Feed supplementation blocks for increased utilization of tanniniferous foliages by ruminants

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Abstract

Ruminant animals raised in arid, semi-arid and mountainous regions in various parts of the world rely heavily on shrub and tree species as the main diet component. The presence of secondary compounds – mainly tannins – in a wide range of these plant species constrains their fodder potential. Tannins may cause toxicity when present in the hydrolysable (HT) form, and may reduce considerably the nutritive value of browse and tree foliage when they are present in the condensed (CT) form. Tannins form complexes primarily with proteins, but also with carbohydrates, amino acids and several minerals, thereby reducing intake, digestion and animal growth. A number of methods have been tested to de-activate tannins in, or to remove them from, woody species. Amongst these, the use of polyethylene glycol (PEG; MW 4 000 or 6 000), which inactivates tannins by forming complexes with them, was shown to be a promising way to increase the nutritive value of tanniniferous browse and tree foliage. PEG was supplied to animals on tannin-rich diets in different ways (in concentrate or feed blocks, dissolved in water, or sprayed on feed). Feed block, a solidified blend of agro-industrial by-products, was found to be an efficient supplement for increasing intake, rumen fermentation, digestibility and daily weight gain in sheep or goats fed on shrub foliage high in tannins. These positive effects were further strengthened when PEG was incorporated into these blocks. The advantage of these supplements lies in the synchronized, fractionated and balanced supply

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of main nutrients to rumen microflora and the host animal on tannin-rich diets, results attributable to the slow release of PEG on licking of the block by the animal. This slow-release characteristic provides an economic use of this relatively costly tannin-inactivating compound, and maximizes its positive effect on the fodder potential of tanniniferous browse or tree species. Information on the use of feed blocks as supplements for ruminant animals on tannin-rich shrub and tree foliage diets is scanty. The importance of these alternative supplements to livestock raised under agro-pastoral systems and the need to pay more attention to this promising technology are highlighted in this paper. An auxiliary role of feed blocks is their possible use as a carrier for additives: several specific minerals for increasing reproductive performance; anthelmintic medicines to control gastro-intestinal parasites in browsing animals; and rumen modifiers such as saponins to decrease protozoa in the rumen, leading to more efficient microbial protein production. Therefore research and development programmes must be undertaken, aimed at field evaluation, economic analysis, dissemination to a large number of farmers, and better integration of the block technology in feeding systems.

Introduction

Increasing population, economic growth and urbanization are increasing demands for livestock products, which in turn is driving demand for increased feed, and generating additional pressure on natural grazing resources. In addition, lack of regulatory mechanisms to control grazing combined with the expansion of cultivation into previously uncultivated areas is aggravating degradation of rangelands worldwide. It has been proposed that fodder shrubs and trees can be integrated into production systems to provide additional feed resources for use in mixed diets for livestock, to provide a source of fuel, to reduce wind erosion when planted as wind breaks and to stabilize or rehabilitate degraded areas. A major part of diets for ruminants in arid, semi-arid and mountainous areas is derived from shrubby vegetation. Recent research into the constituents of many of these woody plants has shown these plants to contain appreciable quantities of secondary compounds. Among the most investigated of these compounds are tannins. Numerous reviews (Kumar and Vaithiyanathan, 1990; Reed, 1995; Waghorn, Red and Ndlovu, 1999; McSweeney *et al.*, 2001) deal with the structure and biological role of tannins in livestock feeding. These aspects are therefore only briefly mentioned here. This article reviews various methods to de-activate tannins, and discusses the potential use of feed blocks with and without polyethylene glycol (PEG), a tannin-inactivating agent, to promote effective utilization of tanniniferous shrub and tree foliage.

Potential use of tanniniferous feedstuffs

Numerous multipurpose browse trees and shrubs have been identified as having significant potential in agroforestory systems in tropical and Mediterranean-type regions (FAO, 1992; Topps, 1992). In many parts of the world, a wide range of shrub species contribute extensively to livestock feed, mainly for sheep and goats, and contain in most cases a high level of proteins. Admittedly, protein is the most limiting nutrient in the diet of livestock, and which, because of its limited supply, should be used more efficiently to promote fermentation of roughage in the rumen to improve animal performance. Tannins are the most widely occurring anti-nutritional factors found in plants. These compounds are present in numerous tree and shrub foliages, seeds and agro-industrial by-products (Aregheore, Makkar and Becker, 1998; Makkar and Becker, 1998, 1999). The availability and usage of various unconventional feed resources, including new and lesser known ones, the presence in them of deleterious factors, and approaches to remove or inactivate these factors have been dealt with in several reviews (Kumar and Vaithiyanathan, 1990; Makkar and Becker, 1999; Makkar, 2002). Phenolic compounds – particularly tannins and lignin – were shown to reduce the nutritive value of feedstuffs and thereby to limit livestock production and reproductive performance (Waghorn, Red and Ndlovu, 1999). Tannins are classified into two groups: hydrolysable tannins (HTs) and condensed tannins (CTs). Both types are hydrosoluble polymers that form soluble and insoluble complexes, mainly with proteins. They also have some affinity towards carbohydrates, amino acids and minerals. HTs, in contrast to CTs, are partly degraded in the gastro-intestinal tract and several precursors may derive from their glucose and phenolic constituents. Untransformed HTs and their phenolic degradation products may be absorbed from the gastro-intestinal tract, resulting in animal intoxication (Waghorn, Red and Ndlovu, 1999; Makkar, 2002). However, most researchers agree that CTs are not degraded in the animal gut and therefore are not toxic (Makkar, Blümmel and Becker, 1995; Makkar, 2000) under normal feeding situations when browse and tree foliage is used as a supplement. At very high level of browse and tree foliage intake, the intestinal wall may become damaged, leading to absorption of CTs and causing toxicity. However, CTs directly affect the nutritive value of feedstuffs. Until a few years ago, CTs were regarded as useless compounds with only negative effects on intake, digestion, production and reproduction in animals. Recent studies have confirmed that CTs may also have positive effects in ruminants (Barry, and McNabb, 1999; Barry, McNeill and McNabb, 2001). Low CT levels in several plant species, e.g. *Acacia albida* pods (Nsahlai, Umunna and Osuji, 1999), *Lotus pedunculatus* (Barry, Manley and Duncan, 1986) and *Acacia cyanophylla* Lindl. (syn. *Acacia saligna*) foliage (H. Ben Salem, unpublished data) increased daily gain in sheep given protein-rich diets. This effect was ascribed to increased levels of post-ruminally available proteins.

Techniques to de-activate tannins

Various methods have been attempted to de-activate tannins in a wide range of browse species, grain seeds and agro-industrial by-products (Makkar, 2000). These methods have included mechanical or physical techniques (e.g. wilting, processing, ensiling, etc.), inoculation with tannin-resistant bacteria (Miller, Brooker and Blackall, 1995; Molina, Pell and Hogue, 1999) and chemical techniques (treatment with alkalis, organic solvents, precipitants, etc.). The use of polyethylene glycol (PEG; MW 4 000 or 6 000), for which tannins have higher affinity than for proteins, is by far the most used reagent to neutralize these secondary compounds (Makkar, Blümmel and Becker, 1995; Silanikove, Perevolotsky and Provenza, 2001). Consequently, it would be possible to increase the nutritive value of tannin-rich browse by adding compounds such as PEG, which preferentially binds the tannins, making plant proteins more available for digestion. This strategy is very useful in situations where foodstuffs contain high concentrations of tannins. Different means of administering PEG have been used in the literature to assess the fodder potential of tanniniferous plant species. PEG was included either in concentrate supplement (Ben Salem *et al.*, 1999a; Decandia *et al.*, 2000), dissolved in drinking water (Ben Salem *et al.*, 1999a), infused orally (Wang *et al.*, 1996; Gilboa *et al.*, 2000) or sprayed in solution on browse foliage (Ben Salem *et al.*, 1999b) given to ruminant animals. The response to PEG supply in terms of intake, digestion and production varied with the mode of PG application. To our knowledge, Ben Salem *et al.* (1999a) were the only authors who have reported a comparison of the three methods of PEG provision for sheep on *Acacia cyanophylla* Lindl. foliage. On the basis of improvement in rates of acacia intake, apparent diet digestibility, rumen fermentation and microbial synthesis, PEG in concentrate ranked first, followed by PEG in drinking water and then PEG sprayed on foliage. However, the relatively high cost of this tannin-inactivating agent for smallholder farmers encouraged a search by others for alternative, more cost effective means of administering PEG, thereby economizing in the use of this tannin-neutralizing agent. Feed blocks seem to satisfy the objective.

Feed block technology to valorize tannin-rich diets

What are feed blocks and why to use them?

Feed blocks are a solidified blend of ingredients based on use of a high level of agro-industrial by-products. The formula of this non-conventional supplement includes one or more binders (quicklime, cement, bentonite, etc.), common salt as a preservative, urea as a non-protein nitrogen source, and other ingredients as carrier of nutrients, mainly energy, nitrogen and minerals. They are intended to supplement ruminants on poor quality diets (cereal straw, stubble, native pastures, etc.). The use of feed blocks in livestock feeding seems to be older than indicated in the literature, where most papers have been published in the last two decades (Sansoucy, 1986, 1995). It appears from Cordier's (1947) review that these alternative supplements were used in Tunisia in the 1930s, but were overlooked thereafter, until the 1990s, when research and development efforts gathered momentum, aiming at wide dissemination and adoption of this technology, mainly for smallholder farmers. At least 60 countries are now using this technology as a strategic supplement for ruminants, mainly cows, sheep and goats raised under harsh conditions. Mini-blocks free of urea have also been developed for rabbits (Sansoucy, 1995; Ramchurn and Ragoo, 2000).

A series of feed block formulas have been developed, evaluated 'on-station' and 'on-farm', and many of them have been adopted by farmers. Ben Salem and Nefzaoui (2003) have recently reviewed about 25 formulas for both molasses-free and molasses-containing blocks. Although several authors considered molasses to be an essential ingredient for feed block manufacture and acceptance by livestock, the lack of this agro-industrial by-product in many countries has encouraged researchers to develop formulas without molasses. Different types of molasses-free blocks have been shown to be efficient in terms of degree of acceptance by ruminant animals and positive effects on the nutritive value of low quality roughages given to penned or grazing animals, with consequent better livestock growth.

The wide use of feed blocks throughout the world indicates their importance in the development of the livestock sector and improvement in farmer revenues. Their use allows a continuous and balanced supply of nutrients (energy, nitrogen, minerals and vitamins) to the animal. Moreover, their greatest value lies in their role as a cost-effective supplement and as a means for utilizing several high-moisture-content agro-industrial by-products (e.g. olive cake, tomato pulp, citrus pulp), and thereby extending their usefulness. Also, material unfit for human consumption can be converted into high quality animal protein. Such technology is technically simple and does not require high investment, so it is easily adoptable by small-scale farmers. This technology offers a mean of making use of agro-industrial by-products and waste so far not fully utilized by domestic livestock. Additionally, it may play an important role in protecting the environment from pollution associated with disposal of some agro-industrial by-products. Finally, current research studies showed that feed blocks are an efficient carrier for tannin-neutralizing reagents, particularly PEG for ruminants on tanniniferous plant species, and also as a carrier for medication, such as anthelmintic medicines to control gastro-intestinal parasites. Table 13.1 reports formulas for blocks used as supplements for tannin-rich diets. These blocks were both with or without molasses and with or without PEG.

Feed blocks as catalytic supplements for animals on tannin-rich diets

Woody vegetation is often the main diet of ruminant animals raised in arid, semi-arid and mountainous zones. The low nutritive value of these diets – due to low levels of energy and nitrogen or the presence of tannins – results in reduced animal performance. In many situations, farmers use considerable quantities of concentrate feeds as supplements for their animals. The replacement of these expensive supplements with alternative feed sources would decrease the cost of feed. Feed blocks seem to be an interesting alternative.

Table 13.1
Formulas and chemical composition of feed blocks given to sheep or goats fed tanniniferous shrubs and trees.

Item	Formula								
	1	2	3	4	5	6	7	8	9
Ingredients (as percentage of DM)									
Olive cake	38.0	31.2	40.1	38.0	35.6	36.7	33.1	13.8	10.2
Wheat bran	28.0	23.0	25.1	23.7	22.2	24.3	21.8	36.5	30.3
Wheat feeds	11.0	9.0	12.3	11.6	10.9	–	–	–	–
Molasses	–	–	–	–	–	–	–	9.5	9.3
Opuntia fruit	–	–	–	–	–	9.0	8.0	–	–
Urea	5	4.1	7.3	–	6.4	7.3	6.6	11.4	11.2
Cement	–	–	–	–	–	–	–	11.6	11.2
Quick lime	12.0	9.9	9.2	8.7	8.1	15.4	13.9	–	–
Salt	5.0	4.1	7.3	–	6.4	7.3	6.6	5.8	5.6
Di-calcium phosphate	–	–	–	–	–	–	–	5.7	5.5
Mineral-vitamin supplement	1.0	0.8	1.3	1.0	1.0	–	–	5.7	5.5
PEG 4000	–	18.0	–	12.5	11.7	–	10.0	–	11.2
Chemical composition (g/kg DM)									
Dry matter (g/kg)	691	705	866	857	863	860	830	–	–
Ash	249	245	309	291	284	357	421	295	280
Crude protein	214	210	235	101	235	225	193	381	369
NDF	206	209	219	212	218	323	199	261	210
ADF	133	121	187	184	182	225	187	117	87

KEY: NDF = neutral digestible fibre. ADF = acid digestible fibre.

SOURCES for formulas: 1 and 2 – Ben Salem *et al.*, 2000b. 3, 4 and 5 – Ben Salem *et al.*, 2002; 6 and 7 – Ben Salem *et al.*, 2003; 8 and 9 – Moujahed *et al.*, 2000.

