	High forage	6	96	105	93
Salinomycin	Feedlot	5	98	106	90

5.1.2 Chemicals reducing methane emissions

Commercial enterprise has been motivated to produce chemicals with properties for propionate enhancement or methane inhibition in the rumen, because of the increased efficiency of feed utilisation improved the economics of feedlotting (even though this is quite small). The results on ruminant performance when some chemicals are fed in the diet are shown in Table 5.1. As can be seen from this table, by the addition of such chemical manipulators to a ruminant diet productivity is increased and as a consequence methane generation is reduced.

There is at least an indication that with halogenated compounds such as chloral hydrate that methane inhibition can be almost complete. However, while not yet completely understood, it appears that their action is not sustained: the microbes may adapt to the compound (See Chalupa, 1988).

Of note is that the mechanisms by which ionophores and halogens reduce methane generation are actually quite different. Ionophores reduce methane emissions in part by increasing feed efficiency. Additionally, they inhibit bacteria that produce hydrogen and are subsequently used by methanogenic bacteria. As a contrast, the halogens are believed to inhibit the methanogens directly. This inhibition may also reduce rumen digestion efficiency, which is counterproductive from a production standpoint.

In the developed countries, industry may need to be persuaded to develop highly effective chemicals agains methanogens and farmers may have to be persuaded to use these even where there is no economic advantage.

5.1.3 Improving efficiency of microbial growth

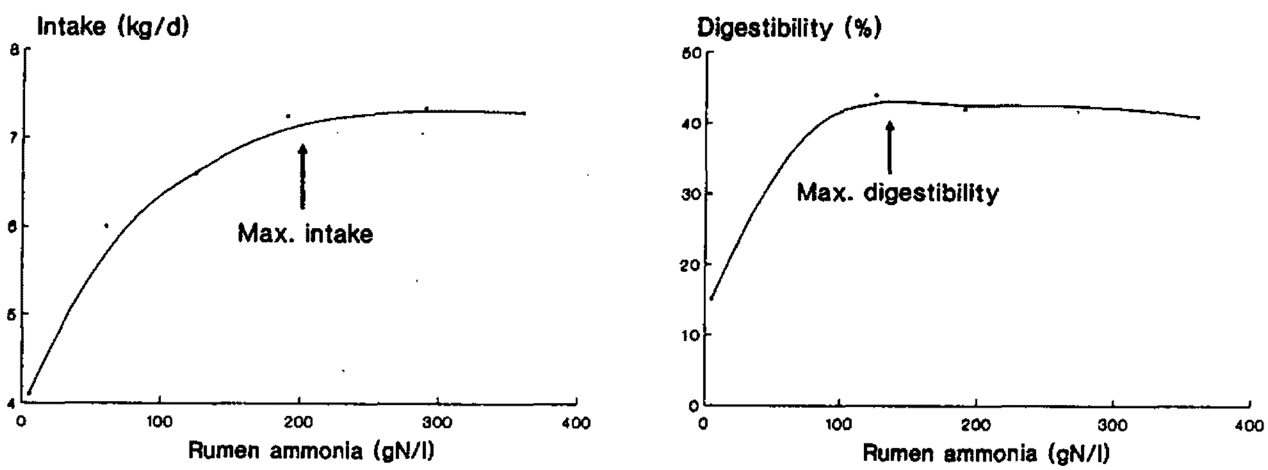
Most forages fed to ruminants in the tropics can be deficient in nitrogen, sulfur, trace minerals and often phosphorus and sodium. Ammonia, sulfur and phosphorus are the most likely deficient nutrients for rumen microbes.

The following have all been found to increase microbial protein availability to ruminants fed forage based diets (and therefore increase P/E ratios):

- supplementation with urea/sulfur
- supplementation with slowly degraded protein which provides amino acids/ peptides for rumen microbes
- elimination of rumen protozoa (see Bird & Leng, 1984)
- increasing rumen digesta turnover, which decreases residence of digestion and bacteria have a lower maintenance requirement.

The first three methods of improving the efficiency of microbial growth have been demonstrated in the animal, whereas the fourth is rarely feasible in practice.

Figure 5.1: *Requirements for ammonia to maximise fermentative digestion in the rumen and optimise intake of a low quality roughage (Perdok* et al.*, 1988). Urea was infused continuously into the rumen to provide a constant supply of ammonia*



5.1.4 Supplying deficient micronutrients for microbes

It has been accepted that the optimum levels of ammonia in the rumen for maximum digestion was about 50–60mg N/litre. However, in recent studies, increasing rumen ammonia levels by infusing urea into the rumen, increased digestibility of straw in cattle until ammonia levels reached 80mg/litre. Feed intake continued to be stimulated until NH_3 levels reached 200mg NH_3/litre (Figure 5.1, see also Boniface *et al.*, 1986). This indicates that the amount of urea required in straw based diets has been underestimated in the past.

Ammonia in the rumen can be supplied along with a number of potentially deficient microbial nutrients by:

- supplying a mixture of molasses (a concentrated plant juice) and urea in the feed;
- feeding chicken manure;

- providing a molasses/urea block lick (MUB);
- providing a source of soluble protein as a forage (e.g., alfalfa) or grain (e.g. lupins, peas, beans)

In most developing countries the first three are feasible but the last is rather wasteful (as protein is fermented) and requires land for production of forage reducing that available for cropping—a better approach that is presently emerging is the use of tree forages for this purpose.

In most developing countries, protein is a scarce commodity and its most useful role will be promoted if the protein is protected from rumen fermentation. This can be achieved by a number of manufacturing processes (see Part 6).

5.1.5 Provision of small quantities of true protein

Although there is a strong body of opinion that supports the concept of a need for amino acids/peptides for efficient microbial growth in the rumen, little evidence from whole animal studies is available that supports this concept. However, recent studies have shown that diet is all important in determining whether the rumen microbes need peptides/amino acids. Microbial growth on sugar and starch, but not cellulose, is stimulated by protein in the incubation media, indicating that there is a low requirement for protein fermentation in the rumen of forage fed cattle.

In theory, the energy cost of microbial protein synthesis is largely associated with formation of the peptide linkages and assimilation of ammonia in amino acids is independent of ATP supply. However, strategies (to be discussed) for feeding a bypass protein, some of which will be inevitably degraded in the rumen, adequately cover this aspect.

5.1.6 Controlling rumen protozoa

Although there has been considerable controversy on the role of rumen protozoa, it seems to be now accepted that protozoa account for the turnover of a large proportion of the bacterial pool in the rumen. They also increase the degradation of dietary protein in the rumen (see reviews in Nolan, Leng & Demeyer, 1989).

The removal of protozoa from the rumen and the maintenance of the unfaunated state may increase microbial cell outflow from the rumen by 25–50%. In turn this will reduce methanogenesis per unit of carbohydrate fermented by approximately 25% (see Table 4.1). The improved protein to energy ratio in the nutrients arising from rumen fermentation increases the efficiency of feed utilisation and decreases the feed required per unit of live weight gain, further reducing methane production per unit of meat or milk production.

The control of rumen protozoa is not feasible at present, but pharmaceutical companies are actively screening chemicals for this purpose. In the author's laboratory a natural forage has been found, which, in small quantities, will eliminate protozoa from the rumen and trials are already underway to test practical strategies for control of rumen protozoa.

5.1.7 Overall effects of improving microbial growth efficiency

Undoubtedly, on poor quality forages, the effect of providing critical nutrients for microbes in the rumen is to increase microbial growth efficiency and digestibility. In tropical areas, or where animals are under heat stress, feed intake is also increased (Leng, 1989*a*). The overall effect is to increase the efficiency of fermentative digestion which decreases methanogenesis per unit of carbohydrate degraded, but it may increase methanogenesis per animal. On the other hand the animal grows with less feed/unit of growth, reaches maturity at an earlier time and feed requirement per unit of liveweight gain is markedly reduced.

The conclusion is that whilst methanogenesis is reduced per unit of feed digested, the methane produced by the animal is increased. On the other hand this is the first step in improving the efficiency of animal production (see later) and reducing overall feed requirements per unit of liveweight gain or milk production.

5.2 Stimulating animal production rate

Increased production per animal and turnoff at an earlier age will have a much greater effect on total methane production than reduction of methanogenesis in digestion of individual animals (see Section 5.3). It is imperative that productivity per animal is stimulated by all means possible to eventually approach genetic potential. However, where individual animal production rates are increased it will be essential that animal numbers are decreased in order to realise the large decrease that can be achieved in methane production. This presupposes that human requirement for animal products (or the market requirements) can be saturated.

5.2.1 General

Animal production rate is a composite of a number of functions and includes:

- age at puberty
- reproductive rate and between pregnancies interval
- survival rate
- growth rate, milk production etc.

Methods for increasing production from roughage based diets include:

- supplementation to ensure an active and efficient fermentative digestion
- supplementation to increase the efficiency of nutrient utilisation of the basal forage
- supplementation to provide nutrients for milk production in a total bypass form
- treatment of forage to improve its digestibility
- manipulation of the rumen to ensure high digestibility and a high microbial growth efficiency.

