

FEEDING STRATEGIES FOR IMPROVING MILK PRODUCTION OF DAIRY
ANIMALS MANAGED BY SMALL-FARMERS IN THE TROPICS

By

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INTRODUCTION

Milk is an important component of diets for all humans as it is high in essential amino acids that are most likely to be deficient in diets based on vegetable protein. Although milk is a high-cost source of protein and fat relative to vegetable sources, it is readily saleable particularly in the more affluent urban areas of developing countries. Improving milk production is therefore an important tool for improving the quality of life particularly for rural people in developing countries.

Milk production systems in tropical countries are diverse. At the one extreme the systems are similar to those in most industrialised countries and are based on cows of high genetic potential given "high quality feeds" which include fodder crops/silages and grain and protein concentrates. Milk production per cow is extremely high and technological inputs are high. At the other extreme are systems which are used by the vast majority of small farmers in developing countries and are based on low inputs and productivity per cow is relatively low. These small-farmer systems vary from ones in which cows or buffaloes are fed on crop residues, agro-industrial by-products and roadside grass to beef cattle grazing tropical pastures that are milked once a day, with the calf having access to the dam for the other half of each day. In the latter systems, the pastures available to these 'dual purpose' animals are typical of most tropical grasslands and are relatively low in protein and digestibility.

Every conceivable system between these extremes is used in various parts of the world. However, the small farmer on low milk production systems are those with the greatest potential for improvement and are the target of most aide programmes. In the discussion presented here, the strategies for improving milk production from cows/buffaloes fed tropical pastures, crop residues or fibrous agricultural by-products are discussed.

On these feed resources, overall productivity is low, animals reach puberty at a late age (often 4 years) and inter-calving interval is often 18-24 months, resulting in a small number of dairy animals in a national herd being in milk at any one time. A strategy for improving milk production in these systems has therefore two components. The first is to improve reproductive efficiency of the dairy animals and secondly to improve milk yield and persistency.

The greatest scope for improving a country's milk production is through a strategy which targets improvement of reproductive performance. This cannot be achieved however without increasing milk production per animal. Reducing age at first calving from 5 to 3 years and inter-calving interval from 24 months to 12 months by better feeding management will at least double the number of animals being milked at any one time. In addition, because the same feeding strategy that improves reproductive performance also increases milk production, the improved production per animal is also increased.

FEED RESOURCES AVAILABLE TO SMALL DAIRY FARMERS

The small farmers of developing countries have limited resources available for feeding to their ruminant livestock. They do not have the luxury of being able to select the basal diet but use whatever is available at no or low cost. The available resources are essentially low digestibility forages such as tropical pastures (both green and mature), straws and other crop residues and agricultural by-products which are generally low in protein.

The major criterion for improvement in production is to optimise the efficiency of utilisation of the available fodder resource and not to attempt to maximise animal production. There is little point in knowing the "energy" requirements of a cow or buffalo for milk production, whose requirements are to be met from whatever crop residue is available. It is imperative, however, to understand the requirements for supplements that will provide nutrients that will optimise the efficiency of utilisation of that feed resource.

THE BASIC CONCEPTS

When considering how to optimise the utilisation of the available forages for dairy animals, two basic concepts must be applied as follows:

- To make the digestive system of the cow as efficient as possible by ensuring optimum conditions for microbial growth in the rumen.
- To optimise production by balancing nutrients so that these are used as efficiently as possible for milk production without jeopardising the reproductive capacity of the cow.

Any further increases in production may be obtained by the use of supplements of protein, starch and lipids to provide nutrients for milk production above those obtained when the efficiency of utilisation of the basal feed has been optimised. These supplements should be processed and must by-pass the rumen and become available for digestion in the intestine and in this way provide the nutrients in exactly the correct balance for additional milk production.

The two concepts can be implemented by feeding a combination of non-protein nitrogen (NPN), minerals and by-pass protein. The third component is a relatively new concept which suggests that milk production, once the efficiency of utilisation of the basal feed resource has been optimised, depends upon providing nutrients needed for the components of milk, e.g. the quantity and balance of glucose (for milk lactose), protein and fat, in a form that will by-pass the rumen.

AN APPROACH TO IMPROVING NUTRITION OF LACTATING ANIMALS

In this paper, research work leading to the application of feeding strategies that emphasise optimal utilisation of available resources for milk production in the tropics are reviewed.