However, very little is known about the effect of feed blocks on the nutritive value of tannin-rich diets and consequent livestock production. Ben Salem, Nefzaoui and Ben Salem (2000) concluded that supplementing with olive-cake-based blocks for goats grazing shrubland dominated by tannin-rich shrub species (*Olea europea, Pistacia lentiscus*, etc.) did not affect their feeding behaviour, but increased their daily gain by 60 percent compared with those not receiving supplements (Table 13.2). The growth rate was further increased when a mixture of small amounts of spineless cactus pads (100 g dry matter) and fresh foliage of *Atriplex nummularia* (100 g dry matter) was offered to goats. The authors are not aware of any other study dealing with the effect of feed blocks on the nutritive value of tree and shrub foliage high in tannins. However, McMeniman (1976) and Gartner and Niven (1978) showed beneficial effects with several minerals (phosphorus, sulphur, etc.) given to sheep on *Acacia aneura*, a tannin-rich shrub species. Increased intake, digestion, daily gain and wool growth suggest that blocks may be used successfully as a carrier for these minerals. The enormous advantage in this case is the possibility of providing a supplement to animals on tanniniferous shrub species whilst they are still in the rangeland.

Feed blocks as a cost-effective carrier of PEG to de-activate browse tannins

Does the synchronization of tannin consumption and PEG supply optimize the beneficial effect of PEG on the nutritive value of tanniniferous browse species? This hypothesis has been investigated and results seem to favour the use of PEG as a tannin inactivating agent in feed blocks. Synchronization with a fractionated and balanced supply of nutrients are the main advantages of feed block use from the nutritional point of view. Therefore, hardness and compactness are crucial criteria that should be borne in mind when defining a formula and making blocks. The choice of appropriate binder and its proportion in the ingredient mixture is important. The assessment of feed block hardness and density, as well as the manufacturing techniques for these non-conventional supplements, have been reviewed by Ben Salem and Nefzaoui (2002). PEG should be dissolved in water, and then the urea and salt added. The final solution is sprinkled gradually on the other solid ingredients. The most-used binders have been cement and lime, in proportions between 10 and 15 percent. A harder block makes the animal lick the feed block continuously. This releases small amounts of the main nutrients relatively continuously into the rumen, in short bursts depending on the licking frequency, which would be catalytic for microbial activity and stimulate digestion of poor quality feedstuffs. Moreover, this also avoids urea intoxication.

Using hard feed blocks could be a way to ensure continuous and slow release of PEG to the animal. Ben Salem *et al*. (2000) confirmed the enormous advantage of PEG-containing feed blocks for sheep on a tannin-rich browse foliage, namely fresh leaves of *Acacia cyanophylla*. These authors included graded levels of PEG 4000 (0, 6, 12, 18 and 24 percent) in olive-cake-based feed blocks (see Formulas 1 and 2 in Table 13.1). Linear increases were recorded in acacia intake, and in organic matter, crude protein and fibre *in vivo* digestibilities of the diet. An improvement was evident in the nitrogen value of the diet, as reflected by an improved nitrogen balance and increased microbial nitrogen supply.

Table 13.2
Effect of feed block supply on behavioural activities and growth of goats on shrublands.

Parameter	Treatment			Standard Error (Significance)
	No supplement	Feed blocks[1]	Cactus + atriplex	
Browsing time[2]	41.9	38.0	43.7	2.76 (NS)
Grazing time[2]	45.7	48.7	44.5	2.72 (NS)
Walking time[2]	6.7	7.3	6.3	0.68 (NS)
Resting time[2]	5.8	5.9	5.4	0.78 (NS)
Daily gain (g)	25	41	60	5.02 (*)

NOTES: (1) Using formula 1 in Table 13.1. (2) Expressed as the percentage of total time spent by goats in the rangeland. NS = non-significant effect ($P > 0.05$). * = $P < 0.05$.

SOURCE: Ben Salem, Nefzaoui and Ben Salem, 2000.

The improvement of the nutritive value of diets resulted in increased growth rates in sheep. Since responses obtained with 18 and 24 percent PEG in feed blocks were similar, the authors recommended limiting the level of PEG to 18 percent to obtain an optimal positive effect from feed block use. Sheep given feed blocks containing 18 percent PEG consumed approximately 23 g PEG/day. The slow release of PEG, and therefore the synchronized consumption of tannins and PEG, is probably the main explanation of the beneficial effect of PEG-containing feed blocks. This hypothesis was corroborated *in vitro* by Getachew, Makkar and Becker (2001), who found that PEG introduced into the *in vitro* rumen fermentation system as split rather than single doses gave the highest microbial nitrogen synthesis from some tannin-rich fodder shrubs.

The contention of one of the authors (H.P.S. Makkar) that inclusion of high levels of urea in PEG-containing blocks may not be necessary since PEG is expected to dissociate tannin-protein complexes, and thus increase the level of available nitrogen was confirmed by Ben Salem *et al.* (2002), who showed that lambs on acacia foliage supplemented with blocks containing PEG and urea had increased dry matter intake of supplemented acacia foliage, microbial nitrogen supply and growth rate (Table 13.4), similar to those with blocks containing PEG without urea (see formulas 3, 4 and 5 in Table 13.1).

Table 13.3

Intake, *in vivo* digestibility, nitrogen balance, microbial synthesis and daily gain in sheep fed on fresh foliage of *Acacia cyanophylla* and supplemented with molasses-free feed block with or without PEG.

Parameter	Acacia + PEG-free block(1)	Acacia + PEG-containing block(2)
Dry matter intake (g/kg $W^{0.75}$)		
Acacia	37.7	58.8
Feed block	13.7	14.0
Total	51.4	72.8
Diet digestibility (%)		
Organic matter	33.3	43.2
Crude protein	43.5	55.1
Nitrogen retained (g/day)	- 1.5	2.5
Microbial nitrogen(g/kg DOMI)(3)	4.9	11.5
Daily gain (g/day)	14	61

NOTES: Except for intake, the difference between the two diets was significant ($P < 0.05$) for each parameter. (1) Formula 1 in Table 13.1. (2) Formula 2 in Table 13.1. (3) DOMI = digestible organic matter intake.

SOURCE: Ben Salem *et al.*, 2000b.

Table 13.4

Effect of administering PEG in concentrate or feed blocks on dry matter intake (DMI; g/day), microbial nitrogen supply (g/kg digestible organic matter intake), daily weight gain and meat quality of Barbarine lambs fed *Acacia cyanophylla* Lindl.

	C	CPEG	BU	BUPEG	BPEG	S.E.
Intake factors [1]						
Acacia DMI	599^{a}	656^{a}	457^{b}	688^{a}	704^{a}	18.1
Microbial N supply	9.9^{b}	24.1^{a}	1.3^{c}	10.0^{b}	14.9^{b}	1.08
Daily gain	78^{b}	116^{a}	2^{c}	59^{b}	62^{b}	5.2
Meat factors [2]						
Lightness (L*)	45.21^{ab}	42.60^{c}	45.89^{a}	43.57^{bc}	42.21^{c}	0.643
Shear force (kgF)	2.51^{b}	2.73^{ab}	3.42^{a}	3.26^{a}	3.27^{a}	0.211
Tenderness	7.65^{a}	7.80^{a}	6.97^{b}	7.32^{ab}	7.27^{ab}	0.180

KEY: C = acacia ad lib + 300 g concentrate daily. C_{PEG} = C + 20 g PEG daily. BU = acacia ad lib + urea-containing block (Formula 3 in Table 13.1). BU_{PEG} = acacia ad lib + block containing urea and PEG (Formula 5 in Table 13.1). B_{PEG} = acacia ad lib + urea-free block containing PEG (Formula 4 in Table 1). S.E. = standard error.

NOTES: Tenderness: Five panellists were asked to score the meat samples, using a nine-point intensity scale for tenderness at first bite (extremely tough to extremely tender) (for further details, see Priolo *et al.,* 2002).

^{a,b,c} = Means in the same line with different superscripts are significantly different ($P < 0.05$).

SOURCES: [1] Ben Salem *et al.*, 2002. [2] Priolo *et al.*, 2002.

Excessive nitrogen supply, mainly in soluble form, results in a release of ammonia that often exceeds its rate of incorporation into microbial protein, resulting in loss of a great part of this nitrogen as ammonia absorbed from the rumen. The situation is aggravated in the rumen in the absence of adequate levels of energy source. In addition, excretion of ammonia from the body in the form of urea in the urine is an energy-expensive process. Therefore, the nitrogen profile and energy content of block ingredients and the basal diet should be considered when fixing the urea level in the block.

In another experiment, amounts close to the optimum level of PEG included in feed blocks (i.e. corresponding to a daily intake of 23 g) observed by Ben Salem *et al*. (2000) eliciting the highest improvement in the daily weight gains of lambs on acacia-based diets were incorporated in concentrate, drinking water or sprinkled as solution on acacia foliage (Ben Salem *et al*., 1999a). Table 13.5 compares the four modes of administering PEG in terms of the response in feed intake, apparent digestibility, nitrogen balance, microbial protein synthesis, rumen fermentation parameters and growth rates. The responses were expressed as percentage change compared with the corresponding PEG-free diet (control diet). Inclusion of PEG in feed blocks was generally associated with the highest increase in dry matter intake. However, the response for crude protein digestibility was lowest when administered in feed blocks. PEG-free feed blocks are often high in crude protein (200 to 350 g/kg DM) compared with concentrate. Therefore, the level of CP in the diet may be sufficient for rumen microflora and probably for the host animal, and therefore the inclusion of PEG in feed blocks did not lead to a significant increase in the CP digestibility of the diet. Whatever the administering mean, PEG had no effect on pH and molar proportion of short chain fatty acids in the rumen fluid. However, similar to findings from *in vitro* investigations (Getachew, Makkar and Becker, 2001), the levels of NH_3-N and the concentration of volatile fatty acids were significantly increased with PEG supply. The extent of this increase was highest with PEG-containing concentrate, while PEG in drinking water or in feed blocks resulted in similar increases in NH_3-N in the rumen fluid of sheep on acacia foliage (+34 and +31 percent, respectively).

Table 13.5
Effects of PEG on intake, digestibility and fermentation parameters in sheep and goats given tannin-rich diets (responses expressed as percentage change compared with corresponding PEG-free diets).

	PEG administration mode(4)			
	Concentrate	Drinking water	Sprinkled on foliage	Feed block
Acacia DM intake				
	+35	+23	NS(1)	+73
	–	–	–	NS[c]
	+9	–	–	+54
Apparent digestibility				
Dry matter	NS[a]	NS(1)	NS(1)	+47(2)
Crude protein	+105(1)	+90(1)	+72(1)	+27(2)
Crude protein	–	–	–	+25(3)
Crude protein	+38(4)	–	–	+45(4)
In sacco degradation of acacia				
DM	+75(1)	+84(1)	+84(1)	NS(3)
Nitrogen	–	–	–	+28(3)
Fermentation parameters				
pH	NS(1)	NS(1)	NS(1)	NS[c]
NH_3-N	+202(1)	+34(1)	+95(1)	+31(3)
Total VFA	+34(1)	+22(1)	+33(1)	+10(3)
Acetic acid	NS(1)	NS(1)	NS(1)	NS(3)
Propionic acid	NS(1)	NS(1)	NS(1)	NS[v]
Butyric acid	NS(1)	NS(1)	NS(1)	NS(3)
Protozoa	–	–	–	+13(3)

KEY: NS = Effect not significant. VFA = volatile fatty acids. DM = dry matter.
NOTES: (1) Data from Ben Salem *et al*. (1999a). Control diet: fresh foliage of acacia ad lib + 300 g concentrate daily. (2) data from Ben Salem *et al*. (2000b). Control diet: fresh foliage of acacia ad lib + feed block (see Formula 1 in Table 13.1; Formula 2 corresponds to PEG-containing block). (3) Data from Moujahed *et al*. (2000). Control diet: air-dried foliage of acacia ad lib + 400 g oat-vetch hay + feed blocks (see Formula 8 in Table 13.1; Formula 9 corresponds to PEG-containing block). (4) *Amounts of PEG administered in concentrate, water, feed blocks or sprayed on acacia foliage were quite similar (20–23 g/day).

This trend seems to be related to the time needed for consumption of the entire amount of PEG. Indeed, PEG-containing concentrate is consumed rapidly by sheep in a few minutes, and therefore a peak of NH_3-N in the rumen fluid is observed during the first few hours post-feeding, which rapidly decreases thereafter. In contrast, consumption of PEG-containing drinking water and feed blocks was fractionated over the day. Consequently, the increase in ammonia concentration generated by PEG-containing blocks would be less pronounced than that from PEG in concentrate.

The effect of PEG supply on the turnover rate of particles in the rumen of sheep fed acacia foliage and 400 g oat-vetch hay was investigated by Moujahed *et al*. (2000). Feed block supply (Formula 8 in Table 13.1) increased the particle outflow rate (from 3.27 to 4.04 percent per hour). The enrichment of these feed blocks with PEG (Formula 9 in Table 13.1) further increased this parameter (to 4.67 percent per hour). Energy, nitrogen and minerals simultaneously provided to sheep through feed blocks may have stimulated microbial activity and thereby increased the rate of fibre degradation in the rumen. Moreover, these authors suggested a possible physical effect of blocks resulting from increase in the proportion of dense particles near the reticulo-omasal orifice, leading to an increased amount of dry matter evacuated. The PEG in feed blocks was released slowly. This may have further increased the level of available proteins from the diet through dissociation of acacia tannin-protein complexes and therefore further stimulated fibre degradation in the rumen. Additionally, the increase in water consumption by sheep given feed blocks with or without PEG may have accelerated the rate of digesta outflow. It is evident that increased water consumption with feed block supply was due to the presence of salt. In addition, salt restricts free intake of the block and obliges the animal to consume small amounts continually over the day. This results in slow release of nutrients and of PEG. However, the increased water consumption by sheep receiving PEG-containing blocks is surprising in the absence of any variation in block and total diet intakes between groups with PEG-containing or PEG-free blocks. Moujahed and co-workers (2000) ascribed this to possible increase in the rate of fermentation in the rumen because water intake seems to be the mechanism by which ruminants adjust the osmotic pressure in the rumen. In the absence of other studies confirming these findings, the effect of PEG supply on water intake by ruminants on tannin-rich diets warrants further investigations.