5.2.2 Supplementation

It is now well established that moderate to high levels of production can be achieved in ruminants given low quality pasture or straw based diets by providing minerals and urea and optimal inputs of a protein that escapes fermentation in the rumen but which is digested in the intestines to augment the nutrients arising in the rumen.

The key roles of supplements (Leng *et al.*, 1987) may be summarised as follows:

- urea increases the efficiency of fermentative digestion in the rumen stimulating digestibility and feed intake.
- urea supplementation through its effects on fermentative digestion ensures sufficient nutrients in balanced amounts to allow the birth of a viable calf or lamb.
- supplementation with a protein meal that largely bypasses rumen fermentation in addition to urea has the following effects. It provides a better balance of nutrients to the animal and increases live-weight gain and efficiency of feed utilisation in (i) young animals, (ii) pregnant ruminants and (iii) lactating animals. In young animals age at puberty is decreased by strategic supplementation with a protein meal during the dry season or on straw based diets.

  It markedly increases conception rate and, by implication, decreases intercalving interval in mature cows with calves at foot and grazing.

Supplementation of genetically high yielding cows given tropical forages and/or straws with a MUB plus a 30% protein meal rich in bypass protein at a rate of 350 g/litre of milk has resulted in milk yields closely similar to that of cows on concentrate based diets in developing countries (NDDB report, 1988).

Cattle (and buffaloes?) that are subjected to periods of low nitrogen nutrition during their early life may be stunted permanently so that their mature weight is often 100 kg less than that of animals that have received bypass protein during these periods.

5.2.3 Treatment of forages to improve digestibility

A variety of physical and chemical treatments can be used to increase the potential rate and extent of degradability of fibrous feeds (see Sundstøl & Owens, 1986). The principal methods use strong alkalis, of which the most widely studied is sodium hydroxide. While this chemical is highly effective in increasing digestibility of, for example, straw, the disadvantages (high cost, pollution through accumulation of sodium ions and the dangers to people and animals due to its corrosive nature) do not allow it to be applied in developing countries. It can be economic for the treatment of bagasse (the fibrous by-product of sugarcane) to produce a cattle feed, where bagasse has a negative economic value because it has to be disposed of from the sugar mills.

There has been much greater acceptance of the use of ammonia to treat and improve straw utilisation by ruminants. Ammonia can be used as gas, as ammonium hydroxide solution, or by generation from urea by bacterial activity during the ensiling of straw at high moisture content.

Hydrochloric acid (especially in gaseous form) and sulfuric acid or sulfur dioxide have also proved to be effective chemicals for treating straw to improve its digestibility. Sulfur dioxide combined with ammonia appears to be the treatment that has most potential for increasing digestibility of straw and has been used with high pressure steam to take straw digestibility up to 80–90% (Ben Ghadalia *et al.*,1988). However, feed intake is reduced by excessive amounts of sulfur. The use of gaseous ammonia and sulfur dioxide could have advantages where high feed intakes are not desired e.g., when cattle and sheep are on sub-maintenance feeding or under drought conditions.

A novel method of using acid hydrolysis is through high-pressure steam treatment, especially with agro-industrial byproducts such as bagasse. Steam at high temperature liberates acetic acid, which hydrolyses the lignin-carbohydrate linkages. The technology has only limited application, for example as in sugar mills, where high pressure steam is usually available at little cost and where the bagasse is also produced and must be disposed of without pollution. As indicated in Figure 5.2, treatment of low digestibility forages improves the rate of animal production, particularly when strategic supplements are also given (Perdok *et al.*, 1988; Wanapat *et al.*, 1986) (see also Table 6.3).

Unfortunately, despite the widely reported effects on cattle productivity of treating crop residues to increase their digestibility, even with the support of well-funded aide programs, there has been a total lack of acceptance of this technology by small farmers in developing countries. The reasons for this are many and varied, but it appears that there is no probability of wide-spread application of straw treatment.

5.3 Improved animal production rate and methane production

5.3.1 Growth rate and methane generation

Improvements in the efficiency of utilisation of metabolisable energy through supplementation of poor quality forage based diets fed to ruminants have been remarkably high. The results of experiments with cattle in which straw or straw treated to improve its digestibility have been supplemented with protein meals indicate that the traditional approach of predicting animal production from ME content of a feed (i.e., M/D in MJ/kg feed) has been highly misleading (this is not accepted by some scientists). This is illustrated when idealised growth efficiency (g gain/MJ ME intake) is related to ME content of a feed (Figure 5.2). The data generated in trials examining response relationships for cattle fed straw and supplemented with protein meals are also shown in the same figure. The latter trials were carried out in hot climates whereas the traditional model depicted in the figure is based on research in temperate countries.

The differences in efficiency of animal growth between the temperate country standards and the results obtained in practice where cattle fed straw have been supplemented with protein are due either to a lower demand to oxidise nutrients for maintenance of body temperature by cattle in the tropics or the "metabolisable energy system" has not recognised a large heat increment in the estimates of basal heat production (see Leng, 1989*b*).

Taking these data for production of cattle on straw based diets, some estimates of the likely reduction in methane production in response to supplementation can be calculated from the model given earlier.

Figure 5.2: *Schematic relationship between diet quality (metabolisable energy MJ/kg dry matter) and food conversion efficiency (g liveweight gain/MJ ME) (- - -) (from Webster, 1989). The relationships found in practice with cattle fed on straw or ammoniated straw or poor quality hay with increasing level of supplementation of protein meals that bypass rumen fermentation. Australia (◇, ○, ●) (Perdok* et al., *1988); (■, ▲) (Hennessy* et al. *(1983); Hennessy* et al.,*1989), Thailand (△) (Wanapat* et al., *1986) and Bangladesh (□) (Saadullah, 1984) This illustrates the marked differences that result when supplements high in protein are given to cattle on diets of low ME/kg DM*

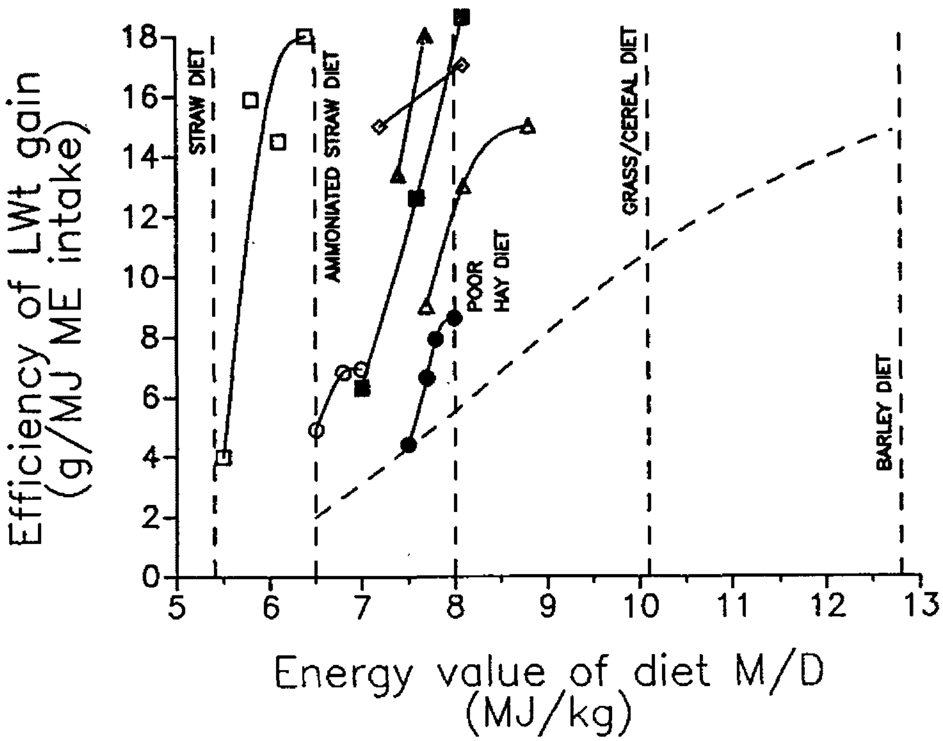
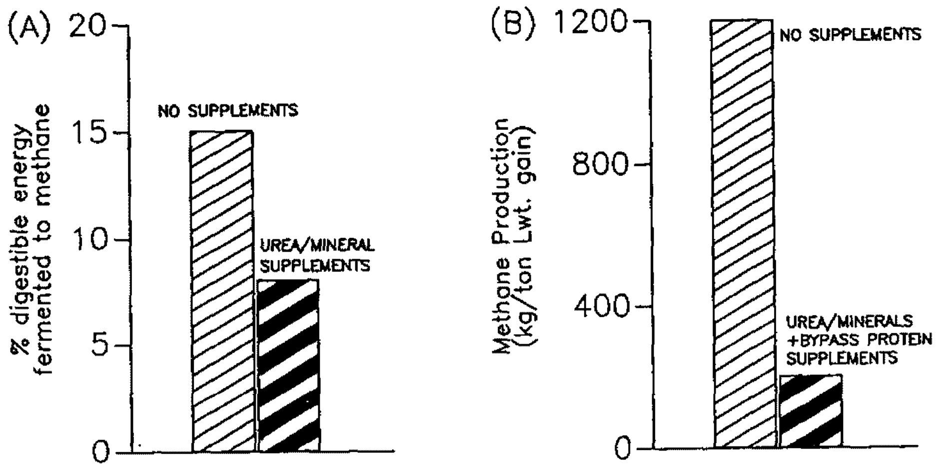