The approach taken has been one in which urea/molasses blocks (UMB) have been provided to lactating ruminants to allow a slow, continuous intake of nutrients needed to optimise fermentative digestion in the rumen. By-pass protein supplementation is used to optimise the efficiency of use of absorbed nutrients. The development of both these strategies has gone along similar lines with testing under laboratory conditions being followed by testing on well managed farms and eventual trials under village conditions (see Leng and Kunju, 1989).

Over the last year, all Friesians imported into India and placed under the care of NDDB have been fed according to the strategies proposed (see Leng and Kunju, 1989). The 300 day lactational yield has been, on average, 6000 litres.

In addition, several thousand tonnes of a by-pass protein have been fed to cattle and buffalo under village conditions in various climatic zones. On the basis of this research and the experience gained, the largest feed mill in India producing 300-600 tons of feed per day (Amul Feed Mill, Anand) commenced the production of a new pelleted feed supplement containing 30% protein and with approximately 75% of the protein in a form likely to by-pass the rumen.

BACKGROUND - THE USE OF NPN AND BY-PASS PROTEIN IN RUMINANT DIETS

Definition

- By-pass proteins are defined here as those dietary proteins that pass, intact, from the rumen to the lower digestive tract.
- Digestible by-pass protein is that portion of the by-pass protein that is enzymatically hydrolysed in, and absorbed as amino acids from, the small intestine.
- Over-protected protein is that protein of the by-pass protein that is neither fermented in the rumen, nor digested in the small intestine.

- Metabolisable protein is the digestible by-pass protein plus the digestible protein in the microbes that enter the small intestine.
- Fermentable carbohydrates are those parts of the feed carbohydrate that are degraded by microbial action in the rumen to volatile fatty acid (VFA) plus that entering into the microbes that grow with the energy (ATP) released when VFA are produced.

Protein digestion in ruminants

In different production systems, ruminants consume many types of carbohydrates, proteins and other plant and animal constituents. All digestible carbohydrates are fermented to volatile fatty acids (VFA) plus methane and carbon dioxide by microbial action. Proteins are degraded by microbial enzymes in the rumen to give the same three end-products (i.e. VFA, CO₂ and CH₄) plus ammonia (see Figure 1). In all cases a proportion of the substrate metabolised by microbes is used for synthesis of the microbes.

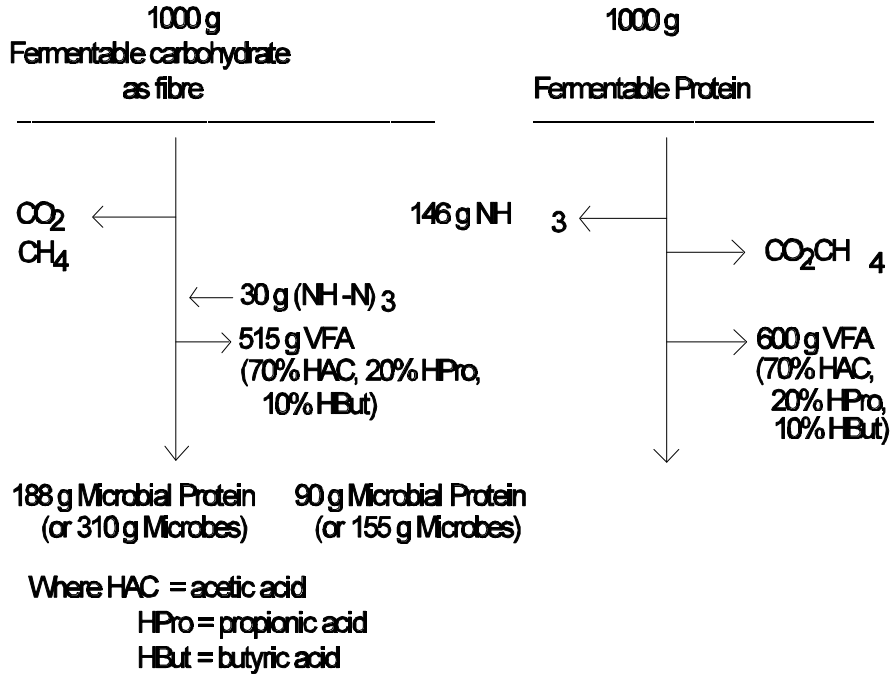
The microbial fermentation of soluble protein in the rumen is an unavoidable consequence of the ruminant mode of digestion. In the absence of other forms of N, it ensures a supply of ammonia nitrogen for micro-organisms from which they synthesize the protein in their cells. Under many circumstances, it is a wasteful process because high quality proteins are broken down to ammonia, absorbed as such, converted to urea in the liver and this is excreted in the urine.