Irrespective of administration mode, PEG supply increased urinary excretion of allantoin and consequently microbial nitrogen supply. The response was more pronounced when PEG was included in concentrate or feed blocks than when in drinking water or sprayed as solution on browse foliage (Table 13.6). Worth noting is that the highest nitrogen retention was seen when PEG was included in blocks. The improved intake of the tannin-rich shrub (acacia foliage), higher organic matter, fibre and protein digestibility of the diet, better rumen fermentation, increased microbial nitrogen supply and better nitrogen balance due to PEG supply explain the increased daily gain of sheep on acacia-based diets. Interestingly, the highest response for growth rate was with PEG-containing blocks.

Table 13.6
The effects of PEG on particle transit, allatoin excretion (as an index of microbial systhesis), microbial synthesis, N balance and daily weight gain in sheep given *Acacia cyanophylla*-based diets (responses are expressed as percentage change from corresponding PEG-free diets).

	PEG administration mode[5]			
	Concentrate	**Water**	**Treatment**	**Feed blocks**
Ruminal mean retention time	–	–	–	-14[3]
Microbial synthesis				
Allantoin in urine	+85[1]	+49[1]	+24[1]	+65[2]
Allantoin in urine	NS[d]	–	–	+1046[d]
Nitrogen retention	+218[1]	+218[1]	+82[1]	+270[2]
Nitrogen retention	–	–	–	+88[3]
Nitrogen retention	+67[4]	–	–	+93[4]
Daily gain	–	–	–	+336[2]
Daily gain	+49[4]	–	–	+3000[4]

KEY: NS = Effect not significant.

NOTES: (1) Data from Ben Salem *et al*. (1999a). Control diet: fresh foliage of acacia ad lib + 300 g concentrate daily. (2) data from Ben Salem *et al*. (2000b). Control diet: fresh foliage of acacia ad lib + feed block (see Formula 1 in Table 13.1; Formula 2 corresponds to PEG-containing block). (3) Data from Moujahed *et al*. (2000). Control diet: air-dried foliage of acacia ad lib + 400 g oat-vetch hay + feed blocks (Formula 8 in Table 13.1; Formula 9 corresponds to PEG-containing block). (5) Amounts of PEG administered in concentrate, water, feed blocks or sprayed on acacia foliage were quite similar (20–23 g/day).

The effect of PEG-free or PEG-containing block supplementation on meat and milk quality of ruminants fed on tannin-rich diets has not been fully investigated. To the present authors' knowledge, the only work addressing this was recently published by Priolo *et al*. (2002). It was evident from this work that meat from Barbarine lambs on air-dried foliage of *Acacia cyanophylla* (CT = 60.0 g equivalent leucocyanidin/kg DM) and supplemented with concentrate or olive-cake-based blocks had the same chemical composition (moisture, ash, protein and fat). Using PEG as the tannin-neutralizing agent, these authors concluded that CT in acacia affected lean colour and lightness. The lightness was higher in those lambs that did not receive PEG, indicating that CT can make meat lighter in colour. Meat from sheep that received supplementation of concentrate had lower values for Warner-Bratzler shear device resistance compared with those that received blocks. The panel test confirmed this result: meat from concentrate-receiving lambs was more tender than that obtained from block-receiving lambs. PEG introduced in either concentrate or blocks increased intensity of flavour, but had no effect on overall acceptability (Table 13.4). According to Priolo *et al*. (2002) and Priolo and Ben Salem (2003), blood haemoglobin level – which was lowered by CT – is correlated with muscle lightness. Increased meat lightness is probably a consequence of reduced muscle iron content in animals fed CT-rich diets. Ben Salem *et al*. (2002) and Priolo *et al*. (2002) concluded that increasing the energy level of feed blocks by including an energy-rich ingredient such as prickly pear fruit (*Opuntia* spp.) or molasses might result in a significant positive improvement in the nutritive value, growth and meat quality of lambs fed on acacia-based diets. This recommendation was considered by Ben Salem *et al.* (2003) in a recent study in which the effects of PEG-containing, PEG-free blocks and PEG given separately in a small amount of barley with a PEG-free block were investigated, assessing intake, digestion, clinical and biochemical parameters in goats given kermes oak (*Quercus coccifera* L.) foliage (Table 13.7).

Kermes oak (*Quercus coccifera* L.) is a shrub species widespread in Mediterranean garigue ecosystems. Its nutritive value is low due to a low level of crude protein and relative high proportion of tannins. Foliage of kermes oak (CT = 71.0 g equivalent leucocyanidin/kg DM) was given as sole diet to goats or supplemented with blocks incorporating olive cake and prickly pear fruit. Prickly pear is the fruit of a cactus, *Opuntia* spp., and is high in soluble carbohydrates, and thus used as an energy source in the block formula. PEG was included in these blocks or supplied separately, i.e. mixed with 5 g of processed barley grains, and offered to the animal at the same time as the blocks (using Formulas 6 and 7 in Table 13.1).

Table 13.7
Effect of PEG-containing feed block (B_{PEG}), PEG-free feed block alone (B) and PEG supply with PEG-free feed block (B + PEG) on intake, digestion and nitrogen balance in goats given kermes oak (*Quercus coccifera* L.) foliage.

Basal diet	**Supplement(1) with kermes oak foliage ad lib**				**SEM**	**C1**	**C2**
	Control	B	B + PEG	B_{PEG}			
DM intake (g/day)							
Kermes oak	331^{b}	627^{a}	604^{a}	747^{a}	34	**	*
Feed block	-	113	141	149	–	–	–
Diet digestibility (%)							
Organic matter	55.2^{b}	65.5^{a}	63.1^{a}	64.9^{a}	1.2	**	NS
Crude protein	33.2^{b}	47.1^{ab}	57.8^{a}	59.6^{a}	2.4	**	**
NDF	42.9^{b}	56.6^{a}	56.7^{a}	55.5^{a}	1.8	**	NS
N intake (g/day)	3.9^{b}	13.6^{a}	12.5^{a}	14.9^{a}	0.8	***	*
Faecal N (g/day)	2.4^{b}	7.2^{a}	5.5^{a}	5.9^{a}	0.4	**	NS
Urinary N (g/day)	0.1	0.1	0.2	0.1	0.03	NS	NS
N retained (g/day)	1.3^{b}	6.3^{a}	6.7^{a}	8.8^{a}	0.5	***	**

KEY: SEM = standard error of the mean. C1 = contrast 1: mean effect of feed block (control vs (B + (B+PEG) + B_{PEG})). C2 = contrast 2: mean effect of PEG supply (control + B) vs (B_{PEG} + (B+PEG)). NS = not significant. ^{a,b} Means in the same line with different superscripts are significantly different ($P < 0.05$).

NOTES: (1) Supplementation: Control = no supplement; B = feed block without PEG; B+PEG = PEG-free feed block, with PEG supplied once daily separately in a small amount of processed barley; B_{PEG} = PEG-containing feed block. The amount of PEG distributed to goats in group B+PEG corresponded to the amount of PEG consumed by goats given PEG-containing blocks (B_{PEG}). On average, goats on B+PEG and B_{PEG} diets consumed 15 g PEG/day.

SOURCE: Ben Salem *et al.*,2003.

Although DM intake of feed blocks was low (113 g/day), supplementation with PEG-free blocks almost doubled consumption of kermes oak foliage (61.2 vs 34.8 g DM/kg $W^{0.75}$) and DOMI and CP intake increased from 17.4 and 1.0 g/kg$W^{0.75}$ to 46.6 and 33.0 g/kg$W^{0.75}$, respectively. There was no obvious improvement in these parameters from incorporation of PEG in the block or by supplying PEG alongside the block (B_{PEG} and B+PEG versus B). Irrespective of dietary treatments, blood constituents, such as glucose, urea, total proteins, albumin, creatinine, calcium, phosphorus and magnesium, and the enzyme gamma-glutamyltranspeptidase were within the normal range for local goats. Feed blocks increased serum urea significantly, probably as consequence of improved nitrogen availability from the diet. Supplementation with feed blocks with or without PEG improved cardiac, respiratory and rumen contraction frequencies, and raised body temperature to the normal value (37°C). Olive-cake-based feed block enriched with squeezed cactus fruits was found to be a cost-effective supplement to substantially improve the nutritive value of kermes oak-based diet and to maintain goat health. This study indicated that the optimal increase in the nutritive value of kermes oak-based diets was obtained with PEG-free blocks. This seems to suggest that appropriate supplementation with major nutrients may be sufficient to improve digestion of browse species high in tannins. The further increase expected from PEG supply is most likely to be plant species specific, based on the level and structure of tannins. Increased intake of PEG with increased tannin content has been demonstrated (Provenza *et al.*, 2000). The level of PEG in the block would depend on the level and activity of the tannins present in the browse fed to the livestock. Protein and PEG both bind tannins and inactive them. The degree of effectiveness of PEG incorporation, therefore, also depends on the level of protein present in the browse (Makkar, Blümmel and Becker, 1995).

Other possible uses of feed blocks

In addition to nutrient supply and slow release of PEG, feed blocks have been used successfully as carriers of anthelmintic medicines to control gastro-intestinal parasites in grazing sheep (Anindo *et al.*, 1998). This is an additional advantage, which facilitates management of grazing livestock and reiterates the importance of this technology in enhancing animal production and promoting sanitary conditions. Improved reproduction performance in ewes and rams supplemented with feed blocks containing

Cu and Zn (Al-Haboby *et al*., 1999) would suggest that these blocks may be enriched with some specific minerals to stimulate digestion of tannin-rich shrub species. Although not yet investigated, it would be interesting to include some specific amino acids and peptide-containing agro-wastes in feed blocks for ruminants on poor quality diets. Finally, some tannin-rich agro-industrial by-products might be introduced into feed blocks (grape marc, etc.) to increase their nutritive value and to increase the level of by-pass proteins in the diet.

Conclusion and research needs

In mountainous, arid, semi-arid and humid zones, shrub and tree foliage is the only feed for ruminants most of the year, so the exploitation of their full nutritional potential is vital for achieving enhanced animal productivity. A wide range of these plant species are good sources of proteins, some others are high in energy or minerals. However, the presence of several secondary compounds, considered to be plant defence mechanisms developed against herbivores, negatively affect the nutritive value of browse species. The feeding of such shrub and tree foliage reduces animal productivity and in some cases causes intoxication. Tannins have been shown to be constraining elements in intake and digestion of numerous temperate and tropical shrub and tree foliage feeds. The effect of tannins can be mitigated by use of tannin counteractants, such as PEG. Amongst various ways of PEG incorporation in the diet, the use of feed blocks containing PEG has several advantages over other methods. The use of these blocks allows slow release of PEG, which enhances its overall effectiveness, leading to higher microbial protein synthesis in the rumen and improved animal responses. In addition, this gives an opportunity to reduce overall cost, as less PEG is needed when incorporated in the feed block, and it enables animals to control their intake of PEG according to the level and activity of tannins in the browse. Block technology offers advantages in terms of easy preparation, storage, transport and use by the farmers. In addition to utilization of agro-wastes, and in particularly those having a short shelf life, block technology provides opportunities for farmers to manage supplementary feeds throughout the year based on the availability of feed resources. The most important advantage of these blocks lies in the possible reduction in concentrate use, thereby reducing feeding costs. The feed blocks could also be used as a carrier for various medicines, natural plant products, minerals, etc. Although the potential of blocks is gradually being recognized, there is need for more research on appropriate formulations and use of these alternative supplements. More effort needs to be directed to ensuring wider adoption of this technology by farmers.

There are some research and development topics related to the use of block technology for enhancing utilization of shrub and tree foliage, including:

- characterizing the nutritional parameters of fodder shrubs and trees, mainly for the presence of secondary compounds and their effect on the nutritive value of shrubby vegetation;
- developing block formulas that use locally available and inexpensive ingredients and reflect the nutrient and anti-nutrient contents of local shrub and tree foliage;
- investigating whether the introduction of PEG in feed blocks is necessary, and, if in the affirmative, identifying national optimal levels based on protein content and tannin content and activity;
- convincing farmers of the effect of secondary compounds on animal production and hence the beneficial effect of blocks, without or with PEG, for increasing utilization of tanniniferous plants;
- conducting economic analyses (cost–benefit ratio) of incorporating PEG in feed block;
- integrating fodder shrubs and trees into existing range-livestock and crop-livestock production systems, in a way that is economically and socially acceptable to farmers and herders;
- developing strategies for facilitating technology transfer and adoption by farmers; and
- assessing the effect of feed blocks containing PEG on product quality – milk and meat in particular – considering consumer preferences for these products.

Whatever strategy is to be followed for promoting feed block integration in feeding regimes based on tanniniferous plant species, the farmer-participation approach should be an integral element. Research on feed block formulation and use must not only address farmers' problems, but also seek their participation and involvement in the adaptive research. The objective is to ensure that technology is developed to meet specific needs, and that it applies to the target environment. This type of research provides researchers with feedback from farmers and end users, enabling the researchers to modify their technology to better respond to end-user circumstances. On-farm trials are a substantial step beyond on-station research, allowing more realistic testing of new technologies while stimulating new research. A participatory approach is a recognized alternative for generating, adapting and transferring new technologies. It is therefore important that scientists develop a working relationship with farmers at all stages of the livestock research process, from the laboratory to on-farm trials to general adoption.

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Experiences with urea-molasses blocks manufacture and use in the Sudan

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Introduction

From the mid-1970s and into the 1980s, the Sudan witnessed successive incidents of drought, coupled with land misuse (e.g. overgrazing, range fires, encroachment, and mechanical plantation of cash crops into rangelands). These led to desertification and deterioration of the natural pasture, which provides about 80 percent of the feed required by the huge national herd, estimated at 102 million head. This difficult situation triggered thoughts of utilizing agro-industrial by-products as animal feeds. The idea was further strengthened by the wide drought that hit the country in 1984, leading to great losses of livestock and a subsequent request from the Government of the Sudan to FAO for assistance in manufacturing and distribution of urea-enriched molasses blocks (UMBs) to save livestock from starvation.