Figure 5.3: *(A) The effects of improving the efficiency of rumen fermentative activity on methane production per kg of digestible energy consumed.*

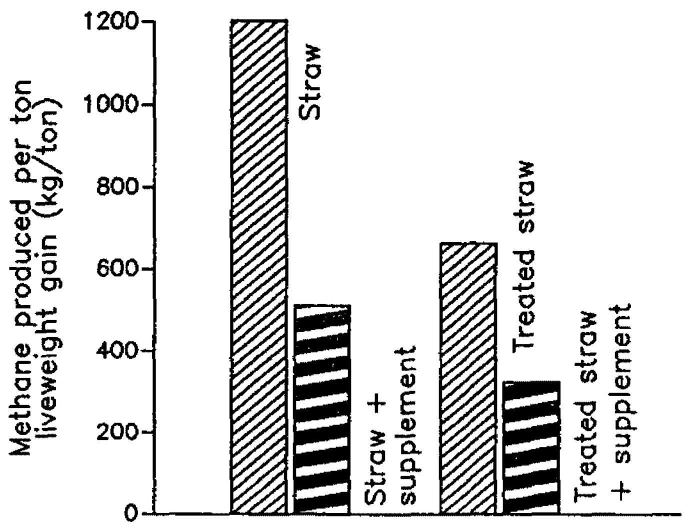
(B) The production of methane per kg gain in supplemented cattle (feed conversion efficiency (FCR) 9:1) or unsupplemented cattle (FCR=40:1) fed straw based diets (after Saadullah, 1984)



The assumptions are that without urea and bypass protein supplements to cattle the efficiency of rumen fermentation of straw dictates approximately 15% of the digestible energy is channeled into methane and about 7% when the rumen is efficient. In the calculations of Crutzen *et al.* (1986) they assumed that dairy cows (feed digestibility 75–80%) produced 5.5% of the gross energy intake as methane for young animals (feed digestibility 65–70%) this became 6.5% whereas for cattle on low quality forage (digestibility 45–55%) the value was 7.5%. Thus the values used by Crutzen would indicate 7, 12 and 19% of the digestible feed energy consumed by cattle in each of these categories was lost as methane.

In the studies reported by Saadulah (1984) from Bangladesh, cattle were fed straw and straw supplemented with 600 g of an oilseed cake. In this case the FCR was approximately 40:1 on a non-supplemented diet and 9:1 when supplements were given. The methane generated per unit of digestible energy or per unit of liveweight gain is shown in Figure 5.3.

Figure 5.4: *Effects of supplementation and straw treatment on the kg methane produced for each kg gain in cattle fed straw that was untreated or treated with ammonia to improve its digestibility. The results are from experiments published by Perdok* et al., *1988*



The effects of straw treatment to improve digestibility and supplementation on methane generation are shown in Figure 5.4. The data in this case were generated in a temperate climate (Perdok *et al.* 1988). The relationship between the metabolisable energy content and the efficiency of growth per unit of methane production is shown in Figure 5.5 and is calculated from the data given in Figure 5.2.

Because there are a number of assumptions made in calculating these values, the total amounts of methane produced will have a large standard deviation depending on a number of factors. The values for methane production are meant to convey the potential for reduction of methane generation by supplementation to improve fermentative digestion and by supplementation and straw treatment to improve efficiency of feed conversion.

Figure 5.5: *Relationship between the metabolizable energy content of a feed (M/D, MJ/kg) and the theoretical methane produced per kg gain. The relationship shown by a broken line is based on the metabolizable energy system in practice in UK (Webster, 1989). The relationship indicated are results from the studies of Perdok* et al., *1988 (◇, ○, ●); Hennessy* et al., *1983, Hennessy* et al., *1989 (■); Saadullah, 1984 (□) and Wanapat* et al., *1986 (△) in which cattle fed straw, straw treated to improve its digestibility or poor quality hay were supplemented with increasing levels of bypass protein. (The data are calculated from Figure 5.2.) Methane produced per unit of gain was lowest when the efficiency of liveweight gain had been stimulated by feeding bypass protein.*

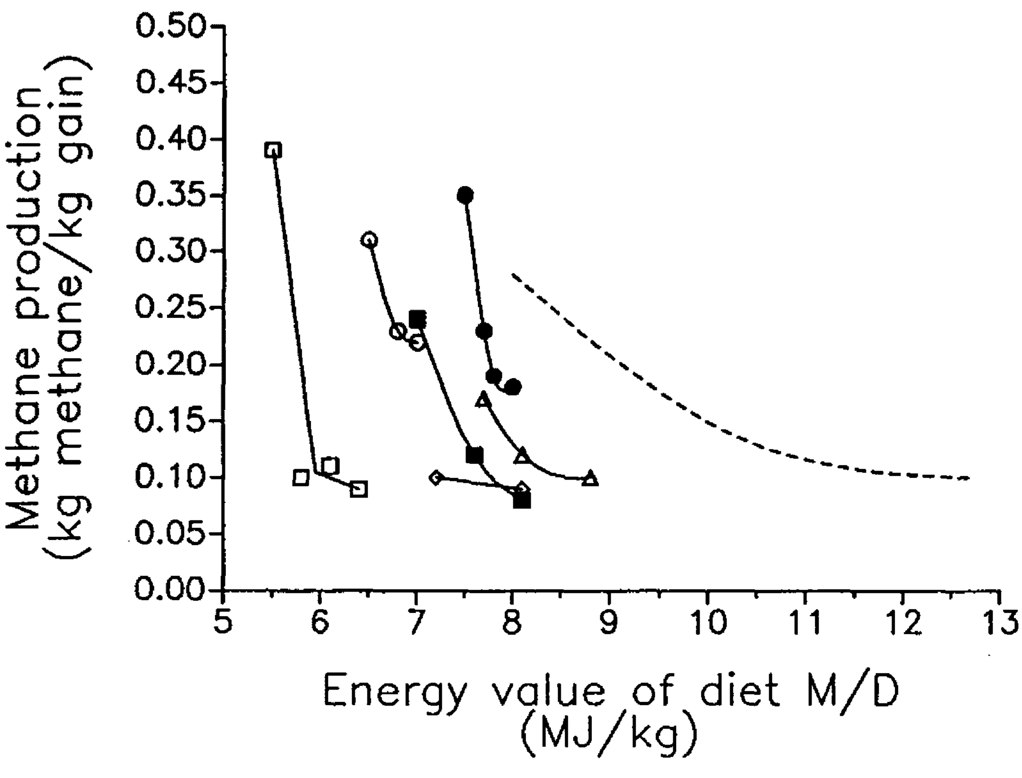


Figure 5.6: *Calculated amounts of methane produced per unit of milk production in unsupplemented (fed traditionally) or supplemented (new feeding systems) cows in India with moderate levels of production. The methane generated (g) per kg milk is also shown for high yielding cows in developed countries (fed traditionally) or high yielding cows in India fed tropical forage with molasses urea block (MUB) + 350 g/d bypass protein per liter of milk production.*

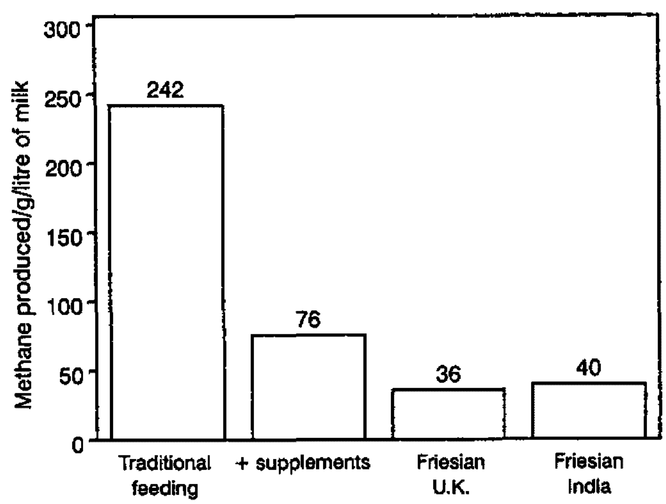
The values represent the methane generated from feed consumed during the lifetime of the cow in relation to the lifetime's milk yield. The assumptions associated with this figure are tabulated.

	Case Study			
	1	2	3	4
Mature weight (kg)	400	400	600	600
Time of first calf (years)	5	3	2	2
Intercalving interval (years)	2	1.5	1	1
FCR* (kg/kg LWt gain)	30:1	15:1	8:1	8:1
Forage consumption (% LWt)	2.5	3	4	4
Digestibility of feed (%)	50	50	65	65
Methane (% Dig. Energy)	15	11	11	11
Life span (years)	13	13	5	8
Number of lactations	4	6	3	6
Lactation yield (tons/year)	1	2.5	6	6

*FCR = Feed conversion ratio (from weaning to first calf)

Case studies:

1. Traditional feeding with native cattle/buffalo in India.
2. New feeding system using MUB/bypass protein with native buffalo in India.
3. Friesian-Holstein fed high quality forage/concentrate in developed countries.
4. Friesian-Holstein fed tropical forage/MUB/bypass protein in India.