EFFICIENCY OF MICROBIAL GROWTH ON PROTEIN

Protein degradation to VFA leads to a relatively low availability of ATP ('energy') to rumen microbes and therefore protein that is degraded in the rumen is inefficiently used for the growth of micro-organisms. In comparison with carbohydrate when protein is degraded in the rumen, only half the ATP (the energy currency of the microbes) is produced in fermentation of protein relative to the same amount of carbohydrate.

The breakdown of carbohydrate in the presence of adequate ammonia and sulphur and other minerals supplied by, for instance urea/molasses blocks, results in more microbial protein being produced than from an equal amount of protein fermented in the rumen. This is shown diagrammatically in Figure 1 and indicates that from a highly soluble protein such as leaf protein, less than 10% of the protein in the diet is available to the animal.

Figure 1. The breakdown of fermentable carbohydrates and protein in the rumen with the production of VFA and microbial protein.



Quite clearly therefore with readily soluble and fermentable protein; whilst little escapes the rumen if the protein is in high concentrations the protein to energy ratio in the nutrients arising from the rumen may be decreased.

Factors that influence the availability of by-pass protein

For a variety of reasons a proportion of the dietary protein passes from the rumen into the small intestine without alteration. On reaching the small intestine this by-pass protein is digested by enzyme hydrolysis and absorbed into the body as amino acid.

The conditions under which some dietary protein may escape the rumen for digestion in the lower alimentary tract include:

- When a protein meal has been made highly insoluble by heat treatment.

- The protein meal contains tannins (2-4%) which bind to make an insoluble tannin - protein complex (Barry, 1985) which is not degraded in the rumen but is degraded in the abomasum/small intestine.
- Chemical treatment has been applied, e.g. formaldehyde treatment (Scott, 1970).
- When a relatively soluble protein meal is fed in very high quantities and is either in a finely ground form or is rapidly fragmented into small particles which move quickly through the rumen. For example, when clover or lucerne (that do not contain tannins) are fed at levels below 2.5% of liveweight (on a dry matter basis), it is probable that no dietary protein escapes to the lower tract. However, at levels above this, some protein escapes because of the rapid movement of digesta out of the rumen. The amount of by-pass protein can be as high as 30% of the total protein in the feed if this is highly digestible (D. Dellow & J.V. Nolan - unpublished; Nolan and Leng, 1989.).
- When heat is applied to a mixture of soluble protein and xylose, when a modified browning reaction can insolubilise the protein.

Microbial protein synthesis in the rumen

Ammonia, peptides, amino acids and amines form the nitrogenous substrate for the synthesis of microbial cells but ammonia is the most important source of N for the microbes that ferment forages. Ammonia is used by many species of rumen micro-organisms as their sole source of nitrogen for protein synthesis (see Leng and Nolan, 1984).

This assessment of the role of ammonia in the rumen can be misleading if it is unqualified. Firstly some species of bacteria and protozoa commonly found in the rumen cannot grow or survive unless small quantities of peptides, amino acids or branched chain fatty acids are provided in the diet and are present in low concentration in rumen fluid (Hungate, 1966).

A high level of rumen degradable protein in the diet may support high levels of all N-nutrients needed by bacteria and may cause specific populations of microbes to develop in the rumen as compared to diets where urea alone supplies the fermentable N.

A deficiency of rumen ammonia results in a low microbial growth rate which may reduce digestibility of fibre and lower intake of feed.

The requirements for ammonia for microbial activity

Estimates of the critical level of ammonia in the rumen fluid for efficient digestion has been reported to be as low as 50 mg N/l or as

high as 200 mg N/l. However, recent studies have shown that, when ammonia concentrations fall below about 200 mg N/l, the rumen, microorganisms are inefficient and are likely to respond to dietary NPN supplements particularly to UMB (Krebs and Leng, 1984; Boniface *et al.*, 1986; Sudana and Leng, 1986; Perdok and Leng, 1989).

Intake of straw by cattle has been shown to be increased by increasing urea levels in the diet until the level of ammonia reaches 200 mg N/l (Boniface *et al.*, 1986; Perdok and Leng, 1989).