Molasses is a major by-product of the sugar industry and is considered a good source of energy for feeding ruminants as it contains high levels of sugars (48–56 percent). Molasses is deficient in protein (<3.5 percent), but it contains water soluble vitamin B, together with iodine, sulphur, cobalt, lead, zinc and manganese. Its proximate analysis indicates 26.5 percent moisture, 3.5 percent crude protein, 0.15 percent ether extract, 57.65 percent N-free extract and 12.2 percent ash.

The sugar industry in the Sudan started initially in 1963, and currently there are five sugar factories, at Kenana, Assalya, Sinnar, Geneid and New Halfa. These factories produce about 250 000 tonne of molasses annually. Although molasses is a good source of energy, its physical form – a sticky liquid – limits its wide use in animal feeds in the Sudan, where storage facilities, transport tankers and pumps that can handle molasses are not easily found in the traditional livestock sector. There was also a great need for efficient extension services among livestock owners who, when

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the project started, lacked understanding of the benefits they could gain by using molasses as a feed substitute. The use of UMBs could have an enormous impact in the Sudan, due to:

- The huge size of animal herd.
- The presence of a flourishing sugar industry in the country.
- An estimated seven-million-tonne animal feed deficit.

The UMB Project

The UMB project was established in 1986 with financial support through FAO, with an annual production capacity of 600 tonne, that could be increased to 2 500 tonne/year. The set up of the project was simple so that the idea could be transferred to other localities. It constituted:

- a 12 × 12 m shed;
- a 12-tonne-capacity tank for molasses storage;
- a 5-tonne-capacity holding tank with tower;
- a mono-pump with three-inch steel pipes, a filter and valves;
- a cement mixer;
- a skip bucket and pulley system; and
- weld-free moulds

UMB production

Initial output was small in volume due to the difficulty of marketing the blocks, as the animal producers were not familiar with them and their use. However, as a result of widespread extension efforts, distribution of the molasses feed supplementation blocks increased from 20.4 tonne in 1986 to over 2 000 tonne in 2000. It is noteworthy that the project contributed to alleviating the effect of shortage of animal feed during the drought of 1990 in the Red Sea area.

Composition and feed ingredients

The project was started in 1986, and production was based on a formula of 50 percent molasses, 25 percent wheat bran, 10 percent cement, 10 percent urea and 5 percent salt. However, it was later observed later that the livestock producers did not follow instructions when offering the blocks to the animals. Some herders used to dissolve the cubes in water, and others broke them into small pieces. It was then felt necessary to reduce the percentage of urea to only 6 percent and cement to 7.5 percent.

Other ingredients that can be used in UMMBs are groundnut hulls and bagasse as structural materials. However, they are not as desirable as wheat bran, which has a high nutritive value and gives a smooth, coherent and compact block. When wheat bran is used, a 25×25×16 cm block weighs about 12 kg. With bagasse or groundnut hulls instead of wheat bran, the same sized blocks are lighter, at about 8 kg. However, it is advisable to use the bagasse and hulls in areas where they are found in abundance. Quicklime (CaO), ash and clay could also substitute for cement as a binding material. Quicklime is a good source of calcium, but its use is constrained by two factors:

- it needs grinding before use, and the dust generated during the milling process is injurious to the workers; and
- its efficiency as a binding material declines quickly upon exposure to air as it absorbs environmental moisture and changes into Ca (OH) in about 3–4 days of open storage.

The use of UMB for maintenance and production

A series of experiments were conducted at the Animal Production Research Centre, Kuku, in 1989 to investigate the use of UMMB for feeding sheep. Table 14.1 shows the results when UMMB licks were offered to sheep with a basal diet of sorghum straw, compared with a conventional concentrate supplement comprising 40 percent cottonseed cake, 16.7 percent wheat bran, 41.7 percent sorghum grain and 1.6 percent salt.

It is noteworthy that all sheep slaughtered at the end of the experiment had no abnormalities in their internal organs. In another experiment (Table 14.2), it was found that addition of groundnut cake at a rate of 5.5 percent in the blocks increased feed intake and daily gain in sheep.

Table 14.3 shows the results of feeding UMB to three groups of dairy cows. Supplementation with UMB substantially increased daily milk production of the three groups of cows.

It is evident from the above that the use of UMB could have a very high impact on increasing livestock productivity in the Sudan. There is need to extend the technology to many more farmers.

Table 14.1
Daily weight gain and nutrient intake with UMB supplementation compared with feeding concentrates, for sheep on a sorghum-straw diet.

Parameter	UMB	Concentrate	Significance
Number of animals	8	8	-
Experimental period (days)	73.5	73.5	-
Initial live weight (kg)	50.9	49.5	NS
Final live weight (kg)	51.8	59.7	**
Daily gain (g/day)	13	140	***
CP intake (g/day)	251	248	NS
ME intake (MJ day)	10.8	14.5	***
Water intake (litre/day)	5.3	3.76	***

NOTES: CP = crude protein. ME = metabolizable energy. NS = not significant.
SOURCE: El Khidir *et al*., 1989a, b.

Table 14.2
Results of adding groundnut cake to the UMBs

	UMB	UMB + cake	Concentration
Number of sheep	10	10	10
Period (days)	84	84	84
Initial live weight (kg)	20.2	20.4	20.1
Final live weight (kg)	25.3	30.6	29.9
Daily gain (g/day)	61	121	117
Concentrates intake (g/day)	189	370	362
Roughage intake (MJ day)	678	617	451
Total daily intake (g)	867	987	813
DCP intake (g/day)	47	76	72
ME intake (MJ/day)	7.4	8.5	7.8
kg DMI per kg gain	14.1	8.2	6.9

NOTES: DCP = digestible crude protein. ME = metabolizable energy. DMI = dry matter intake.
SOURCE:: El Khidir *et al*., 1989a, b.

Table 14.3
Daily milk production (litres) of cows fed on diets with or without UMB.

Group of cows	Without UMB	With UMB	Percentage increase
High producers	10.25	12.28	19.8
Medium producers	5.79	7.13	23.1
Low producers	4.13	5.45	32.0

SOURCE: Ahmed and Mohamed, 1992.

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Editors' note

Readers wishing to know more about the work in the Sudan are directed to the references listed.

Production and evaluation of medicated urea-molasses mineral blocks for ruminants in Malaysia

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Introduction

Nutrient deficiencies and imbalances are among the principal constraints that severely inhibit the improvement of ruminant productivity in Malaysia (Wan Zahari and Devendra, 1985). Much of the pasture herbage available throughout the country does not completely satisfy all of the nutrient requirements of grazing animals. Under extensive management systems, grazing ruminants normally have access to native grass and crop residues, which have low crude protein (CP) content (<6 percent), high fibre content (>25 percent), low in digestibility (<45 percent) and are deficient in many minerals and vitamins. Poor body conformation, low growth rates and low fertility are some of the clinical symptoms associated with undernutrition. Production losses are aggravated when undernutrition is associated with gastro-intestinal nematodes.

Strategic supplementation with energy, protein and minerals offers an important approach to ensure animal performance is not reduced, especially during critical periods of feed shortage. The supplements can provide ruminal microbes with the nutrients that may be deficient in basal diets, thus stimulating animal digestion and intake. Improvements in feed intake, body weight gain and reproductive efficiency of ruminants associated with feeding urea-molasses mineral blocks (UMMBs) have been

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reported by many researchers (e.g. Leng *et al.*, 1991; Kunju, 1986; Sansoucy, 1995; Knox and Steel, 1996; Knox and Wan Zahari, 1997).

Gastro-intestinal Nematodes and Helminthiasis

In Malaysia, helminthiasis is a common problem in grazing animals, particularly in sheep and goats. *Haemoncus contortus* is the main parasite, mainly causing anaemia and hypoproteinaemia (Sani and Rajamanickam, 1990). Other common nematodes include *Trichostrongylus* and *Oesophagostomum* species, both damaging the intestinal epithelium and causing leakage into the gastrointestinal tract of ruminants. These parasites cause heavy mortality and production losses, which has led to heavy anthelmintic use. In 1990, the estimated cost for controlling local ruminant diseases was $M 100 million. Chemicals widely used for parasite control in Malaysia include benzimidazoles, levamisole, closantel and ivermectin. The last two drugs have been used intensively by smallholders and the efficacy in sheep has been 100 percent (Chandrawathani and Waller, 1997) with 6–12 treatments annually (Chandrawathani *et al.,* 1994). However, where anthelmintics have been used frequently, anthelmintic resistance is emerging as a major problem. Based on local surveys, about 34 percent of local goat farms showed resistance in *H. contortus,* while 25 percent showed levamisole resistance (Dorny *et al.,* 1994). Closantel resistance in *H. contortus* was also reported (Sivaraj *et al.,* 1994).

Apart from intensive use of drugs, the threat of anthelmintic resistances has necessitated a search for alternative method of helminth control in local flocks of small ruminants (Sani and Chandrawathani, 1996). To date, strategies such as pasture management and breeding worm-resistant animals have been adopted, with partial success, but the use of drugs is still on the increase. This has lead to increasing concern about chemical residues in livestock products and the environment. Although rotational grazing is effective under plantation systems, it is not suitable for smallholder farmers due to the high cost of fencing and limited land availability.

Another approach is to introduce medication through nutrient supplementation using medicated urea-molasses mineral blocks (MUMMBs). This method saves labour, as drenching is not required, the animals are not stressed, and it mitigates the problem of drug resistance.

MUMMB Production

Work on non-medicated UMMBs was initiated in Malaysia in the late 1980s, using a cold production process. ACIAR Project 9132 introduced the use of MUMMBs from early 1993. One of the objectives of this project was to determine a suitable MUMMB formulation for use as nutritional supplement for grazing small ruminants whilst providing a steady dose of medication. The main aim was to develop suitable parasite control strategies by using medicated-nutritional blocks as a supplement in sheep production, particularly for immature and peri-parturient females. This is in line with the national interest in sheep rearing under major plantation crops, including oil-palm.

Similar methodologies were applied in the production of both MUMMBs and UMMBs. Several local feed resources were utilized as components, mainly as fillers. These included agricultural by-products like palm kernel cake (PKC), palm oil mill effluent (POME), rice bran, cassava starch, tapioca waste, brewer's waste and others. In certain formulations, meals from high-protein legumes and weeds were used as nitrogen (N) sources. These included *Leucaena leucocephala, Asystasia intrusa* and kenaf (*Hibiscus cannabinus*). Table 15.1 shows the nutritive values of selected legumes and agricultural by-products suitable for use in MUMMB production.

All of the raw ingredients were accurately weighed and the sequence of mixing is as shown (Figure 15.1). The mixing time for each ingredient was 3 minutes. Depending on the formulation and the ingredients used, sun drying took between 2 and 6 hours.

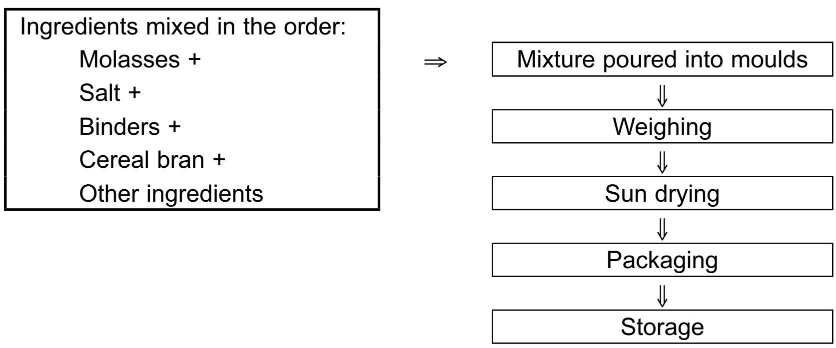

Figure 15.1

Flow chart of MUMMB and UMMB processing

Table 15.1
Nutritive values of selected legumes, agricultural by-products and other feed sources for MUMMB.