5.3.2 Milk production and methane generation

Recent research by Kunju (1990) has shown that when strategic supplements are provided to lactating animals, a marked increase in the efficiency of conversion of feed to milk is also apparent. This research, carried out in India, clearly suggests that at low levels of milk production the requirements for metabolisable energy and hence feed are reduced when the feeding strategy emphasises the balanced nutrient approach. Milk was produced at 16–50% of the feed costs accepted under traditional feeding methods. The results of a trial to establish response relationships to feeding protein concentrate to lactating animals is shown in Table 5.2.

Methane production per litre of milk can be calculated using some rules of thumb. In the calculations made in this presentation the feed conversion to milk is calculated from the feed required to grow the animals to first lactation and the feed utilised in its adult life. The calculated data are shown in Figure 5.6.

5.4 Strategic supplementation and the target groups

A total supplementation package consisting of a multinutrient block plus a bypass protein feed needs to be applied to ruminants fed relatively poor quality forages/pastures.

The target groups of large ruminants for this strategy include the following:

1. Cattle/buffalo in developing countries:
    - fed crop residues or cut/carry grass and agro-industrial byproducts
    - grazing in areas with monsoonal climates in the tropics, particularly in the dry season
    - grazing tropical grasslands on infertile soils (e.g. Los Llanos, Colombia; Brazil and the Pampas, in Argentina)

Table 5.2: *Milk yield corrected to 4% fat (i.e., FCM) and liveweight change (LWt) are shown together with the requirements for bypass protein (BP) and metabolisable energy (ME) in relation to their availabilities from the feed.*

LWt change (kg/d)	Milk yield FCM (kg/d)	MUB intake (kg/d)	Supplem. intake (kg/d)	BP (kg/d) Req*(a)	BP (kg/d) Avail**(b)	BP (kg/d) a/b	ME (MJ) Req (a)	ME (MJ) Avail (b)	ME (MJ) a/b
A. Buffaloes									
0.03	5.2	0.44	0	0.19	0.01	0.07	75	37	0.49
0.14	6.6	0.33	1	0.43	0.20	0.46	88	48	0.55
0.27	7.3	0.28	2	0.48	0.41	0.85	96	59	0.61
0.28	7.7	0.27	3	0.50	0.61	1.22	100	71	0.71
0.38	7.3	0.24	4	0.52	0.80	1.54	100	84	0.84
B. Cows									
-0.11	5.5	0.58	0	0.19	0.02	0.11	71	38	0.53
-0.13	7.5	0.39	1	0.28	0.20	0.71	84	47	0.56
0.16	7.8	0.36	2	0.48	0.41	0.85	96	58	0.60
0.29	8.5	0.46	3	0.53	0.61	1.15	105	71	0.68
0.09	8.0	0.31	4	0.52	0.80	1.54	100	84	0.84

* Required according to NRC feeding standards

** Availability calculated assuming that rice straw has ME content (M/D in MJ/kg DM) of 5, the protein concentrate M/D 11.5 and the MUB M/D 5.

2. Cattle in the developed or industrialised countries:

   - fed agro-industrial byproducts (e.g. molasses, sugar beet pulp or pineapple waste)
   - fed relatively low-protein grain based diets in feed lots (e.g. sorghum and whole maize cobs)
   - grazing relatively poor pastures in semi arid grazing areas (e.g. parts of the Southern United States and Northern Australia)

5.5 Conclusion

The technology for improved animal production on low quality feeds is available, the resources for implementation of new nutritional strategies are also usually available. However, there is a long time lag in acceptable. This time-lag is largely due to institutional, political and sociological constraints and these are the major limitations which are preventing their application to increasing livestock production in developing countries.

It is possible that even in developed (temperate) country conditions, widespread use of protein supplements may allow a reduction in the dependence on grain based concentrates or even increase production levels where these are below the average for a country and so reduce methane production per unit of product.

Part 6

Strategic supplementation of cattle and buffaloes in India

Part 6 outline: Strategies that can be used in practice to stimulate feed conversion efficiency of large ruminants in India are discussed. These include supplementing cattle (buffaloes) on crop residues with molasses urea multinutrient blocks (to stimulate rumen microbial activity) and with bypass protein to stimulate the efficiency of feed utilisation per unit of product (milk) formation.

The background research and demonstration trials undertaken in India are reviewed.

The effects of such feeding strategies on growth, age at first calving and lactational yield all indicate that productivity can be stimulated many fold.

The effects of introducing these feeding systems in India to cattle and buffalo in villages covered by a major milk shed is reported. In this milk shed, milk production increased by about 50,000,000 kg (or 30%) in 1989 when these strategies were introduced, as compared to the previous two years.

6.1 Introduction

Feeding systems based on an inexpensive (and available) basal carbohydrate resource such as a crop residue or pasture supplemented with a multinutrient/minerals block and a protein meal rich in bypass protein, have major implications for increasing productivity of cattle/buffaloes in many tropical countries.

There is, however, a natural reluctance particularly of smallholder farmers to use feeds containing urea, because its mis-application can easily lead to death of a cow from ammonia toxicity.

The use of bypass protein meals to increase feed conversion efficiencies, although scientifically established, is only beginning to be applied. The reason for this is associated with the uncertainty of the content of bypass protein in the protein meals that are locally available.

The NDDB of India recently commenced the production of a 30% bypass protein meal in one major feed mill (Amul) and this is rapidly expanding to all 28 mills controlled by the NDDB. Estimated production at the time of writing is about 400 metric tons per day, but trials from a number of mills have raised the daily production rate of bypass protein pellets to in excess of 500MT/day.

6.2 Molasses/multi-nutrient blocks

The National Dairy Development Board (NDDB) of India has successfully introduced multi-nutrient blocks based on molasses/urea for lactating buffaloes and cows under village conditions to meet the need of these animals for fermentable-nitrogen (urea), minerals, and growth factors for rumen microbes such as amino acids and possibly peptides normally deficient in diets based on crop residues. Multi-nutrient block-licks (MUB), based on molasses/urea, have increased the intake and growth of cattle on straw based diets (Table 6.1). Some idea of the block, its commercialisation and its application can be seen in Figures 6.1 and 6.2. Under village conditions providing cattle and buffaloes with blocks has led to substantial increases in milk yield and milk fat percentage (Table 6.2). The average increase in milk yield of buffaloes and cows when MUB is introduced into

Table 6.1: *Intake of rice straw and growth rate of Jersey bulls (350 kg liveweight) given 1 kg of concentrate with or without access to a urea/molasses block (see Kunju, 1986)*

	Straw intake (kg/d)	Intake of block (g/d)	Livewt. change (g/d)	Total feed costs (Rupees/d)	Feed costs per kg gain (Rupees/kg)
Straw + 1 kg concentrate	6.4	0	220	2.0	9.3
Straw + 1 kg concentrate + block	6.8	530	700	2.6	3.7

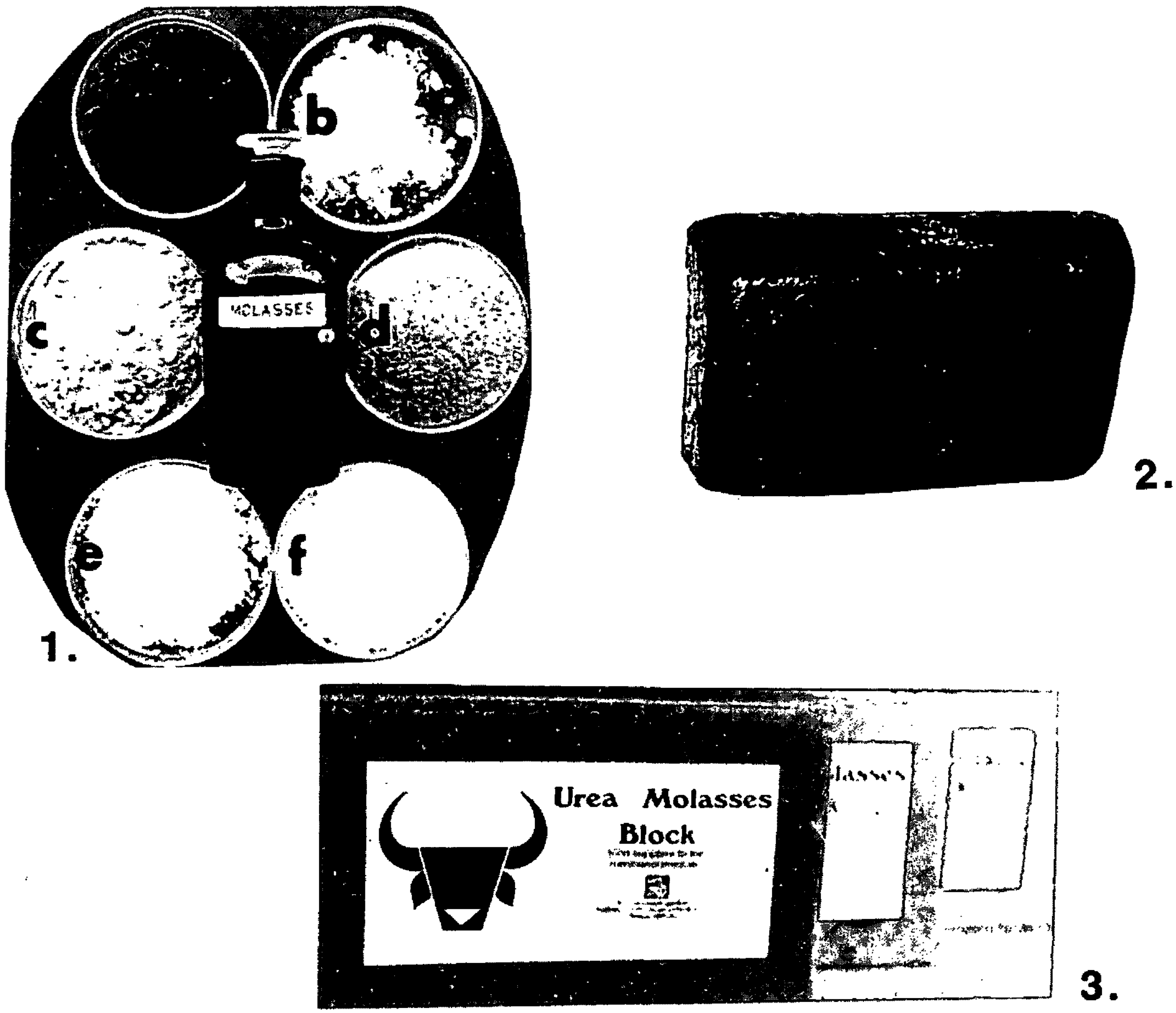
a traditional system is around 0.5 litres/day indicating the block-licks corrected a widespread deficiency of nutrients in the diets normally fed to cattle and buffalo in village situations. Figure 6.2 illustrates the method of presentation of MUB to milch animals under village conditions.