Recent studies with buffaloes fed forage based diets showed that, given a period of access to molasses/urea blocks, these animals learn to modify their intake according to the protein content of the basal diet (Table 1).

Table 1. The influence of N content of the basal diet given to lactating buffaloes on the intake of a block lick based on molasses/urea (Leng and Kunju, 1989).

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Group No.	Diet N content (gN)	Intake of block lick (g/d)	Milk produced FCM (kg/d)	Liveweight changes (g/d)
1.	0	586	4.3	- 357
2.	30	256	5.7	- 455
3.	83	293	6.3	+ 276
4.	111	173	6.1	+ 89

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Can the rumen microbes supply all the protein needs of the ruminant?

Even when ammonia and other nutrients are supplied, the quantities of microbes that leave the rumen in digesta do not supply sufficient protein to meet the needs for productivity in ruminants (*i.e.* moderate to high growth rates and milk yields). In such a situation, the deficiency symptoms indicate an insufficient supply of essential amino acids to the tissue. Under these conditions supplementation with a protein meal (which has a high content of by-pass protein) to supply

additional dietary amino acids increases both the level and efficiency of animal production (see Preston and Leng, 1987).

Protein (or Amino Acid) Requirements of Ruminants

In the past, the protein requirements of ruminants and evaluation of the protein value of feeds for ruminants have been based on digestible crude protein ($N \times 6.25$). This is now recognised as a misleading concept. The use of digestible crude protein has arisen largely because it was considered that cattle and sheep could obtain their essential amino acids from microbes produced in the rumen. This in turn led to suggestions that extensive use could be made of non-protein nitrogen in high carbohydrate feeds and that a special role of ruminants could be to convert non-protein nitrogen to high quality animal protein.

These have now been superseded by new concepts which take into consideration that when amino acid requirements are high, insufficient digestible microbial protein is available from the rumen to meet these needs. It is now necessary to assess the requirements for N by ruminants in terms of the amount of ammonia (or NPN) and amino acids needed by the rumen microbes, and the amount of digestible by-pass protein needed by the animal to augment the total protein (amino acids) available to the animal and to create an efficient metabolism. The sum of the two sources of digestible protein represents the metabolisable protein.

Protein or amino acid requirements relative to energy requirements of ruminants are, however, influenced by a number of factors and cannot be stated with any degree of accuracy. The requirements are influenced by:

- physiological state of the animal,
- rate of growth and milk production,
- body composition as influenced by previous dietary and health history,
- basal feed (particularly fat content),
- proportions of the different amino acids absorbed,
- patterns of rumen fermentation (i.e. acetate:propionate ratio),
- availability of volatile fatty acids,
- requirements for glucose for essential purposes,
- environmental heat or cold stress, and
- the extent of the work load of the animal.

With all these unknowns, the need for by-pass protein under conditions pertaining to small-holder cattle can only be assessed in feeding trials aimed at developing response relationships. The effects of physiological state of the female goat on the utilisation of protein and, therefore its requirements, is well illustrated by the data shown in Figure 2.

Metabolisable Protein Available to Ruminants

Metabolisable protein available is the sum of digestible dietary by-pass protein plus digestible protein from microbes reaching the lower tract. On most straw based diets the metabolisable protein is mainly of microbial origin (i.e. there is no by-pass protein in the diet). The amount of protein available therefore depends on the efficiency of microbial growth in the rumen.

This in turn depends on several factors:

- the presence of all the essential nutrients in the balances and amounts needed by the rumen microbes to grow e.g. ammonia, sulphur, phosphorus, trace minerals, amino acids, peptides, etc.,
- a source of fermentable dry matter, i.e. the feed consumed,
- to a small extent the rate of digesta turnover and therefore feed intake. However, this depends on degradability of the feed, type of carbohydrate and the physiological status of the animal.
- buffering capacity of the rumen and pH of the rumen fluid which largely depends on diet, and
- the balance of micro-organisms in the rumen. If supplementation with carbohydrate promotes protozoal population this can actually decrease the protein to energy ratio in the nutrients available from the rumen (see Bird and Leng, 1985).

As an example of how the balance of microbial protein to VFA energy can be altered in a cow given a straw based diet, the effects of an inefficient rumen (low rumen ammonia supply) and an efficient rumen (optimum rumen ammonia) are shown in Table 2. (see Leng, 1982 for the assumptions and calculations).