	CP(1)	Ca	P	Mg	K	Na	Mn	S	Cu	Zn	Co	B	Fe
	%	%	%	%	%	%	ppm	%	ppm	ppm	ppm	ppm	ppm
	expressed on a dry matter (DM) basis												
Legumes													
Asystasia intrusa	13.8	0.50	0.31	0.50	4.70	0.06	203	–	11.0	69	–	–	–
Centrosema pubescens	23.9	0.55	0.33	0.23	1.92	–	77	–	15.2	47	–	–	–
Leucaena leucocephala	27.1	0.47	0.16	0.16	1.27	0.01	38	0.23	15.0	25	–	17	147
Stylosanthes sp.	20.4	1.47	0.31	0.38	1.71	–	178	–	15.5	55	–	–	–
Agricultural by-products and other sources													
Banana, whole, rejected(2)	–	0.40	0.68	0.73	1.54	0.28	11	0.06	2.8	18	–	–	35
Fish meal	55.0	4.33	1.92	0.31	0.82	1.00	37	–	4.4	54	–	–	1 671
Cocoa bean shell	20.0	0.42	0.76	0.68	2.65	0.18	145	0.29	45	118	–	–	1 792
Cocoa pod husk	10.8	0.34	0.11	0.41	5.00	0.01	287	0.21	12.3	61	–	23.6	92
Copra cake(3)	20.5	0.09	0.52	0.31	2.28	0.11	87	0.29	34.8	53	–	8.6	398
Copra cake(4)	–	0.07	0.35	0.25	1.63	0.11	69	–	20	42	–	–	1 202
Corn	–	0.28	0.06	0.06	0.52	0.05	61	0.08	–	22	–	–	44
Distillery waste	–	0.25	0.61	0.16	1.51	0.06	16	–	3.7	70	–	–	224
Oil-palm fronds	6.8	0.36	0.07	0.10	0.67	0.03	44	0.10	2.1	10	–	–	104
Oil-palm trunk	2.3	0.18	0.06	0.04	1.13	0.02	12	0.10	0.6	43	–	4.9	281
Palm kernel cake (SE) (5)	16.3	0.20	0.57	0.30	0.80	0.01	126	0.22	21.4	50	–	6.0	636
Palm kernel cake (EP) (6)	15.9	0.17	0.61	0.20	0.61	0.11	218	0.16	19.2	42	–	8.5	987
Palm oil mill effluent(3)	–	0.46	0.72	0.32	6.50	0.05	180	–	8.5	120	–	–	6 100
Palm oil mill effluent(4)	–	1.18	0.24	0.38	1.29	0.07	47	–	46	54	–	–	91
Palm press fibre	5.4	0.27	0.08	0.14	0.44	0.01	25	0.07	10.1	37	–	6.1	879
Poultry litter@(7)	–	5.65	2.42	1.35	3.48	0.45	498	–	62	568	–	0.4	2 529
Rice bran	9.5	0.15	0.60	0.29	0.59	0.08	47	0.10	–	47	–	–	88
Rice husk	–	0.07	0.08	0.42	1.69	0.03	1	–	0.1	0.2	2.3	–	–
Rice straw	7.4	0.32	0.11	0.10	2.00	0.02	300	0.17	2.4	60	–	–	470
Sago meal(8)	–	0.10	0.89	0.35	1.02	0.02	119	0.18	5.1	64	–	–	171
Sago waste(8)	0.6	0.23	0.11	0.19	0.16	0.74	80	–	5.5	19	–	–	720
Soya bean meal	–	0.25	0.66	0.25	2.02	0.02	38	0.33	7.9	43	–	–	232

Alternative processing method

Collaborative work between the Japan International Research Centre for Agricultural Science (JIRCAS) and the Malaysian Agricultural Research and Development Institute (MARDI) has developed an alternative processing method for block processing, intended for pilot-scale production (Oshibe and Wan Zahari, 1998). The technique consists of grinding and homogenizing the solid components, mixing the solid components with molasses, and then moulding (Figure 15.2). Table 15.2 outlines the general composition of the MUMMB or UMMB suitable for the process. The uniformity of the blocks produced by the current method is encouraging, both in terms of physical characteristics and nutritive values. The labour requirement for this method is minimal.

Table 15.2
The general composition of MUMMBs and UMMBs suitable for the alternative method.

Ingredient	Proportion
Molasses	More than 50 percent
Filler	Less than 25 percent
Binder	Less than 10 percent
Salt	More than 10 percent

MUMMB formulation and nutritive value

The generalized formulation for preparing MUMMB licks for use in Malaysia is shown in Table 15.3. Fenbendazole (FBZ, containing 40 percent active ingredient) was added at a rate of 0.5 g/kg block. The hardness (penetration resistance) of the blocks is between 5 and 8 cm/kg^2. This is suitable to allow reasonable intakes of blocks of 100–120 g/day for small ruminants and 600–800 g/day for large ruminants. The typical nutritive value of MUMMB is shown in Table 15.4. Several MUMMB formulations for sheep and goats suitable for different feeding systems have been developed by MARDI and the Department of Veterinary Services.

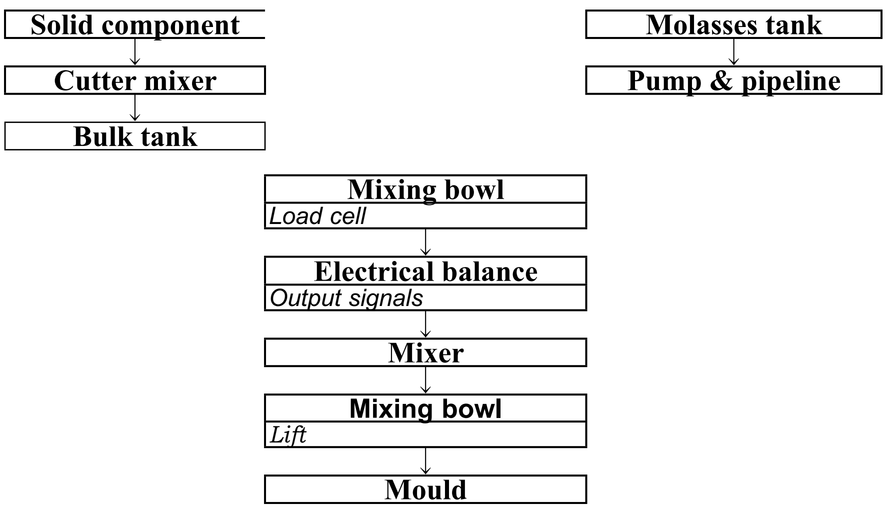

Figure 15.2
The process flow for MUMMB or UMMB using the alternative method

Table 15.3
Generalized formulation for the preparation of MUMMBs for Malaysian conditions

Component	Component ingredients	Quantity (%)	Example (%)
NPN[(1)]	Urea, poultry manure	5 – 10	10
Molasses	Sucrose, minerals	20 – 40	10
Salt	Common salt	1 – 10	10
Binder[(2)]	CaO, $Ca(OH)_2$, MgO, cement, Na-bentonite	5 – 15	10
Water		0 – 30	15
Mineral mix	Commercial products or tailor-made to meet local requirements	1 – 2	1
Protein meal	Fishmeal, coconut meal, leucaena leaf meal, kenaf leaf meal, *Asystasia* leaf meal	5 – 25	10
Filler	Wheat bran, rice bran, rice husks, ground oil-palm fronds	5–25	19

NOTES: (1) = non-protein nitrogen source. (2) Local cost and availability will determine the most appropriate binder or combination of binders. (3) Locally available agricultural by-products (preferably those high in P).

SOURCE: Knox and Wan Zahari, 1997.

UMMB and MUMMB performance evaluation

It is interesting to highlight some Malaysian experiences with regard to the use and benefit of MUMMB and UMMB with pen-fed and grazing small ruminants. The main aim of supplementing with these blocks is to provide additional nutrients to the animals. The effect of anthelmintic agent supplied through MUMMB will appear most clearly when requirements for major nutrients (especially energy and protein) are met.

Table 15.4
Nutritive value of MUMMB (Block DM in range 92.4–94.2 percent).

Component	Range
Percentage in DM	
Crude protein	14.7 – 30.1
Crude fibre	4.21 – 8.80
Ether extract	0.90 – 1.62
Ash	24.2 – 40.8
Energy (cal/g)	1 755 – 2 751
Calcium	0.15 – 5.1
Phosphorus	0.20 – 0.35
Magnesium	0.16–0.83
Potassium	0.60–6.19
Sodium	0.29 – 4.22
Sulphur	0.22 –0.30
ppm in DM	
Iron	5.9 – 424
Copper	4.7 – 31
Zinc	29 – 60
Manganese	20.9 – 69

Several UMMB and MUMMB formulations have been tested on sheep raised under plantation conditions, with varying results (Table 15.5). Trials undertaken on oil-palm, rubber and coconut small-holdings in Peninsular Malaysia revealed that responses under extensive grazing conditions have been variable, and a major problem was intermittent or limited intake. Block consumption was much less than the targeted intake of about 100 g/head/day. Intake was observed to depend largely on the type and nutrient status of feed available, and animal-related factors such as exposure time, previous experience and behaviour (Bowman and Sowell, 1997). Factors implicated in poor MUMMB consumption included higher salt content in the blocks, water shortage in sheds or grazing areas, and, in certain cases, the extension of grazing periods. Sheep grazing pasture of high nutritive value seemed to consume less block if dry matter intake is not limiting. In the majority of the trials, responses in term of liveweight gain (LWG) were not conclusive, despite improved parasite control through MUMMB use.

Field evaluations on pen-fed sheep revealed that low protein + low salt block was consumed well by the animals when compared with other formulations, with no significant differences in LWG. Intake was comparatively higher than similar studies conducted elsewhere (see, for example, Knox, Berger and Anderson, 1990). The formulation was also successful in reducing parasitic infection in sheep, based on later studies undertaken at institutional and smallholder farms (Table 15.6). The improved nutritional level achieved through MUMMB was generally sufficient to eliminate infective larvae ingested from pasture, as has been reported (Chandrawathani *et al.*, 1996).

Infected ewes receiving about 60 g MUMMB/head/day increased their lambing percentage to a level exceeding those without supplementation (Table 15.7). The supplementation markedly improved the survival rate 9of newborn lambs from ewes with poor nutrition. There was no significant improvement in terms of birth weight and litter size between treatments. In a separate trial, growing performances of Siamese Long Tail (SLT) ram lambs supplemented with MUMMB were comparable to those receiving commercial salt lick (Table 15.8). The use of low protein + low salt MUMMB (containing 16.6 percent CP and 1.83 percent Na) was found to reduce the incidence of "fallen-fleece" in growing lambs raised on *Leucaena leucocephala* wafer (containing high mimosine content), while maintaining intake and live weight. Improved lambing performances were also observed in grazing SLT and Malin (Malaysian indigenous) lambs, but, surprisingly, not in Dorset-Horn lambs (Abdullah *et al.*, 1995).

Further development of MUMMB formulation is being carried out, and the use of local copra meal as a non-degradable bypass protein source in block making seemed to be beneficial.

Table 15.5
UMMB and MUMMB formulations tested at selected locations in Peninsular Malaysia

Location	Type of plantation	Sheep breed	Management system	Major feed resources	Block formula	Block intake (g/head/day)	Mean live-weight gain (g/d)
Changkat Cermin Estate Perak	Oil palm	Polled Dorset x SLT	Rotational grazing	*Asystasia*[1] *intrusa*, Native grasses	WZ 38[3]	UMMB 15 - 17.4 MUMMB 5.7–18.0	48.2[8]
	–	Polled Dorset x SLT	Rotational grazing		WZ 37A[4]	MUMMB 19.1–37.7	ND
Sungai Siput Research Station, DVS Perak	–		Rotational grazing	Improved pasture *Guinea grass* + *Setaria* sp.	WZ 38	MUMMB 5	16
	–	SLT + CMBL crosses	Set-stock		WZ 38	MUMMB 4.5–7.2	46.8
Veterinary Research Institute, Perak	–	NC	Pen-fed	Grass pellet[2]	WZ 38	MUMMB 12.9–54.3	ND
UPM, Serdang Selangor	–	NC	Free grazing	-	WZ 37A	UMMB 17 MUMMB 22	38.6 40.6
MARDI, Serdang Selangor	–	Dorset Horn	Pen-fed	Chopped rice straw + 20% concentrate. Straw intake increased	WZ 30[5] WZ 20[6] WZ 28[7]	UMMB 29.3 UMMB 38.7 UMMB 31.7	10.9 15.4 7.9

NOTES: (1) Containing 21 percent CP, 37.3 percent CF; (2) Containing 12.1 percent CP, 15.8 percent CF; (3) Containing 20.5 percent CP; (4) Containing 25.6 percent CP; (5) Containing 35.4 percent CP; (6) Containing 34.8 percent CP; (7) Containing 35.6 percent CP; (8) Liveweight gain obtained comparable to PKC supplemented group receiving 50–60 g/d.

KEY: UPM = Universiti Putra Malaysia; SLT = Siamese Long Tail; UMMB = urea-molasses mineral blocks (non-medicated); MUMMB = medicated urea-molasses blocks; DVS = Department of Veterinary Services; ND = not determined; NC = not indicated; SLT = Siamese long-tailed.

Table 15.6
Evaluation of low protein+low salt blocks for grazing sheep

Location	Plantation type	Sheep breed	Manage-ment system	Major feed resources	Block intake (g/head/day)	Mean live-weight gain (g/day)	Note
Rubber Research Institute (RRI) Sg. Buluh, Selangor	Rubber	NC	Free grazing	Native pasture	UMMB 100–150 MUMMB 100–200	14.6 17.1	(1)
Felda Laka Selatan Jitra, Kedah	Rubber	NC	Free grazing	Native pasture	UMMB 79–209 MUMMB 62–184	ND	–
Gopeng(2), Perak	Oil palm	Mixed	Free grazing	Native pasture	MUMMB 60	ND	Limited supply of MUMMB
Veterinary Research Institute (VRI) Ipoh, Perak	–	NC	Pen fed	Free grazing	MUMMB 31-225	ND	–

KEY: NC = Not reported; ND = Not determined; UMMB = Urea-molasses mineral blocks; MUMMB = Medicated urea-molasses mineral blocks; * = Nutritive value (CP, 16.6%; Na, 1.83%; Ca 4.9%; P, 0.34%).

NOTES: (1) Liveweight gain obtained was less than PKC supplemented group (22.4 g/day).
(2) Smallholder farm.

Table15.7
Lambing and mortality of newborn lambs from ewes raised by a smallholder farmer.

Treatment	Lambs born	Mortality
UMB	8 (2 twin)	0
UMMB	8 (2 twin)	0
Control (No supplement)	4 (1 twin)	1
Supplementation via liquid feeder	6 (1 twin)	1 (due to dystokia)
Total	26	2

NOTES: Location: Bachok District, Kelantan, Malaysia. Feeding system: free grazing under coconut plantation. Lamb mortality was about 85 percent throughout the 3 years of rearing; Farmer's income through the sale of lamb increased 70 percent after supplementation. Body condition of ewes improved markedly with supplementation.

SOURCE: Wan Zahari *et al.*, 1996a,b.

Table 15.8
Growth performances of Siamese Long Tail ram lambs supplemented with UMMB and salt lick.

Treatments	Initial live weight (kg)	Live weight changes (kg) (1)	Liveweight gain (g/day)
UMMB	12.4	+19.1	78.7
Salt lick (2)	13.1	+17.8	74.1
Control (3)	12.9	+13.0	53.5

NOTES: (1) Determined after 242 days of the trial. (2) Phosphorus-rich blocks with a basal diet of oil-palm frond silage (OPF)-based rations. (3) Grazing native pasture with salt lick. n = 30.