6.3 The use of bypass proteins in India

6.3.1 Research with bypass protein

When digestibility of straw is increased by chemical treatment and strategic supplements are given, growth rates of cattle approach the level that is supported by medium quality pasture; but the efficiency of feed utilisation is much higher than that of cattle fed unsupplemented hay. The effects of straw treatment and supplementation are illustrated by the studies presented in Table 6.3 and also in Figure 5.2. The efficiency of productivity of cattle on straw based diets (g liveweight gain/MJ ME) supplemented with MUB and a bypass protein feed are higher than temperate country standards would predict.

Figure 6.1: *Colour plates to illustrate the ingredients of the molasses urea blocks, the manufacturing plant, block in slab form and ready for sale (Kunju, 1989)*



1. Ingredients with their % content in the block:
   a.cottonseed meal (10%), b.salt (8%), c.mineral mix (15%), d.bentonite (3%), e.calcite powder (4%) f.urea (15%), molasses 45%
2. Block as manufactured. 3. Packaged block for sale.

Figure 6.2: *Colour plates to illustrate the method of presentation of MUB to cattle and buffaloes.*

A: Cattle in Indian village. 1. Small farmer condition, bowl being used as a receptacle for the block. 2. Large farmer condition, plastic containers attached to the wall of the shed.
B: Buffaloes under institutional management, blocks without holders simply placed on a concrete slab.

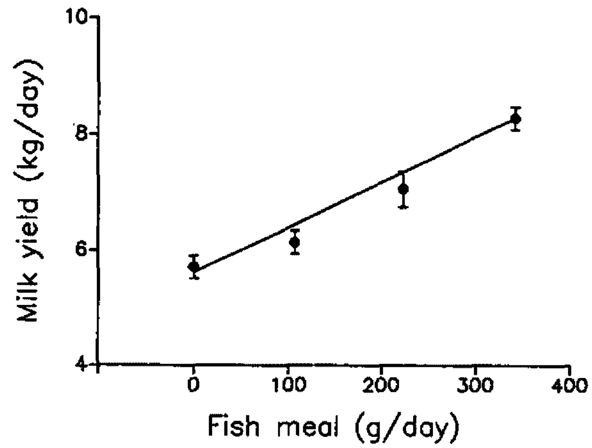
Table 6.2: *Average milk and milk fat sold per buffalo before and after the introduction of molasses/urea blocks into villages in the Kaira Milk Producing Union Ltd., Anand, India*

	Average milk sold (kg/d/animal)		Fat (g/d)	
Village	Before (no block)	With block	Before (no block)	With block
Alwa	4.8	5.9	330	450
Punadhara	4.0	4.8	270	340
Fulgenamuwada	2.4	3.5	160	280
Hirapura	4.2	5.2	350	480
Banroli	3.6	4.2	270	380
Dehgam	4.3	4.7	310	350

Source: Kaira District Co-operative Producers' Union Ltd., Anand, India. (Kunju, 1986)

Milk yield of native and crossbred cattle fed ammoniated (urea-ensiled) rice straw supplemented with fish meal (range was 0–400 g/d) (from Saadullah, 1984) are shown in Figure 6.3. The results of this experiment clearly indicate the improvements possible in milk yield of exotic animals of high genetic potential. More recent applied results from milk production systems based on low quality forages and protein meals are shown in Table 6.4.

Figure 6.3: *Effects of increasing supplement levels (fish meal—a recognised bypass protein) on milk yield of cows fed ammoniated straw (i.e., treated to increase digestibility) (Saadullah, 1984)*



6.3.2 Dairy husbandry activities

The improved production that can be achieved by superior feeding and breeding can be seen by recent practical results of feeding trials conducted on one of the farms managed by the NDDB of India (Sabramati Ashram Gaushala, which was founded in 1915 by Mahatma Gandhi as part of the Haryan Ashram at Ahmedabad.) The major aim of the Gaushala, besides multiplication of high yielding milch animals, is to enhance the productivity of land and milch animals by harnessing the latest technologies in the field of animal husbandry and agriculture.

The Gaushala has had a herd of Jerseys and has been cross breeding these with the local breed—Kankrej (Zebu), and more recently has introduced Holstein-Friesians from Germany.

The dairy animals are zero-grazed and fed on a good quality green fodder, hay, silage and rice straw depending on season. These animals are also fed a 'bypass protein meal' proportionate to their body weight, growth potential, pregnancy status and milk production. A molasses/urea multinutrient block is always available and experience suggests that the cattle only use this when they need extra non-protein nitrogen. Diseases are controlled by vaccination and the herd is free of Tuberculosis, Johne's disease and Brucellosis. A regular culling of poor quality animals or low productive animals is carried out.

Figure 6.4: *Average 305 d lactation yield of different breeds of cattle in the first five lactations. The animals were all fed a tropical forage supplement with MUB/bypass protein (Source: Annual Report, Sabramati Gaushala, 1987–88 NDDB Anand*

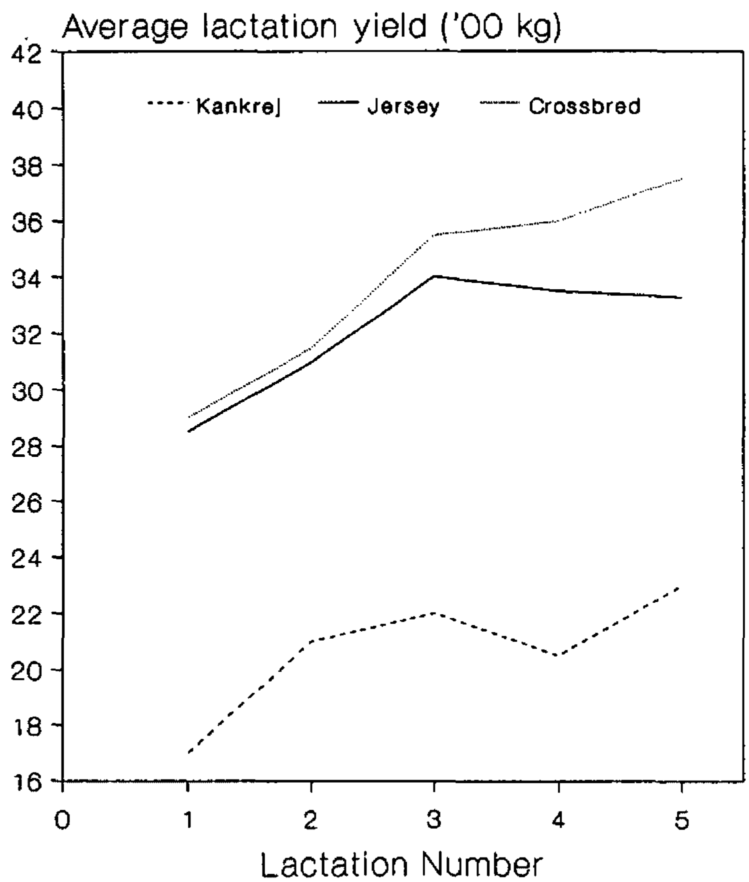


Table 6.3: *A comparison of liveweight change of cattle (320 kg) when given treated or untreated rice straw plus molasses/urea block (15% urea) to supply fermentable-nitrogen and with 0.6 kg rice pollard to supply small amounts of starch and lipid and various levels of a bypass protein meal (Perdok* et al.*,1988)*

Straw preparation	Supplement (protein meal) (kg/d)	Growth rate (g/d)
None	0	38
	0.4	365
	0.8	292
	1.2	306
Treated with 3% NH_3 gas	0	236
	0.4	497
	0.8	601
	1.2	639

The point is that with these management strategies, milk production, age at first calving and reproductive rate have equalled those of cattle in developed countries, but using only forage based diets supplemented according to the principles explained by Preston & Leng (1987) i.e. molasses urea blocks and high bypass protein (30% CP) meals based on oilseed meal residues and rice pollard.