The point is that the P:E ratio in the nutrients absorbed is altered according to how efficiently the rumen organisms are digesting the feed or how much by-pass protein there is in the diet.

Figure 2. The effects of physiological state on the intake and retention of nitrogen in goats fed oaten hay/lupins (11% crude protein) (Halais, 1984)

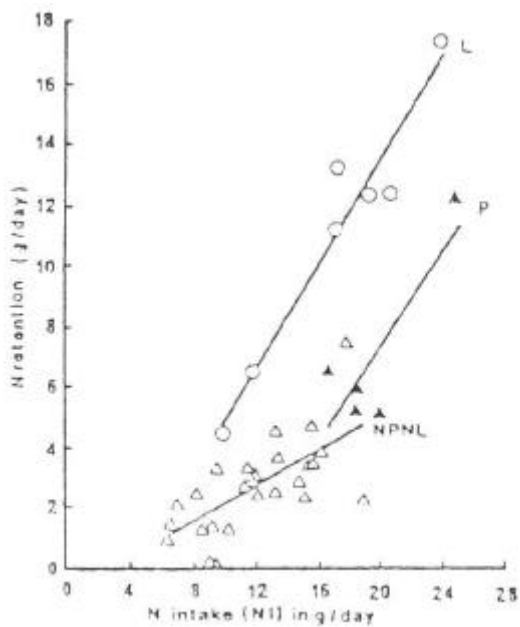


Table 2 The theoretical effect of feeding urea and urea plus by-pass protein on the P:E ratio in cattle. The values were calculated for a bovine consuming 4 kg of digestible organic matter without or with urea or with urea and 400 g of a by-pass protein source.

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Rumen condition	Microbial protein synthesised (g/d)	Total protein available (g/d)	VFA produced (MJ/d)	*P/E ratio (g protein /MJ/VFA)
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Deficient in ammonia	500	500	41	12:1
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Sufficient in ammonia	1010	1010	30	34:1
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Ammonia sufficient + 10% of the diet as by-pass protein	1010	1410	30	47:1
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* no consideration is taken here of the digestibility of the microbial or dietary by-pass protein

efficiency of utilisation of the feed is improved by supplementation. In other studies the increased efficiency is not readily discernible as the effect of such supplements is to increase forage intake (see Preston and Leng, 1987).

Table 4. The growth rate of calves (live weight 150 kg) given rice straw and supplemented with an oilseed meal Saadullah, 1984).

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Daily Supplement (g/d)	Straw intake (kg/d)	Liveweight-gain (g/d)	Feed conversion ratio (kg feed/kg gain)
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0	3.8	84	46:1
200	3.8	371	11:1
400	3.8	373	12:1
600	3.8	508	9:1

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RESEARCH ILLUSTRATING THE RESPONSES OF CATTLE TO UREA/MOLASSES BLOCKS AND BY-PASS PROTEIN MEAL SUPPLEMENTATION

Growth studies

Jersey bulls (350 kg live weight) fed rice straw plus a concentrate (low in true protein i.e. about 15%) trebled their rate of weight gain when fed a molasses/urea block in conjunction with 1 kg of this concentrate (Table 5).

Studies with lactating cows/buffaloes

In ten villages, the average milk sold in the collection centres increased by 0.4-1.1 litres/day when the farmer made a molasses/urea block available to their diary buffaloes (Table 6). Other trials showed that concentrate supplementation could be reduced without loss of milk production when a molasses/urea block was given.

Table 5. The effects of supplying molasses/urea blocks to cattle fed rice straw plus 1 kg 15% concentrate (Kunju, 1986).

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	Straw intake (kg/d)	Block intake (g/d)	Live Wt. change (g/d)	Feed cost/kg gain (Rupee/kg)
No block	6.4	0	220	9.3
With block	6.8	530	700	3.7

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Table 6. The observations on response of feeding block licks in villages (Kunju, 1986). The results show the milk or milk fat sold to the local collection centre (Kaira District Co-operative Milk Producers' Union Ltd., Anand, India).

Village	Milk (kg/d)		Milk fat (g/d)	
	S))))))))))))))))))Q pre lick	S))))))))))))))))))Q with lick	S))))))))))))))))))Q pre lick	S))))))))))))))))))Q with lick
Alwa	4.8	5.9	300	450
Punadhara	4.0	4.8	270	340
Fulgenamuwada	2.4	3.5	160	280
Hirapura	4.2	5.2	350	480
Bamroli (N)	3.6	4.2	270	380
Dehgam	4.3	4.7	310	350

More recently it has been demonstrated that feeding a meal high in by-pass protein (low in grain) as compared to a cattle feed concentrate based on traditional requirements increased milk production and live-weight gain without substantially influencing basal feed intake (Table 7).