SOURCE: Hassan *et al.* (1994)

Efficacy and Effectiveness of MUMMB For Parasite Control

Several efficacy studies were carried out on the use of MUMMB for parasite control in small ruminants in Malaysia. Based on the concentration of FBZ and oxfendazole (OFZ), MUMMB was observed to maintain safe therapeutic levels throughout the 18-day trial period. In contrast, the FBZ and OFZ concentrations of drenched animals dropped after 48 hours, leaving them again making them susceptible to infective larvae (Chandrawathani *et. al.* 1996).

Two trials were conducted at the Veterinary Research Institute, Malaysia, on 10-month-old pen-fed sheep, where two groups of five animals were given either MUMMB or UMMB. In the first trial, the MUMMB contained 0.25 g/kg FBZ and animals were challenged with a single dose of infective *Haemonchus* larvae. In the second trial, MUMMB contained 0.5g/kg FBZ and animals were challenged with 500 infective larvae per day for 6 days. A faecal egg count (FEC) was performed twice, once before and then four weeks post-challenge. In the pen-fed sheep, FECs fell by 84 percent in Trial 1 and 90 percent in Trial 2 (Table 15.9).

In a field trial, 42 five-month-old lambs grazing under rubber trees were divided into three groups of 15 animals each. All animals were grazed together from 08.00 to 12.00, and were exposed to natural infection. Each group were separately penned after grazing. One group had access to MUMMB containing 0.5 g/kg FBZ while another group had access to simple UMMB. The third group had no blocks, but was given PKC supplementation. FECs were done before and fortnightly after exposure to natural infections for a period of 100 days. FECs were lowest in the group given PKC supplementation throughout the 100-day study period. There did not appear to be a difference between the FECs of the UMMB and MUMMB groups. The mean block intake per animal and the average daily gain values are as shown in Table 15.10. An analysis of variance showed that differences in the average daily gain values between the groups were not significant. The reduction in FEC (at the sixth week post-challenge) was only 42 percent. This reduced efficiency under field conditions may be attributed to the greater infection challenge provided by increased numbers of infective larvae in the herbage contaminated by the control animals, since all animals were grazed together. Another reason was that the grazing animals consumed much less of the blocks compared with penned animals (Sani *et al.*, 1995).

In a separate study, 45 2.5-month-old lambs (half Santa Ines × quarter Dorset × quarter Malin crosses) were used for the MUMMB evaluation. The lambs were grazed extensively together from 08.00–12.00 under mature rubber trees. They were divided into three groups and were housed separately in pens. The first group was given concentrate (100 g/day) based on PKC, while the other two groups were given MUMMB and UMMB blocks, respectively. All lambs were given a single injection of ivermectin to remove existing worm burdens at the start of the trial. The mean FEC in the MUMMB group was consistently lowest among the three groups, while FECs for the UMMB and PKC groups did not differ.

Table 15.9
Block consumption, faecal egg count (FEC) and efficacy of medicated block in pen-fed sheep.

Trial	FBZ (g/kg)	Treatment	Average intake (g/day)	Challenge	Mean FEC Pre-challenge	Mean FEC Post-challenge	Efficacy (%)
1	0.25	Medicated (MUMMB)	40	200 L3	10	100	84
		Unmedicated (UMMB)	23		30	640	
2	0.50	Medicated (MUMMB)	63	6 × 500 L3	0	175	90
		Unmedicated (UMMB)	37		0	1 840	

Note: FBZ = Fendbendazole. Dose is g a.i. per /kg block.

Source: Sani *et al.*, 1995.

Table 15.10
Mean block intake and average daily gain of sheep

Treatment	n	Mean birth weight	Block intake (g/day)	ADG + SE (g/day)
MUMMB	14	3.0	22	40.6 + 5.0
UMMB	14	2.7	17	38.6 + 5.1
No block	13	2.8	–	46.5 + 3.7

Table 15.11
Block intake and average daily gain values in three groups of sheep (148-day period).

Treatment	n	Mean birth weight (kg)	Block intake (g/day)	ADG (g/ day)	CV	ADG (+ PKC)	CV
PKC	15	3.2	-	22.24	57.07	95.3	27.02
UMMB	15	3.2	100 – 150	14.61	64.25	92.6	24.51
MUMMB	15	3.2	100 – 200	17.06	60.12	109.7	23.34

NOTES: CV = coefficient of variation. ADG = average daily gain
SOURCE: Sani *et al.*, 1995.

Table 15.11 shows the mean block intake and the average daily gain values for the respective groups. The mean average daily gain in the group given PKC was highest, but the differences between treatments were not significant. After the study ended and the blocks were withdrawn, all animals were given PKC at the rate of 150 g/head/day and joined the main herd during grazing. The average daily gain values at two months post-treatment with PKC were 95.3, 92.6 and 109.7 g/day respectively.

MUMMB was shown to reduce markedly the FEC. However, the nutritional benefits of UMMB and MUMMB were not manifested in improved LWG. The improved nutritional status with PKC supplementation was found to be more important than parasite burden in affecting LWG. It should be noted that the parasite burden in these animals was relatively low (<2 000 epg) in comparison with other farms in Malaysia.

In a separate study, four farms were selected, each with an average population of 80–100 head of sheep. Ten sheep, 3–4 months old, weighing 10–15 kg, were identified from each farm. Sheep on Farm 1 were supplemented with MUMMB, while sheep on Farm 2 also received UMMB. The initial anthelmintic treatment given was an oral drenching of moxidectin 1 g/litre (Cydectin R) at 0.2 mg moxidectin per kilogram live weight. Farm 3 sheep were only given an initial treatment of anthelmintic, while sheep on Farm 4 were given MUMMB with no initial anthelmintic treatment. All sheep on the four farms were grazed under rubber trees and had similar management. No concentrate supplement was given. The mean pre-treatment FEC of sheep in the four farms ranged from 1 480 to 4 188 epg (Table 15.12), indicating the high incidence of helminthiasis, a common phenomenon on smallholder sheep farms. The post-treatment FEC after 1 month dropped drastically, to 0–30 epg for farms 1, 2 and 3. However, high FECs were recorded from farm 4, despite adequate MUMMB intake. The mean FEC (2 months post-treatment) of farms 1 and 2 were lower (less than 500 epg) compared with farms 3 and 4 (more than 1 500 epg). Intake of MUMMB ranged between 62 and 184 g/day/animal, and it is evident here that the amount of FBZ consumed was 2–6 times higher than the recommended amount of 15 mg FBZ/day for sheep (Knox, Barger and Anderson, 1990). Higher intake of MUMMB can be expected to increase the FBZ metabolite levels in the blood and this can give full protection against larvae ingested from pasture.

Both MUMMB and UMMB given with an initial anthelmintic treatment to clear out existing adult worms were found effective in controlling helminthiasis, as shown by the results from Farms 1 and 2. With the use of MUMMB, there was a continuous supply of anthelmintics at a low dose. Therefore, it is advantageous to give MUMMB with the initial treatment as the medication in MUMMB would be able to kill incoming larvae, as shown on Farm 1, with the lowest FEC after 2 months. This will prevent the serious consequences of helminthiasis, thus improving the productivity of sheep. MUMMB or UMMB alone or treatment alone were ineffective in controlling helminthiasis, as shown on Farms 3 and 4.

Table 15.12
Average daily intake of blocks and pre and post mean faecal egg counts of sheep

Farm	Treatment	Block intake (g/day/ animal)	Faecal egg count (epg)		
			Pre-treatment	1 month post-treatment	2 months post-treatment
1	MUMMB + Tx	62 – 184	1 480	0	390
2	UMMB + Tx	79 – 209	1 600	30	510
3	Tx only	–	3 980	10	1 856
4	MUMMB only	101–111	4 188	5 038	2 275

NOTES: Location: smallholder farms in FELDA, Laka Selatan, Jitra, Kedah, Malaysia. Tx = treatment with Cydectin^{R}. epg = egg per gram.
SOURCE: Maria *et al.*, 1996.

Blocks as a carrier for biological parasite control

There are many biological methods known to be effective for parasite control. Methods of current interest include the incorporation of fungal spores through the blocks. Studies in Denmark (Gronvold *et al.*, 1993), Australia (Waller and Faedo, 1993) and Malaysia (Chandrawathani *et al.*, 2001; Chandrawathani *et al.*, 2002) have shown the positive implications of using nematophagous fungi as a biological agent for ruminant helminthiasis. *Duddingtonia flagrans* and *Arthrobotrys oligospora* have been reported to be the most suitable fungi apart from their ability to survive gut passage and delivery as a feed additive to ruminants (Chandrawathani *et al.*, 2001). About 2 000 spores of *Arthrobotrys oligospora* were needed to reduce the *Strongyloides* larvae from calf faeces by 90 percent (Chandrawathani, Omar and Waller, 1997).

Incorporation of pasture plants in blocks for parasite control

Several legumes and plant extracts are known to have anthelmintic properties. Forages containing condensed tannins have been reported as providing some resistance to parasite infection in sheep. This might be attributable to direct anthelmintic properties of tannins, or to better supply of protein to the intestine due to the role of tannins in protecting dietary protein from ruminal degradation. Work is in progress in Malaysia to incorporate plants containing tannins as components in UMMB. Raw materials include leucaena, OPF and kenaf. A MLPR leucaena line established in Malaysia contained higher tannin content (31.6–55.6 mg/g compared with ML1 (containing 12.9–23.2 mg/g). Condensed tannin levels in OPF were found to vary between 15.21 and 34.80 mg/g. Supplementation of pelleted kenaf-based diets (at 45 percent inclusion level) was found to decrease FEC by 69 percent compared with the control group (Figure 15.3). The diets for all groups were isonitrogenous and isocaloric, with CP and energy content of 14.1 percent and 9.60 MJ/ kg, respectively.

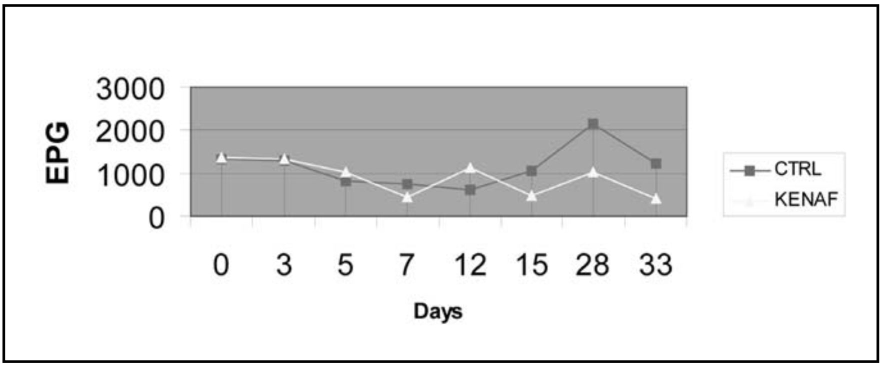

Figure 15.3

Effect of kenaf (at 45 percent feeding level) on mean faecal egg count (FEC) (eggs per gram (EPG)) of infected sheep (n = 5; 33-day experimental period).

Other anti-nutritional factors of interest in overcoming parasites are saponins. Local plant species that are rich in saponins are *Albizia stipulata, Medicago sativa* and *Sesbania sesban*. Leaves from Neem (*Azadirachta indica*) were found effective in overcoming parasites in goats. Other plants of potential use are sentang (*Azadirachta excelsa*), jackfruit (*Artocarpus heterophyllus*), angsana (*Pterocarpus indicus*), hibiscus (*Hibiscus* spp.), and forest species such as ludai (*S. baccatum*), memaya (*Sapium discolor*), kesinai (*Streplus asper*) and ficus (*Ficus* spp.), which are thought to have anthelmintic properties as well as being good protein sources (Chin, Wong and Halim, 1998). Jackfruit leaves are extensively used for feeding sheep and goats in villages. Further studies are needed to identify other locally available feed resources with high tannin and saponin levels, mainly as feed additives to increase the supply of microbial protein post-ruminally, and that are at the same time effective for parasite control in small ruminants.

Transfer of the Technology and The Benefits of MUMMB to Smallholders

Extension workers, technicians and several groups of small-scale farmers from selected districts in Malaysia were trained in MUMMB production through demonstrations at experimental sites or at MARDI and the Department of Veterinary Services. *In situ* trials were carried out in selected villages as models for small-scale farmer associations. Crop residues and agricultural by-products available in those areas were utilized as ingredients in MUMMB making. Discussions and visits were undertaken separately to meet specific needs of interested groups. With further promotion efforts, MUMMB production technology and knowledge concerning the benefits of supplementation could be further disseminated to users, thus supporting socio-economic development.

The benefits to the farmers are related to better animal appetite, higher rate of growth, improved body condition and reduction in animal mortality, resulting in higher sales and higher income. The improvement in livestock productivity, coupled with more efficient utilization of locally available feed resources (especially fibrous feed), will lead to economic and social benefits for the local population.

MUMMB Commercialization Potential

MUMMB technology has the potential to be commercialized for supplementing ruminants in Malaysia. The production cost is low compared with the cost of producing salt blocks or importing MUMMBs. The use of MUMMB should be better suited to local environments as formulation can be adjusted according to breed requirements, the local environment and local resource availability. MUMMBs need to be used strategically when the parasite challenge is high or expected to increase.

Conclusion

Adequate intake is imperative in utilizing MUMMB as a nutritional supplement and chemotherapeutical delivery agent for the control of helminth parasites in grazing small ruminants. MUMMB containing 0.05 percent fenbendazole given at a rate of about 60 g/head/day has been found to be effective in controlling helminths in sheep. In situations where pasture management (rotational grazing) is not possible, the introduction of MUMMBs is advocated as an alternative to frequent drug use for the control of helminthiasis in sheep. The integration of sheep under major plantation crops also justifies the use of MUMMB as a replacement for commercial mineral blocks, which at present are being imported. Having extra nutrients like protein and energy sources, MUMMBs provides greater benefit to ruminants. Its use is cost–effective compared with routine de-worming programmes. This method of worm control is suitable for smallholders, whereby an initial treatment with anthelmintic followed by an improved nutritional regime with MUMMB or UMMB licks can keep sheep from developing severe helminthiasis.