Virtually no grain is fed (only 10% grain is included in the bypass protein to promote a 'good' pellet). Yields of milk from the two pure breeds and the crossbreds are shown in Figure 6.4. The average milk yield of the recently introduced Friesians in their first 305 day lactation is around 5000 litres/300 d.

Table 6.4: *Some practical results from commercial milk producing systems where feed resources are based on forages (Leng, 1989*b*)*

Basal feed	Supplements	Milk production
1. Tropical grass/maize silage or other crops plus 1–2 kg rice straw/day (Fresian-Holstein)	Free choice mollasses/urea blocks + protein pellet (30% CP) (350 g/kg milk)	5,000–6,500 kg/305 d
2. Rice straw/millet straw (8 kg/d) (crossbred Jersey x Kankrej)	Bypass protein pellet 300 g/kg milk	25 litres/d (at 3 months)
3. *ad lib.* mixture of cottonseed hulls (46%); molasses (17%); cottonseed meal (18%); sesame seed meal (15%); crude lecithin (4%) and 10 kg freshly harvested kikuyu grass (2 kg DM/d) (Friesian)		6,200 kg/300 d (2nd calf cows) 5,700 kg/300 d (1st calf heifers)
4. Cane tops (50% more than daily intake) + cut carry grass as available (Crossbred cows)	Cottonseed meal 250 g/kg milk	2,800 (4)

References: (1) NDDB, Anand Bull Mother Farm (Kurup, M. P. J. pers. comm.) (2) Personal observations—in village system one animal only (3) C.E. Payan, V. (pers. comm.) Aceitales S.A. Calle 12 Apartado Aero 3840 Bogota, Colombia (4) Ramjee *et al.*,(1988) The age at first calving is shown in Figure 6.5. The native breed (Kankrej) even when fed well did not calve until 4 years of age as compared to 18 months for the pure breed and about 2 years in the crossbred.

An elite herd of Murrah buffaloes has also been established with 305 day milk yields of 3000–4500 litres and an on average fat percentage of 6–9% (see Annual Report 1987–88, Sabarmati Ashram Gaushala National Dairy Development Board, Anand, India).

6.4 Conclusion

Research and demonstration trials have indicated the huge potential increases in animal productivity that may result from improved nutrition at the village level in India. When the principles were also applied to institutional-herds of animals with high genetic potential the improvements of milk yield were much higher than anticipated. This indicates that at the village level the maximum milk yields obtained with supplementation were primarily constrained by genetic potential of the animal and not by sub-optimal nutrition. Thus there is enormous potential to improve milk production by a combination of feeding and breeding (the assumption being made that disease is controlled).

6.5 Case study: application of strategic supplementation

The compounding Feed Mill at Amul (Kiara district), (the largest feed mill in India), changed from the production of concentrates to the production of a high-protein pellet on December 1st 1988, after substantial in-village trials had clearly demonstrated the superiority of the high protein feed.

The conversion was marked by considerable unrest at the village level, but after a period of one to two months the farmers of the Kiara district appear to be convinced of the value of the new feed, which is approximately 50% more expensive but is recommended to be fed at half the rate of the previous concentrate.

Figure 6.5: *Age at first calving of cows of different breeds fed tropical forages and supplemented with bypass protein and MUB according to their needs (NDDB report—Sabarmati Ashram Gaushala, 1987). Kankrej is a local cattle breed (*Bos indicus*)*

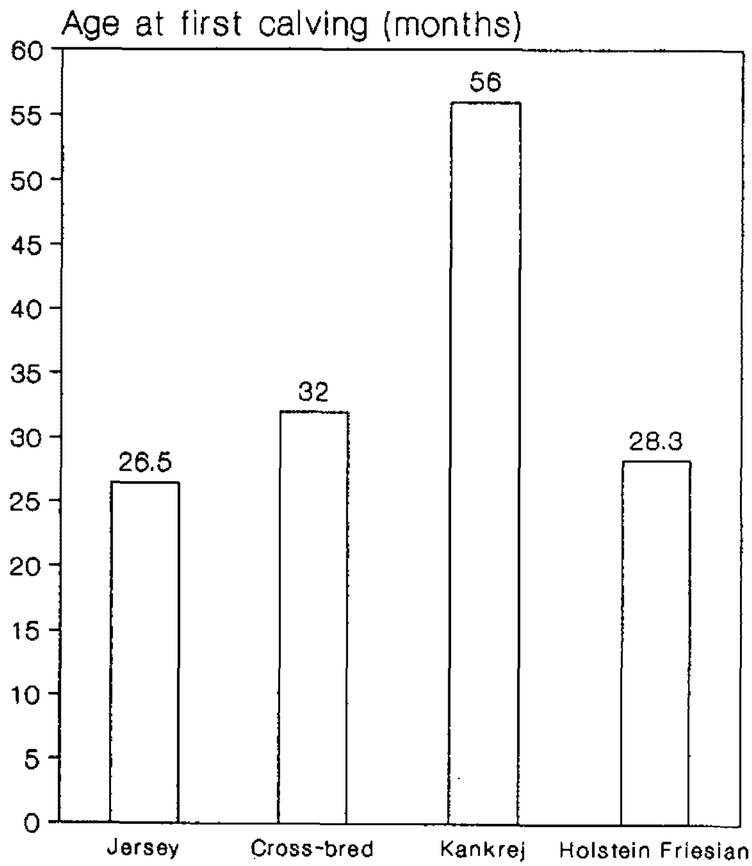


Figure 6.6: *A case study of the implementation of feeding strategies for large ruminants based on bypass protein (commencing Dec 1st, 1988) (NDDB records). In the Kiara district, Anand, India, there are some 18,000 crossbred cows (70% in milk), 55,000 indigenous cows (55% in milk) and 350,000 buffaloes (40% in milk) (Kunju, 1989).*

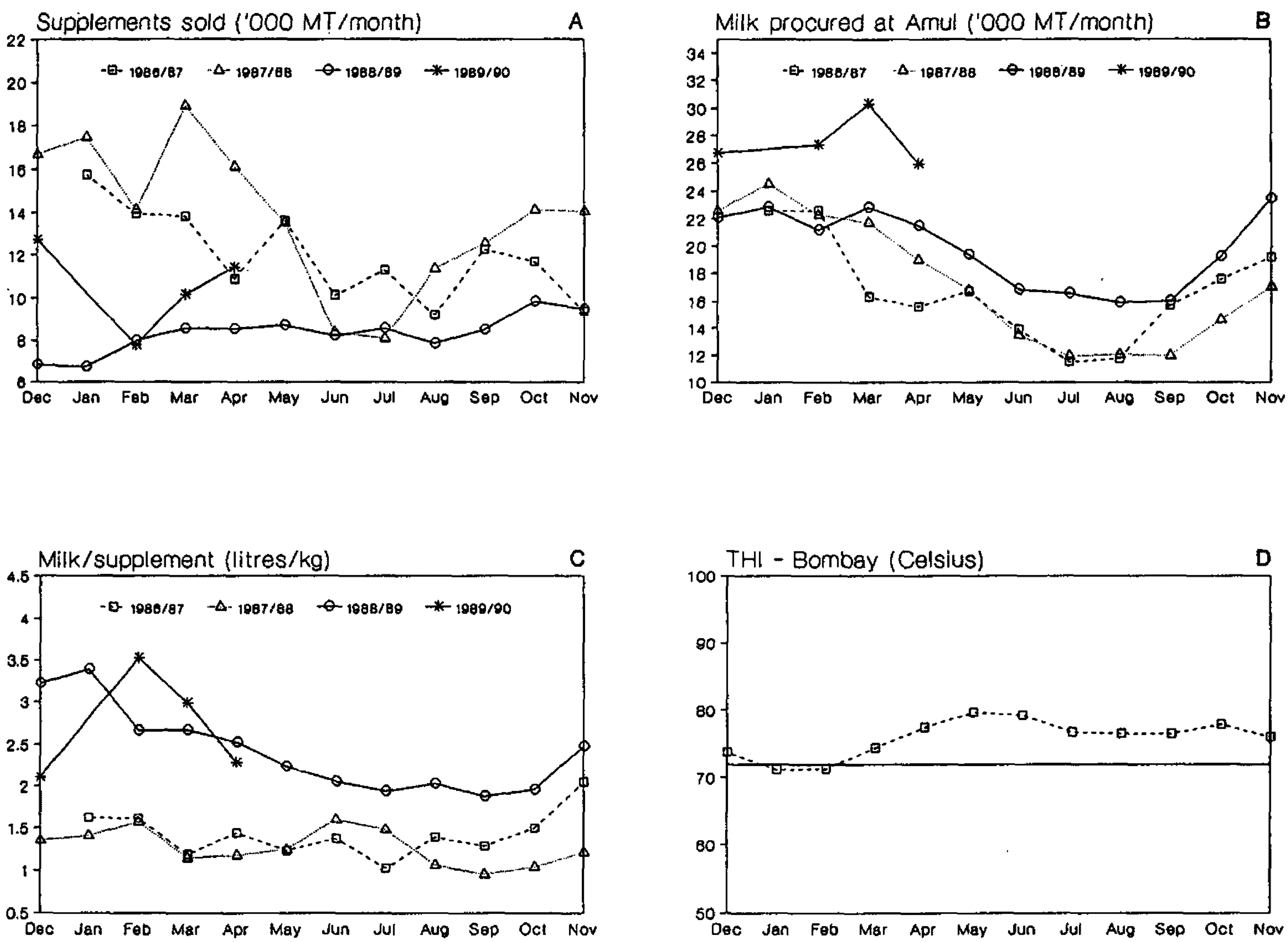
(A) shows the sales of a supplement-feed in the district from the Amul Feed Mill when a so-called balanced concentrate was available (1987/88) and after the change (1st Dec, 1988) to a 30% protein meal (bypass protein). In the latter system, the recommendations are to feed a molasses/urea block and half the previous quantity of supplement. Initially, there was some stockpiling of the original feed and there was marked resistance by farmers to the new feed. This resistance subsided.