The cattle were each fed 40 kg of green forage daily. The forage consisted of 60% legume (mostly lucerne/cowpea) and 40% non-legume (maize, sorghum/oats). The concentrates for cattle in group 1 were fed according to NRC recommendations. The cattle in group 2 were fed a

protein concentrate based largely on solvent extracted protein meals demonstrated to have a high by-pass protein content. A major point here is that the animals in group I disposed of nutrients equivalent to 20-25 MJ of energy presumably through 'futile cycles of metabolism'. This additional metabolic heat production could have increased body temperature by 16.5°C if the animal had been in an environment where this extra heat could not have been dissipated. The feeding trial was conducted during the cool season but

Table 7: The effects of replacing balanced concentrates with a high by-pass protein pellet on live-weight change and milk yield of Jersey x Kankrej cows (M.G.P. Kurup, G. Kunju NDDB, India - pers. comm.).

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Group	No./group	Crude Protein in supplement (%)	Intake of supplement (kg/d)	Milk Yield (kg/d)	Live-weight change (g/d)
1	75	18	4.7	8.0	- 210
2	75	30	2.6	8.8	+ 202

S))Q

1	75	18	4.7	8.0	- 210
2	75	30	2.6	8.8	+ 202

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clearly in the hot season feed intake could not have been maintained. Put another way, if the environmental temperature was critical for cattle in group II then the animals in group I would have needed to reduce their feed intake by 20 MJ ME.

CONCLUSION DRAWN FROM STUDIES IN INDIA

The efficiency of feed utilisation is enormously improved if the rumen of the animal has a healthy microbial population adequately supplemented by providing a molasses/urea block which often increases the intake of a basal diet. Adding a by-pass protein supplement will further improve the efficiency of utilisation of the basal feed resources but will also allow animals to maintain feed intake at high environmental temperatures and humidity. Conversely, the productivity of lactating animals can be maintained at a lower feed intake provided the rumen is made efficient and the animal's metabolism is made efficient by supplementing with a molasses/urea blocks and by-pass protein meal respectively.

CONSTRAINTS TO APPLICATION OF THE BY-PASS PROTEIN TECHNOLOGY

Even though the application of UMB/by-pass technology is highly promising, a few constraints are still to be overcome before it can be widely applied with confidence. Some of these are given below and indicate areas for intensive research:

1. The information regarding the degradabilities of protein in all raw materials used in cattle feed are not yet available and may be quite variable depending on source, manufacturing conditions and presence of other compounds.
2. Easy laboratory tests for protein degradability are still not available and there is still some considerable disagreement as to which method provides the best indication of the content of by-pass protein in a protein meal.
3. There are insufficient data from feeding trials available on milk production per unit input of by-pass protein under the systems commonly used by small farmers.
4. There are no response relationships for milk production for economic analysis of the feeding of by-pass proteins which covers at least two lactations. This is important as by-pass protein supplementation on these diets often improves the body condition of cattle and therefore reproductive performance. The second lactation after introduction of these systems may show the greatest economic response.
5. Many protein meals are undegradable in the rumen. However, their digestibility in the intestines may be very low. This applies particularly to protein meals with high tannin content. Such protein meals are not good sources of protein to the animal since much of the protein is lost in faeces.
6. For the most efficient utilisation of by-pass protein for production, the essential amino acid to total N ratio must be high.
7. The limits of responses to by-pass protein resides in the digestible energy content of the diet and at low digestibilities, high level feeding of a by-pass protein meal will result in amino acid degradation as an energy supply.

PRACTICAL APPLICATION OF BY-PASS PROTEIN IN VILLAGE SOCIETIES

Feeding Friesian cows of high genetic potential for milk production - The National Dairy Development Board of India (NDDB) experience

Friesian cows of German origin were imported into India as potential mothers for the next generation of bulls for cross-breeding with indigenous cows. These animals were distributed to (1) NDDB farms with management and accurate recording of milk yield and (2) individual village farmers in cool environments. The NDDB farms, which are situated at Anand and Bidaj in Gujarat, are in areas with extremely high summer temperatures which often exceed 40°C and may at times exceed 50°C.