The processing technology and formulations can be improved or simplified to suit the needs and requirements of the users. The main objective is to produce a cost-effective feed supplement that can be adapted and adopted by local farmers by utilizing cheap, available resources. MUMMBs can be made with a variety of feed resources, depending on their availability, nutritive value, cost and the facilities available. The proper strategy in any livestock venture is to produce and utilize this feed supplement to achieve a maximum benefit to cost ratio.

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Nematode parasitism of cattle and buffalo: prospects for control using medicated urea-molasses blocks

Malcolm Knox[28]

Introduction

Attempts to increase the productivity of ruminants in developing nations generally encounter two principal constraints: nutrition and health. Depending on the particular environment and production system, undernutrition interacts with infectious or parasitic disease, or frequently both, to limit animal performance. Nutrition of ruminant animals in these areas is constrained by the available forage, which is usually of medium to low quality and made available by grazing or cut-and-carry methods. At certain times of the year, the quality of this resource deteriorates due to seasonal influences, and productivity consequently declines unless supplements are offered. As demonstrated elsewhere in this book, urea-molasses blocks can provide a low-cost means of providing deficient nutrients and optimizing production from the available feed resource. Of the health constraints, bacterial and viral diseases can be successfully controlled in most livestock production systems through conventional vaccination and quarantine procedures. However, for parasitic disease, these approaches are either not yet possible or impractical, and chemotherapy, coupled with grazing management, is the only control method currently available. In developing nations, the losses induced by clinical and subclinical parasite infections have been estimated to equal the value of the present output of ruminant industries, and improved control has the potential to yield considerable productivity benefits.

The primary focus of the present chapter is to describe the potential for using urea-molasses blocks (UMBs) for the delivery of anthelmintic medication to control gastrointestinal nematode parasitism. However, before describing the formulation and application of medicated blocks, it

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is essential that a basic understanding of the epidemiology of infection be gained through studies of the livestock system of interest. This includes an assessment of the factors affecting parasite abundance and survival, and the impact of parasitic infection on production. These parameters are briefly described below so the reader can gauge the scope of the problems likely to be encountered in their local environment. Only after this assessment is complete, and any missing information identified and gathered, can an informed decision be made as to whether or not to treat with anthelmintic, and strategies formulated to control nematode parasites.

Gastrointestinal nematode parasitism of cattle and buffalo.

The incidence and severity of nematode parasite infection is dependent on several interacting factors, determined by the species of parasites present, the environmental conditions, and the host and its physiological state. The following section describes the important factors influencing infection with nematode parasites.

Table 16.1
Gastro-intestinal nematode parasites infecting cattle and buffalo.

Species of major economic importance	Species of minor economic importance
Haemonchus placei, H. contortus	*Bunostomum phlebotomum*
Trichostrongylus axei	*Dictyocaulus viviparous*
Cooperia pectinata, C. punctata, C. oncophora	*Strongyloides papillosus* (calves)
Ostertagia ostertagi	
Oesophagostomum radiatum	
Mecistocirrus digitatus	
Toxocara vitulorum (calves)	

The parasites

In general, for most developing countries, little information exists about the incidence and severity of nematode parasite infection of large ruminants beyond the identification of species present in animals at post-mortem after untimely death or from slaughter observations. One or more of the major pathogenic species are usually present, but species of minor importance are also routinely encountered (Table 16.1).

Most of these nematodes have a direct life cycle with a pre-parasitic stage on pasture and the parasitic stage in the host animal. Eggs passed in the faeces hatch to produce the larvae (L_1), which feed on bacteria, grow and then moult to progressively become L_2 and L_3, when the sheath is retained for protection against desiccation. The L_3 are the infective stage and do not feed but migrate from the faeces onto nearby herbage to await ingestion by a suitable host. Once inside the host, the protective sheath is cast off and the larvae are transported with the digesta to the predilection site, where they remain to grow and become adult. Eggs produced by adult worms are voided into the digesta and are eventually passed in the faeces. For *Bunostomum phlebotomum* and *Strongyloides papillosus,* infection occurs by larval penetration of the skin and migration to the predilection site via the bloodstream and lungs. *Toxocara vitulorum* eggs are consumed by animals with pasture and the larvae hatch and penetrate muscle tissue, where they can remain dormant for many years. Near parturition, the larvae migrate to the mammary glands and are passed to the calf in the colostrum in the first few days after birth (Roberts, Fernando and Sivanathan, 1990). The larvae then develop into adults that commence passing eggs at around 27–42 days and may cause clinical disease in the calf. Treatment of calves at 10–16 days of age with effective anthelmintic has been shown to be a simple and effective means of controlling this problem and reducing calf mortality (Roberts, 1990).

Factors affecting parasites abundance and survival

Environment

Climatic conditions have a major impact on the development, migration and survival of free-living stages of nematode parasites and, depending on the climatic region, different nematode species predominate. In tropical and subtropical areas, *Haemonchus* spp., *Cooperia. punctata, C. pectinata, Oesophagostomum radiatum* and *Mecistocirrus digitatus* are the main species, along with *T. vitulorum* in calves. In temperate areas *Ostertagia ostertagi, Trichostrongylus axei* and *C. oncophora* predominate. Seasonal weather patterns within climatic zones determine the abundance of infective larvae surviving on pasture at different times of year, and hence rates of infection of animals. Seasonal factors also determine the abundance and growth of feed resources, which influence the nutritional status of the host animal and its ability to resist infection. Surveys to establish the seasonal incidence of infection and the abundance of larvae on forage are therefore essential elements for consideration before trying to determine the most appropriates methods for controlling nematode parasite infections. Other factors that require consideration are: what happens to the dung after being deposited by the animal (dried and burnt; composted and used for fertilizer; spread on pasture area) and whether other animals enter areas where the target group graze or their forage is collected (nomadic herdsmen on communal lands; free ranging goats).

Host factors

Disease caused by gastrointestinal nematodes in cattle and buffalo is primarily a problem of young animals. From the time of first exposure to infective larvae, calves will harbour nematode infections until they reach mature body weight, when they normally attain a level of acquired immunity and resist further infection. In temperate areas, this usually occurs between 1 and 2 years of age in well-grown animals but in tropical areas, resistance to infection may be delayed due to inadequate nutrition and slow growth rates of young animals. Immunity to helminth parasites may render the animal totally refractory to infection but immunity is often exhibited through reduced size and fecundity of adult worms, increased numbers of inhibited larvae and/or delayed maturation of developing worms (Gasbarre, Leighton and Sonstegard, 2001). All of these factors result in reduced transmission of the parasite within the cattle or buffalo herd and its environment. Mature animals may therefore exhibit low levels of infection with standard diagnostic procedures, such as faecal egg counts (FECs), but still harbour a number of parasites. The metabolic cost of maintaining the immune response during continued infection is difficult to estimate and, depending on the severity of infection or larval challenge, or both, may reduce weight gain or milk production in situations where nutrients are limiting, as is the situation in many developing country livestock production systems.

Considerable variation exists between and within breeds of cattle in their ability to resist infection with parasitic nematodes (Barger, Brenner and Waller, 1983; Gasbarre, Leighton and Sonstegard, 2001). In general, locally adapted breeds appear more resistant to infection than imported breeds particularly those that have been bred for high productivity. In many tropical environments, imported breeds suffer heat stress, are more susceptible to endemic diseases and parasites and require high nutritional inputs to maintain production. Ideally, breeding programmes in these areas should attempt to retain the resistance status of locally adapted breeds while integrating the higher production characteristics of imported animals through appropriate cross-breeding strategies.

Impact of gastrointestinal parasites on production in ruminants

In general the efficiency of any ruminant production system is determined by the extent to which gastrointestinal parasitism affects mortality; growth rate or product yield; reproductive performance; and utilization of available feed resources. Each of these factors is considered in more detail below.

Mortality

The most severe form of production loss due to gastrointestinal parasitism is death since there is a cost in terms of the replacement value of the animal and often the year's production by that animal is also lost. Post-natal infection with *T. vitulorum* has been shown to result in up to 30 percent mortality of buffalo calves in some areas of South-East Asia (Fabiyi, 1986) and helminth parasitism is considered to be a major factor in mortality rates of up to 40 percent in calves in tropical areas during their first year of life (Hörchner, 1990). The stress of weaning combined with immature immunological status renders the young animal more susceptible to severe levels of infection and in temperate areas mortality rates in young cattle may be as high as 33 percent (summarized in Barger, 1982). Although adult animals are normally less susceptible to high levels of parasite infection, mortality of adults does occur, particularly during or after periods of stress. Stresses such as presence of other diseases, parturition and lactation, drought or other periods of nutritional insufficiency and certain husbandry practices render adult animals more susceptible to infection and increased mortality may occur. Periparturient infection of females can affect the post-natal survival of offspring through reduced birth weight and reduced availability of milk for their growth and development. Maternal behaviour can also be altered in infected animals, with increases in mismothering and desertion the likely result.

Reduced growth rates and product yield

Production losses due to helminths at subclinical levels of infection can appear as lower carcass growth rates and lower yields of milk. In field experiments in temperate areas with grazing cattle, 24 to 40 percent reductions in weight gains have been observed (summarized in Barger, 1982). Studies in infected cattle in southeast Asia have shown similar reductions in weight gain (Supan, 1986; de Rond *et al.*, 1990). For some time, the effect of nematode parasites on milk production of dairy cattle has been a contentious subject, but a recent review of 87 studies in 382 dairy herds in temperate areas demonstrated an average 3 percent increase in milk production attributable to nematode control (Gross, Ryan and Ploeger, 1999). In developing nations, treatment with nematocides increased milk production by 12 percent in Sri Lanka (de Rond *et al.*, 1990), by 11 percent in cattle in India (Sanyal, Sigh and Knox, 1992) and by 13 percent in buffalo (Sanyal *et al.*, 1993). Use of albendazole, which has nematocidal and some flukicidal activity, yielded increased milk of 0.5 litre/day in cattle in Indonesia (Supan, 1988) and 0.8 litre/day in buffaloes in India (Kumar and Pachauri, 1989). Milk quality was also affected by helminth infection, with higher levels of total fat, total solids and protein content being recorded in treated animals (Kumar and Pachauri, 1989).

Reduced reproductive potential

Infestation with helminth parasites can affect the reproductive performance of a herd or flock. In efficient dairying enterprises, farmers try to minimize the time taken for replacement heifers to reach sexual maturity thereby reducing the unproductive portion of the animal’s lifetime. By reducing bodyweight gains, parasitism can significantly delay the onset of puberty and increase the age at first service in young cattle (O’Kelly, Post and Bryan, 1988; de Rond *et al.*, 1990). Liveweight depression post parturition can affect the time to first oestrus, and healthy animals are more likely to have minimal time intervals between births of offspring than those suffering from infection with helminth parasites. This is of particular importance to dairy enterprises, where dried-off cows waiting to calve are unproductive but still need to be fed and maintained. In developing nations, one of the biggest herd management problems is the number of anoestrus animals, and improved control of helminth parasites may help to reduce the occurrence of this problem. Infection by helminth parasites can affect reproductive potential through decreasing the conception rate in the herd, as shown in studies in the USA, where treatment with anthelmintic increased pregnancy rates in maiden heifer cattle by 44 percent (Loyacano *et al*., 2002) and by 22 percent in lactating cows (Stuedemann *et al*., 1989).

Reduced efficiency of feed utilization

Livestock must make optimal use of available feed resources to achieve maximum production potential. Gastrointestinal helminth parasites can affect the utilization of feed through depression of both intake and conversion efficiency of feed and by causing behavioural changes in the host, rendering it a less efficient gatherer of forage. Parasites can also cause losses of nutrients through their feeding habits or by damaging host tissues during migratory phases. The interactions of parasites and nutrition are quite complex and are reviewed in more detail elsewhere (McKellar, 1993; Coop and Kyriazakis, 1999) but consideration of the situation in developing nations where helminth parasites are usually present generally leads to the conclusion they will probably exacerbate problems caused by suboptimal nutrition.

Anthelmintic delivery through feed supplement blocks

During the past 30 years, attempts at delivery of anthelmintic medication through feed supplement blocks have met with varying levels of success. Blocks containing phenothiazine at sufficient concentration to inhibit the development of parasite eggs to larvae proved successful in reducing nematode parasite levels in intensive livestock rearing systems (Martin, 1986; Beriajaya *et al*., 1988) but in extensive grazing systems effective control was not demonstrated (Elliott, 1970; Cummins, Callinan and Atkinson, 1978). The inclusion of the benzimidazole anthelmintic fenbendazole (FBZ) into feed blocks in sufficient concentration to give an effective dose from expected normal daily consumption of block successfully controlled nematode parasites of sheep (McBeath, Preston and Thompson, 1979; Bogan and Marriner, 1983) and cattle (Blagburn *et al*., 1987; Bransby, Snyder and Webster, 1992; Miller *et al*., 1992), but adoption of this means of control has been poor due to low requirement for supplementary feeds in the livestock rearing systems where these blocks were promoted (United Kingdom; USA) and the low cost of alternative treatments. Variability observed between individuals in intake of the blocks (Cummins, Callinan and Atkinson, 1978) may have also contributed to the limited adoption of this technology in extensive grazing systems.

With the emergence of strains of parasitic helminths resistant to anthelmintics, coupled with the high cost of developing new compounds for commercial application, considerable research effort has been devoted to seeking methods of increasing the efficacy of available compounds in order to extend their useful commercial life. The observation that prolonged application of low levels of some benzimidazole anthelmintics enhanced their efficacy (Prichard, Hennessy and Steel, 1978; Boisvenue, Colestock and Hendrix, 1988) led to the development of continuous release devices (CRD) for the intraruminal administration of anthelmintics (Anderson *et al.*, 1980). The increase in efficacy is thought to be due to the continued presence of the anthelmintic preventing establishment of incoming larvae, decreasing viability and fecundity of mature worms in the host and having an ovicidal effect on any worm eggs that are produced. Studies of CRDs containing albendazole by Barton, Rodden and Steel (1990) and Barger, Bremner and Waller (1993) in sheep have demonstrated the effectiveness of this technology in areas where parasite strains are known to be partially resistant to benzimidazole anthelmintics, with no exacerbation of the resistance problem after treatment. Similarly, a CRD containing fenbendazole (FBZ) was shown to be effective in controlling major nematode parasites of calves during their first grazing season (Le Stang and Hubert, 1995).