(B) shows the milk procurement at the Amul Dairy Factory over the same three years.

(C) shows that farmers have faithfully followed instructions and that the rate of supplement (high protein feed) used, has dropped to about 350 g/litre of milk as compared to 700–800 g/litre of milk on the traditional concentrate. Milk yield has increased from 1.25 l/kg (old supplement) to 2.8 l/kg (new supplement).

(D) shows the thermal humidity index for Bombay. This is an index of the relative heat stress. Above 72 milk production is adversely affected in cattle fed on high quality feeds.

See next page.


Supplements sold ('000 MT/month)
A
1986/87
1987/88
1988/89
1989/90
22
20
18
16
14
12
10
8
6
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Milk procured at Amul ('000 MT/month)
B
1986/87
1987/88
1988/89
1989/90
34
32
30
28
26
24
22
20
18
16
14
12
10
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Milk/supplement (litres/kg)
C
1986/87
1987/88
1988/89
1989/90
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
THI - Bombay (Celsius)
D
100
90
80
70
60
50
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

The decision to turn over the feed-mill to producing the new feeds has been vindicated by the large increases in milk procurement by the Amul milk factory. The milk collection by the Amul plant for the three years 1987, 1988 and 1989 are shown in Figure 6.6.

In summary, immediate benefits of the new feeding systems are:

- a 30% increase in milk procurement without any increase or change in the feed-base
- a reduction in the recommended level of supplementation with compounded meal, increasing the effective capacity of the mill to supply critical supplements for twice the number of animals
- an improved efficiency of utilisation of feed. The conversion of supplement has been reduced from about 750 g/litre to 350 g/litre milk production
- a lowered requirement for fossil fuels in manufacture, transport and storage of supplement

The increased milk production that has been observed is possibly an understatement of the longer term results. It is anticipated that there will be improved reproduction rates in females in the coming year, possibly increasing the proportion of lactating to dry cows (buffaloes) significantly in the villages. This may result in a further 50% increase in milk production from the available feed resources.

Part 7

Consequences of widespread application of feeding and breeding in India

Part 7 outline: Strategic feeding of ruminants in India has important flow-on effects that may allow additional improvements in production. The better feeding allows improved genotypes for milk production to be more widely distributed and may allow multipurpose animals to be used more effectively leaving the way clear for a reduction in cattle or buffalo population densities. Reduction in large ruminant densities are seen as the most effective means of reducing methane emissions on a world wide basis, provided productivity per animal is increased.

7.1 Milk production

The policy makers of NDDB of India have a clear perspective on feeding and breeding. Combining the principles of feeding discussed in this presentation with improved genotype (usually 50:50 indigenous: Friesian) can have a dramatic effect on milk production in India.

The strategy for meeting the increased milk production estimated to be 23 million metric tons 1985–86 to 80 million metric tons in 2000 A.D. requires much planning.

There is basically only one option and that is to employ the new feeding systems and to replace a proportion of the present herd with crossbred cows and selected buffaloes (with widespread use of AI) and eventually reduce overall animal numbers.

7.2 Effects on reproduction rate

Using the feeding strategies discussed above, it has been unequivocally demonstrated that age at puberty can be reduced from 4 to 1.5 years and that intercalving interval can approach 12–15 months as against 2 years in most nondescript cattle/buffaloes in India. Even mature cows and buffaloes subjected to long term undernutrition begin their reproductive cycle when given only MUB with their allowance of straw. It is obvious that even with low producing animals, increasing reproduction rate to one calf per year can almost double milk production within the country.

7.3 Milk production and draft power

To produce the 80,000,000,000 kg of milk needed/year in India would need only a population of 27 million crossbred cattle and buffaloes with an annual milk production of 3000 litres. In addition to this India requires about 10 million bullocks annually to meet replacements required to maintain the 75 million herd of draft animals. These could be available from the 27 million dairy animals as this could be expected to produce 13 million male offspring per year. This supposes a cross-bred is produced with suitable draft characteristics.

7.4 Draft power—body size

The extremely small bullocks (150–250 kg liveweight) seen in developing countries are mostly a result of nutritional stunting in early life. This has been shown by researchers in Australia. Applying the principles of balancing nutrition during periods when protein is deficient in the basal feed in early life has resulted in a difference in mature size of cattle of 80–100 kg (Hennessy, 1986). Similarly a comparison of breeds in Africa under ranch conditions (where nutrition is moderate and the young animal has access to milk for up to 12 months), or in the herds of traditional farmers (where nutrition is nearly always poor and the young animal often competes for milk with humans, i.e., they are often protein deficient) have demonstrated similar results.

The need for bullocks can be contracted by producing larger bullocks, better implements and by feeding to promote greater draft capacity. The simple application of molasses/urea blocks to bullocks increases straw intake, the nutrients extracted from that straw and the efficiency with which those nutrients are used. This, in turn, improves health and work capacity. The replacement of two bullocks by one could reduce the feed requirements for draft power by more than 25%. The rationale for this is that a working bullock probably needs 2.5% bodyweight as forage; so two 400 kg bullocks consume 20 kg of feed. If a single bullock (500 kg LWt) was fed a molasses urea block it may be able to extract 30–50% more nutrients from the forage (which is usually straw) and could eat, say, some 15 kg forage. Supplementation with a molasses urea block will halve methane production in the rumen. The net reduction of methane production on feeding MUB and halving numbers would be of the order of 60% from the national herd of bullocks.

7.5 Population densities of dairy animals

The net effect of strategic feeding to balance nutrients in the available resources for dairy animals, and better feeding of bullocks is to reduce the needed number of mature animals from 275 million to 112 million, with, say 26 million young stock in the process of maturation.

If the low producing animals could be somehow removed from the national herd, the decreased competition and therefore increased availability of better quality forage per milking animal would have a multiplier effect to further increase milk production per animal and further reduce the number of animals needed.

7.6 Overall conclusions

Improved nutrition of large ruminants fed on crop residues, agro-industrial byproducts or tropical pastures can considerably influence the rate of individual animal production through its direct effects on the efficiency of liveweight gain and through improved reproduction rate.

Improved animal production per animal reduces methane generation by its effects in the rumen and through decreases in age to slaughter for meat animals. The likely improvements in milk yield, combined with a decreased intercalving interval and age at first calving, will have a multiplier effect and eventually allow a decrease in numbers of dairy animals to occur. The calculated production of methane relative to milk yield over a lifetime may be reduced in cattle fed poor quality forages fron 250 g/litre milk to 50–70 g/litre milk.

Establishing large numbers of crossbred cows in developing countries for milk production and using the male offspring as bullocks could reduce the need for large national herds of cows which provide the young stock for draft purposes. Such action would remove the need to maintain at least 40 million milch animals in India alone.

Better feeding of male offspring in early life will increase adult size and with better agricultural implements could replace two small draft animals with one well grown animal.

Better feeding of draft bullocks, using molasses/urea blocks, will reduce methane generation from this source by about 50%.

The net effect of improved management on methane production will be a reduction of approximately 60% in methane produced per unit of milk or meat production. Provided individual production is increased and cattle numbers are reduced, the methane production from large ruminants in India may be reduced to 25% of its present estimated level.

7.6.1 Methane production by cattle fed high v. low quality forages

A major conclusion of this review is that, in the tropics and with cattle fed on a basal diet of poor quality forage, (but with supplements to balance the nutrients to requirements) the production of methane per kg gain is about the same as that on high quality feeds. This is surprising since growth rates on the supplemented-poor quality feeds are often half that on the high quality feeds. It is possible that this difference arises from climatic differences.

The need to oxidise more nutrients to maintain body temperature in cold climates as against hot/humid climates could account for some of the difference. However, it seems more realistic that "energy requirements" are overestimated by traditional feeding standards. Therefore, more widespread use of protein meal supplements to ruminants will improve efficiency of use of even high digestibility/high concentrate feeds. There is, therefore, scope for a significant reduction in methane generation by ruminants in the industrialised countries.

Part 8

Application of strategic supplementation: some important considerations

Part 8 outline: Application of the feeding strategies must consider socio-economic aspects and also the local availability of resources, particularly protein meals.