All animals are fed whatever forage is available and were provided with urea/molasses blocks and fed only a by-pass protein concentrate (30% CP) at 300-500 g/litre of milk production. All animals have thrived, most are now in their second lactation and where accurate records have been kept have produced between 6000- 6900 litres of milk per 300 day lactation with peak daily lactations often exceeding 30 l/day.

The point that has to be emphasised is that these animals were apparently relatively unaffected by the hottest period of the year and maintained milk production at a time when there is usually a marked reduction in milk yield. They were fed the available forage which varied from mixtures of rice straw and green oats/crops through to a mixture of rice straw and tropical grass. The practical observations support the more controlled research under institutional/ laboratory conditions and indicate a major influence of balancing nutrition on amelioration of heat stress in lactating animals.

Amelioration of Anoestrous in Village Buffalo/Cattle

A major problem associated with milk production in village societies is that the "non-descript" animals which are by far the majority of dairy animals are often fed the poorest feeds particularly in early life and between lactations. The reason for this is that without the cash flow that comes from milk and with no rapid cash return on their outlay, village people (who always experience cash flow problems) are not prepared to purchase supplements.

In general, in developing countries, cattle and buffalo often calve for the first time at 4-5 years of age and have an inter-calving interval of up to two years. Infertility is therefore a major problem.

The improvements in growth rates mediated by the feeding strategies discussed here also suggest that reproductive rate may be similarly improved. A demonstration trial was established to test this hypothesis. Within two village societies, cattle and buffalo were selected that had exhibited (over an 8-12 month period) either infantile genitalia (buffalo heifers) or no ovarian activity in mature cows/buffaloes. These animals were provided with molasses/urea multi-nutrient blocks over the hot summer months and 90% of these animals came into oestrous after 3-4 months (Table 8). These studies have also been supported by studies of grazing cows supplemented with molasses/urea blocks in Africa which have shown a marked decrease in the lactational anoestrous period (Table 9).

The implications for improving milk production of these discoveries is extremely large. Decreased age at first calving, together with decreased inter-calving interval, may increase the total number of animals lactating at any one time by 2 or even 3 fold, this in turn will increase milk production from the national herd by the same increase.

TREATMENT OF CROP RESIDUES TO IMPROVE DIGESTIBILITY

The treatment of crop residues with alkalis to improve digestibility is a well researched and established technique. Feeding treated straw as compared to untreated straw considerably improves ruminants productivity (see Sundstøl and Owen, 1984).

Simple techniques based on ensiling the wet straw (50% moisture) with 3-4% urea are well established and could be applied under village conditions. However, these techniques are only being accepted slowly or are unacceptable to small farmers for a variety of reasons which vary from country to country and within districts in the same country. The main constraints to implementing straw treatment as a means of improving milk production in small-farmer systems are economic, sociological and logistic.

Economic considerations

Small farmers invariably have a cash flow problem and purchase of urea is restricted generally for crop production. Often plastic covers for the straw are costly and impractical. In addition, the returns for use of urea on a rice crop must be offset against the income from milk.

Sociological considerations

Often the most appropriate time for treatment of crop residues is at harvest time, when most the family are involved in long hours of work and have no time to treat straw. The availability of water is often a constraint. In most countries this would be carried in urns by the women from a distant source. These wives/daughters of small farmers generally have very full working days. Often, for security or convenience purposes, straw is stored in or close to the residence of the family and the smell of ammonia is highly unacceptable and may lead to eye disorders particularly in children. Finally, wet straw is much more difficult to store, preserve and feed to the cattle.

A major constraint is that farmers, from experience, have a fairly accurate annual feed budget. The main benefit from treated straw comes from increased feed intake and therefore the budget has to be adjusted. Failure to do this often results in the farmer having to purchase expensive straw which will be economically disadvantageous.

Conclusion

For straw treatment to be successfully accepted by small-farmers in developing countries the methods must be made easy, low cost and must have low labour inputs. It seems that, for the foreseeable future, straw treatment is unlikely to develop as a national strategy but will be used by the larger farmers particularly those that can afford to buy labour.

RESEARCH NEEDS

For the implementation of the new feeding system, more feeding trials need to be carried out in which response relationships of milk production/weight change can be correlated with level of by-pass protein feeding. However, some of this can be left to individual farmers who can be instructed to slowly increase the level of protein meal until they are satisfied with the response. They will automatically take the most economic option and the important point to stress is that farmers must have access to the supplements.