Research by the author's institute has followed similar pharmacokinetic principles to those applied in CRD applications to develop a UMB containing FBZ for use in livestock production systems where regular consumption of the block occurs. Control of parasites can be achieved through the animals consuming a daily low-level dose of FBZ via the feed block. Early studies determined that the bioavailability of FBZ was not affected by incorporation into the block formulation, but that dose rates differed between target host species (Knox *et al.*, 1994, 1995). Field testing of the efficacy of the block formulations has been carried out in cattle and buffalo and the results of these tests are presented below.

medicated block Studies with Indian dairy buffalo and cattle

Efficacy studies

Sanyal and Singh (1993) carried out two experiments to determine the therapeutic and prophylactic efficacy of medicated urea-molasses blocks (MUMB). First, ten 20–24-week-old, worm-free calves were divided into 2 groups of 5 animals each and maintained in tick-free pens and fed on chaffed *Sorghum* spp. hay, UMB and water ad lib. Fifteen days after acclimatization to the specified diet, both groups were experimentally infected with 10 000 infective *Haemonchus* spp. larvae. After patency of infection, one group was given access to MUMB containing 0.5g FBZ/ kg for 15 days while the other had continued access to drug-free UMB. Faecal egg counts (FECs) indicated that within 4 days of being offered MUMB, FECs declined to zero, while the counts in the untreated group remained above 400 epg (Figure 16.1). At slaughter, 45 days after infection, no adult worms or larvae could be detected in the abomasum of animals receiving MUMB, while animals in the untreated group had 378 ±72 (mean ±SD) worms.

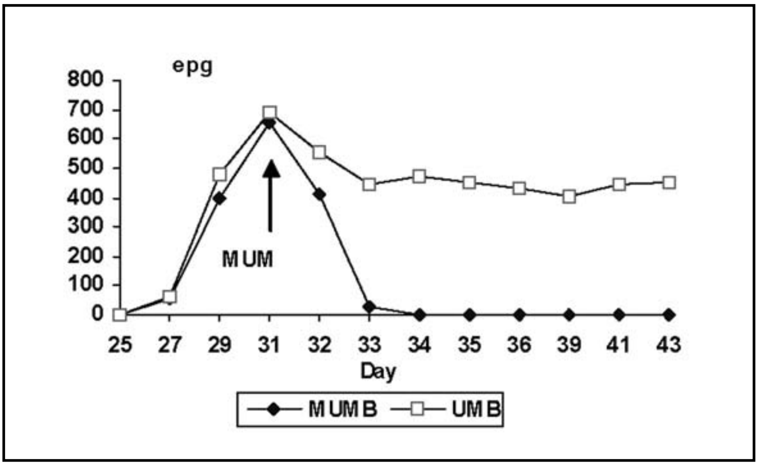

Figure 16.1

Therapeutic efficacy of medicated (MUMB) vs unmedicated (UMB) supplementary feed blocks.

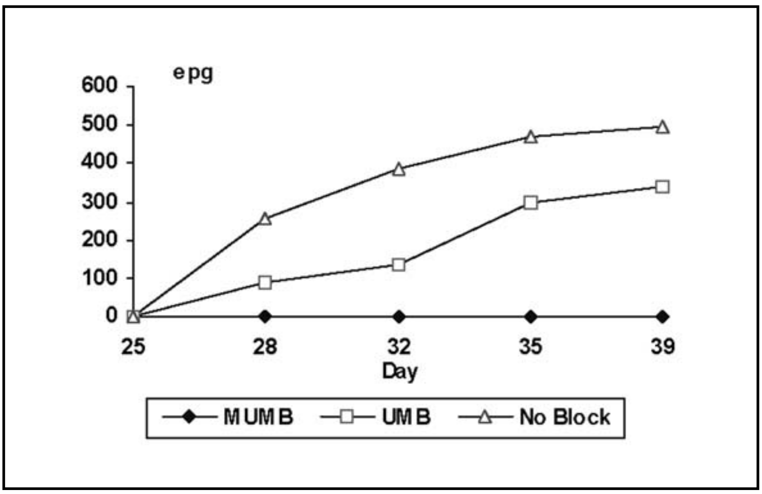

Figure 16.2

Prophylactic efficacy of medicated (MUMB) and unmedicated (UMB) supplementary feed blocks compared with no blocks.

In the second experiment, fifteen 20–24-week-old worm-free calves were divided into 3 equal groups and maintained in controlled conditions and fed on chaffed *Sorghum* spp. hay, UMB and water *ad lib*. After fifteen days acclimatization to the diet, one group was given access to MUMB and 4 days later was experimentally infected with 1 000 infective larvae of *Haemonchus* spp. per day for the next 10 days. MUMB access was continued up to the last day of experimental infection. The same parasite infection schedule was followed for the other groups, which were offered UMB or received no blocks. Zero FECs (Figure 16.2) and worm counts demonstrated that MUMB was able to prevent infection in calves undergoing daily parasite challenge. It was also interesting to note that animals receiving UMB showed lower egg counts and worm counts than those animals without access to blocks, which suggests that the nutritional benefits of the supplement assisted the host to inhibit establishment of infection.

Replacement heifers

Sanyal and Singh (1995a) evaluated the benefits of MUMB on a commercial dairy farm in India where cattle were maintained in open barns and fed on green fodder, protein concentrate pellets and UMB. Forty 20–33-month-old heifers weighing 165–240 kg were divided into two equal groups and maintained in two different barns. Over a period of 5 months, one group had unlimited access to MUMB (containing 0.5g FBZ/kg) at two sites in the barn, and the second group had similar access to UMB. FECs indicated moderate levels of infection in the untreated animals, while MUMB animals were zero on all occasions after MUMB introduction. MUMB animals gained 18 percent more weight during the experiment compared with untreated animals (Table 16.2). Such an increase in growth rate would enable the MUMB heifers to reach the target weight for first service some 6 to 7 weeks earlier than those that remained untreated.

Lactating cows

An experiment to test the efficacy of MUMB in adult lactating buffalo was conducted on an organized farm where the animals were tethered in barns and fed on dry and green fodder and UMB (Sanyal and Singh, 1995b). Twenty-five buffaloes showing low grade subclinical nematodosis were divided into two groups of 13 and 12 animals, and maintained in separate rows of the animal shed. One group was offered MUMB (0.5g FBZ/kg) individually in dispensers kept in front of each animal, and the other group was offered drug-free UMB. FECs of MUMB buffaloes declined to zero after MUMB introduction, and remained zero throughout the experiment, while egg counts of UMB animals remained at low levels (<30 epg). Comparison of daily lactation records indicated milk yield in MUMB buffaloes was 1.2 litre/day higher compared with those buffaloes offered UMB without medication. A similar study in cross-bred cattle showed a 0.6 litre/day advantage in cows treated with MUMB (Sanyal *et al*., 1995) (Table 16.2).

Table16.2
The effects of MUMB on weight gain of replacement heifers.

Group	Gain/month (kg)[1]	Gain/day (kg)[1]	Net milk yield gain/day (kg)[2]
MUMB	12.02	0.40	0.06
UMB	10.14	0.34	–

SOURCES: [1] Sanyal and Singh. 1995a. [2] Sanyal *et al.*, 1995.

Further evaluation of MUMB was undertaken by the same authors in the mid-1990s through large-scale field trials in Gujarat State, India (P.K. Sanyal, personal communication). FECs were reduced with MUMB use and farmers indicated that the general health of MUMB-treated animals had improved and estimated that a >5 percent improvement in milk production had occurred. Detailed lactation records were, however, not kept due to the inherent difficulties involved in such recording at the village level.

Alternative anthelmintics for use in medicated blocks

Apart from fenbendazole, albendazole has been used to prepare anthelmintic blocks for nematode parasite control in sheep (Tan *et al.*, 1996) and triclabendazole included in blocks for *Fasciola* spp. control in cattle and buffalo (Sanyal and Gupta, 1998). Febantel, a probenzimidazole anthelmintic, has been successfully used in in-feed formulations for nematode control (Stiefelhagen and Uhlemann, 1978; Kutzer, 1981) but initial trials of inclusion of this compound in UMB were unsuccessful since bioavailability was reduced to zero even at three times anticipated dose rates (M.R. Knox, unpublished). Other modern anthelmintics do not have the safety index or stability of the benzimidazoles and their use in blocks is not recommended without detailed studies of toxicity and bioavailability.

In developing nations where commercial anthelmintic preparations are expensive or difficult to obtain, farmers sometimes rely on traditional herbal remedies for nematode parasite control. Although anthelmintic activity has been attributed to numerous plant species in most localities (FAO/APHCA 1991a,b,c, 1992), quantitative data on efficacy is rarely available and detailed studies are required to determine the efficacy of herbal remedies before more wide-ranging recommendations for their use can be made. These studies should include botanical description, records of stage of growth and plant component used (leaf, stem, flower, seed, root), mode of preparation, dose rate and frequency and details of response to treatment. Once effective remedies are identified and their preparation standardized, they may then provide a simple, low-cost means of controlling helminth parasitism. The inclusion of some of these compounds in UMB formulations may be particularly beneficial if ease of delivery is improved.

Discussion

Gastrointestinal nematode parasites continue to be a major constraint on efficient production of milk and meat in cattle and buffalo throughout the world. This problem is exacerbated in production systems in developing countries where nutritional inputs are sub-optimal and anthelmintic compounds are costly and often difficult to obtain. Coupled with this, the lack of knowledge of nematode parasite epidemiology in these systems leads to treatments only being given when acute disease is evident, or provided sporadically when budgetary allocations are provided through government veterinary services. This means that production losses due to subclinical levels of infection will continue unless greater recognition of this problem occurs and alternative approaches are adopted. To maximize the production potential in these areas, there is an urgent need to gather essential epidemiological information on helminth parasites so that locations where losses are occurring are identified and a more integrated approach to control can be taken. Identification of the parasite species present, their seasonal abundance and impact on production will determine whether changes to grazing management (or fodder gathering) practices can reduce helminth infection, or whether anthelmintic intervention is necessary to derive economic benefits for the livestock producer. Once this is established, the timing and means of anthelmintic therapy can be decided from the locally available options, with cost and efficacy being important drivers of the decision-making process.

Medicated UMB may provide one option for anthelmintic intervention in production systems where this form of nutritional supplement is part of routine husbandry practice. It has been clearly shown that MUMB containing FBZ at 0.5 g/kg can satisfactorily clear established infections of *Haemonchus* spp. in calves and that infection can be prevented by offering MUMB to calves during parasite challenge (Sanyal and Singh, 1993). Efficacy of MUMB treatment has also been established in field trials, with increased growth rates in young cattle, which substantially reduces the time to first service. Similar results after treatment for nematode parasites have been observed in young cattle by de Rond *et al*. (1990) in Sri Lanka, with considerable savings in husbandry costs involved with keeping the non-lactating portion of the herd. Milk production increases after MUMB treatment of lactating adult buffaloes and cattle recorded above were of similar magnitude to those achieved by suppressive anthelmintic treatment of buffalo (Sanyal, Singh and Knox, 1993) and cattle (de Rond *et al*., 1990; Sanyal, Singh and Knox, 1992). In subtropical areas where *Haemonchus* is the predominant parasite species it appears that MUMB may be an appropriate treatment, particularly at times when parasite larvae are seasonally abundant.

From the studies of Sanyal and Singh (1993), it is also noteworthy that, in young calves in India, UMB supplementation resulted in lower FECs and reduced worm burdens compared with unsupplemented animals. These findings demonstrate the practical nutritional benefits of UMB supplements and further support the proposal that such supplements can influence the animal's ability to resist infection, as shown in pen studies with young sheep (Knox and Steel, 1999) and field studies with sheep in Fiji (Manueli, Knox and Mohammed, 1995). In situations where nutritional deficiencies are likely to exacerbate the detrimental effects of parasitic infection, the use of such supplements should therefore be considered an integral part of husbandry practice in order to reduce the debilitating effects of parasitism and minimize the requirement for anthelmintic chemotherapy, as suggested by Knox and Steel (1996). Substitution of MUMB for UMB can then occur for short periods during times when parasite challenge is high or during periods of lowered host immunity caused by immaturity or physiological stresses such as reproduction and lactation. For these reasons, it is likely that MUMB will form an integral part of strategic parasite control programmes in developing nations where UMB have been shown to offer substantial nutritional benefits.

Summary

Gastrointestinal nematode parasites continue to be a major constraint to efficient production of milk and meat in cattle and buffalo throughout the world. This problem is exacerbated in production systems in developing countries, where nutritional inputs are sub-optimal and nematode parasitism is not adequately controlled. To maximize the production potential in these areas, there is an urgent need to gather epidemiological information on nematode parasitism so that appropriate control measures can be implemented. In situations where urea-molasses blocks are considered beneficial, introduction of blocks containing anthelmintic medication can then occur for short periods during times when parasite challenge is high or during periods of lowered host immunity caused by immaturity or physiological stresses such as reproduction and lactation. For these reasons, it is likely that medicated blocks will form an integral part of strategic parasite control programmes in developing nations where urea-molasses blocks have been shown to offer substantial nutritional benefits.

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In facing ever more limited resources and changing market conditions and in the attempt to enhance productivity for strengthening livelihoods, many technologies have been used to improve feed use and animal performance at the farm level. A particularly successful example, in terms of both geographic range of use and relative simplicity in formulation and preparation, is the urea-molasses multi-nutrient block technology. This publication provides a comprehensive overview of development and use of the block technology in countries around the world and it might be of great practical value to extension workers, students, researchers and those thinking of using such feed supplementation technology or of starting commercial production.

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