The future, probably, lies, for most countries and districts, in developing a by-pass protein concentrate from locally available protein meals. Some approaches to this are indicated. In most developing countries there will be a need to develop the facilities (for feed manufacture) and markets for products.

Most importantly the need for education in the new feeding strategies is emphasised. This is particularly important for the farmer, the extension worker and the University graduate.

8.1 Introduction

Both large and small ruminants in developing countries are owned in small herds by farmers. The large numbers of farmers presents an enormous problem in applying any technology for improving productivity by supplementation.

In India the immediate economic returns through the system of marketing of milk, particularly in cooperatives, readily convinces farmers of the benefits of supplements. It is the objective of the NDDB to make available the supplements for feeding to all animals within the cooperatives which will eventually then be accessible to 6–8 million milch animals. The same strategy is also the recommendations of the Technology Mission to the Indian Government.

It is, however, difficult to convince farmers to use blocks and/or protein feeds under the following conditions:

- where the basal feed resource is so poor or of low availability that responses are not easily seen. It is difficult, for instance, to recognise a 10–20% increase in milk yield in a buffalo producing 1 litre of milk per day and this has mitigated against the use of MUB by small farmers.
- where there is no economic return for a considerable time; for example, where animals are sold only at maturity or income only begins when milk is produced. Most small farmers have no cash flow to allow the purchase of supplements.
- where the young female is being grown-out for lactation, even though the age at puberty may be reduced by several years, this is difficult to communicate to farmers and even farmers with cows of high genetic potential often fail to provide them the supplements needed to improve growth. (This also applies to bullocks being grown out for draft.)
- where numbers of animals are more important than total liveweight (as in parts of Africa or with nomadic people in India).
- where the cattle are owned by nomadic people.

The problem is one of convincing the enormous numbers of small farmers of the benefits of supplementation and providing the supplements at low cost (with possible deferred payments). The molasses/urea block alone, when given to cattle and buffalo on crop residue feeds does not result in spectacular increases in productivity; whereas the use of bypass protein has a large effect and this is again improved where both MUB/bypass protein meals are given together.

From the point of view of this review, the establishment of MUB supplementation could be important for two reasons:

- it halves the methane production per unit of feed digested
- it is likely to be a vehicle for drugs or chemicals to increase productivity (e.g. antiprotozoal, antimethane reagents, antihelmintics).

The strategic use of protein meals is important because of their effect on efficiency of feed utilisation and promotion of growth, which has a much larger effect on the life time production and therefore methane generation.

8.2 Application of MUB

Although MUB appears to be the best method for supplementing urea/trace minerals/macro minerals/vitamins, there are a number of other methods for achieving the same end result particularly in countries where molasses is unavailable or fully utilised and therefore unavailable for the purpose. These include:

- liquid molasses mixtures fortified with urea/minerals
- blocks made from clay/minerals/nutrients by pressure
- blocks made by pressure from any raw materials
- blocks improvised from any ingredients (e.g. recently blocks were produced from a seed pod of a tree legume with added urea/minerals and cement)
- dry supplements which are attractive to stock (e.g. salt, with which the ingredients can be mixed

8.3 Availability of bypass proteins

There are a large number of "naturally" occurring protein meals that are rich in bypass protein. These are largely the byproducts of the edible oil industry. The rationale behind this is that in an oil extraction process using either pressure or solvent, a considerable amount of protein is heat denatured and becomes insoluble in the rumen. Undoubtedly, there is considerable variation between meals produced by differing treatments but cottonseed meal has been found to be consistently rich in bypass protein.

The oil seed meals have been a traditional export commodity for many developing countries and these exports are important to their economies because they are a source of "hard" currency. However, it will be important to retain these meals within a country in the future.

There are a wide variety of oil seed meals within developing countries, including the meals from cottonseed, niger (noug), linseed, sunflower, safflower, guar (cluster bean), groundnut and soyabeans. The content of bypass protein in these feeds varies with processing methods and source of protein. In general, cottonseed and linseed meal are very good sources of bypass protein (50–75% of the protein is protected) whereas the others vary from very little to about 50% protection (see Leng *et al.*, 1977). Undoubtedly it would be biologically more efficient to protect those protein meals low in bypass protein by simple procedures. There is a considerable need for assessment of the suitability of the available protein meals in a country.

8.4 Protection of oil seed meal residues

There are a number of methods for protection of protein meals to allow them to escape degradation in the rumen when they are fed to ruminants. For developing countries, there are possibly three which may be applicable: treatment with (1) formaldehyde, (2) heat or (3) xylose and glucose or heat.

Formaldehyde has been outlawed in most countries because of the potential formation of gaseous carcinogens. Heat treatment is often too expensive but the recent developments with xylose treatment has great promise and may be the method of choice. This is especially important as xylose can be very easily and inexpensively produced in a crude form by acid or alkaline hydrolysis of bagasse or other fibrous feeds. A major, useful source of xylose is the sulfite liquor from the paper industry which contains 5% xylose.

The treatment method is to spray the xylose solution on to the protein meal, heat it to 200°F for 2 hours (Lewis *et al.*,1988). The benefits of such treatment is illustrated by the data in Table 8.1.

Table 8.1: *Effects on liveweight gain of supplementing a basal forage/concentrate based diet with soyabean meal or soyabean meal treated with sulfite liquor at 200°F for 2 hours (Lewis* et al., *1988)*

	LWt gain (g/d)
No supplement	591
+ 7% soyabean	673
+ 9% soyabean + 10% SL	823
+ 8% soyabean + 5% SL	841

8.5 Sources of bypass protein in countries with no oilseed industries

Some countries have no oil seed meals and may not be able to import such materials. One of the options is to produce high protein sources locally and to treat these to give optimum protection, e.g. crops such as lupins, peas, beans or other high protein seed crops may need to be grown and processed for the ruminant industries. The methods to be used may be similar to that suggested above for soyabean meal (i.e., heat/xylose treatment).

A further possibility is to grow high protein legumes (trees or forages) from which the leaves are harvested, treated and distributed for use by farmers.

Some legumes that contain tannin may be protected by the tannin (3–6% being optimum) and this should be given prominence for research.

8.6 Overview of providing protein meals in developing countries

The options for making protein meals available are:

- more local use of protein resources rich in bypass protein
- reduced emphasis on export of protein meals as a foreign currency source and perhaps subsidise imports of protein meals in developing countries
- development of treatment methods to ensure a high proportion of a protein in a meal reaches the small intestine of the ruminants to which it is fed
- development of crops that can be locally grown and processed to give a high degree of protection to the protein
- development of forage/tree legumes whose leaves can be harvested and processed to produce a meal rich in bypass protein

8.7 The need for feed mills

The need is for feed mills to manufacture both the MUB (or other forms of supplements) and treat or at least process protein meals. Undoubtedly, except for cottonseed, linseed and possibly guar meal, most protein sources will need to be processed. In addition, the protein meals will need to be fortified with minerals/vitamins where they are to be used to feed lactating animals. Therefore, the development of small mills for this purpose would be an important priority.

8.8 Education

The steps to be taken to ensure application must be

- to make generally available for purchase by farmers, a multinutrient block and a protein meal rich in bypass protein
- to educate personnel at all levels of the industry, from University teachers through to extension officers and farmers
- to provide markets for the products as incentives to use the supplements.

The emphasis in nutrition must be away from the traditional dogma to the new balanced nutrient approach (see Preston & Leng, 1987).

The steps to educate must include:

- production of postgraduate text books (Preston & Leng, 1987)
- production of more applied text books for undergraduate students and educated farmers
- production of simple texts that can be understood by farmers
- highly simplified word/picture texts for illiterate farmers
- education of village children in the simple application of these technologies. Most children in India, for example, have some education to 12 years of age. Most of them live in households that own a cow or a buffalo but the nutrition of these animals is not considered in the curriculum.
- massive educational programmes drawing on all forms of media, from videos through to lectures at the village level

8.9 Cash flow of small farmers and purchase of supplements

Undoubtedly, in most developing countries MUB and bypass protein should be fed to ruminants from an early age through their productive life. The most economic responses will be to an improvement in reproduction. To achieve this, there will need to be incentives to farmers.These could be of the form of a no/low interest rate loan, repaid when the animal is marketed, or free distribution of feed with a tax at the sale of the product. A priority in such a situation would be provision of insurance against death of an animal. This is important, particularly for promotion of potentially high yielding milch animals, as without insurance the high cost of acquisition makes the proposition of owning an animal often too risky. The death of an animal may mean financial ruin and even starvation for the family. Again, insurance of farm animals is being done at the village level in India.

8.10 Government subsidies

The question of subsidies is a difficult one. At present in India through the co-operative, the feeds are provided at a no profit/no loss basis and the price of commodities fluctuate according to demand and availability. The large purchasing power of the feed mills limit price fluctuations. There is a need to consider long term, low interest rate loans for both the purchase of animals and supplements—a practice already being applied for the purchase of milch animals in India. The use of supplements for raising bullocks and meat animals can only be promoted slowly with education. Initially, farmers will have to be convinced by demonstration trials and perhaps provision of supplements that are subsidised for 1–2 years.

Part 9

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