The influence of these feeding strategies on reproductive performance needs further research as it is likely to have the greatest effect within a country.

The feed processing technology should be modified in view of the new system with a view to increasing, in processing, the by-pass protein content of a pelleted feed. A suitable feed formula based on the nutrient supply, processability and economics of feeding needs to be developed, for use with the important basal feeds available to small-farmers.

There is a wide gap today in this technology between the research nutritionists who use only single ingredients or a combination of two or three protein meals and the practical feed manufacture who uses a variety of feeds compounded on least-cost basis. Since many developing countries have large quantities of protein meals in the country then technology development to ensure its efficient utilisation should be a matter of priority. In countries where the oilseed meals are unavailable, the potential of forage trees containing tannins, or the treatment of forage tree leaves to protect the protein need to be developed.

THE FUTURE

The challenge for the scientist in many developing countries is to how best combine in a diet for dairy animals the available green forage, crop residues and agro-industrial by-products with the available protein resources and molasses/urea block to optimise milk production. It is likely that the availability of protein for dairy animals is likely to be the primary economic constraint, it is therefore necessary to develop new protein resources (e.g. aquatic plants, tree crops) and to find ways and means of protecting the protein from degradation in the rumen whilst remaining of high digestibility is an urgent priority.

Increasing milk production following optimisation of the efficiency of utilisation of the basal feed resource

The "Greenhouse effect", that is the warming of the Earth's atmosphere because of increased content of carbon dioxide and methane, will in the future require a reduction in production of these gases. Methane produced by ruminants probably contributes about 25% of the increase in global methane concentration in the atmosphere (which is 1% per year at present) and this source of methane can be reduced by decreasing the number of ruminants in the world. This will necessitate a move to increase production per animal to maintain and increase this source of human food. This increase per animal will need to be made within the constraints of the available feed resources.

Milk is essentially water, lactose, protein and fat. To boost production of milk from animals fed available forages above that stimulated by the optimum level of by-pass protein plus urea/molasses blocks, it will be necessary to supplement well balanced mixtures of amino acids (from by-pass protein) and lipids (as unreactive LCFA combined with calcium to form soaps) and by-pass starch.

The role of dietary fat in the nutrition of ruminants has traditionally been looked upon as a means of increasing the energy intake of ruminants without a proportional increase in the quantity of feed consumed. A strong case for inclusion of fats in ruminant diets was made by Milligan (1971) on the basis of the energetic efficiency of incorporation of dietary long chain fatty acids (LCFA) into tissue LCFA of fattening animals. Kronfeld (1976,1982) proposed that an optimal balance between aminogenic, glucogenic as well as lipogenic nutrients is required for maximal efficiency of milk production and prevention of ketosis in highly productive dairy cows. Theoretically, this should be achieved when, amongst others, exogenous LCFA contribute 16% of the total ME intake (Kronfeld, 1976). Similar levels of LCFA inclusion in the diet of lactating cows, was determined to result in an optimal efficiency of nutrient utilization for milk production by Brumby *et al.* (1978).

Very little information is available, however, on the influence of dietary LCFA on the efficiency of nutrient utilization by growing and lactating ruminants, especially when they are fed roughage-based diets. Although results reported in the literature are highly variable, generally it is believed that the inclusion of more than 4-6% fat in the diet will result in a reduced digestibility of fibre in the rumen and sometimes a reduced DMI (Kronfeld, 1982; Moore *et al.*, 1986), unless these lipids are offered in a form which makes them relatively inert in the rumen.

Calcium salts of LCFA (Ca-LCFA) are such a source of ruminally inert LCFA (Palmquist and Jenkins, 1982; Jenkins and Palmquist, 1984) and have been shown to increase milk production by dairy cows when used as a feed supplement (Palmquist, 1984). Interactive effects of dietary LCFA with nutrients other than fibre have received little attention.

An interaction between dietary LCFA and protein meals has been found and on low protein diets, the benefits of dietary fat are only apparent when a by-pass protein is fed (van Houtert and Leng, 1986).

The quantitative importance of these possible nutrient interactions is unknown in dairy animals fed forage based diets but since the nutrients in milk arise from long chain fatty acids, amino acids and glucose, research is now being aimed at developing a supplement which provides directly to the animal.

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