LEUCAENA FORAGE SUPPLEMENTATION OF RUMINANT DIETS IN THE ASEAN REGION

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ABSTRACT

The paper discusses the value and economic significance of Leucaena (Leucaena leucocephala), possibly the most widely used forage for ruminants in the ASEAN region. The primary value rests in its use as a source of supplemental dietary nitrogen (N) and also energy, minerals and vitamins in the context of its easy availability and accessibility in small farm systems throughout the region. The benefits of supplementation are dependent however on leafiness, mimosine content and the relative proportions of leaves, stems and twigs with the leaves having a higher N content than the leaves and stems. Research on its utilisation and the effects on buffaloes, cattle, goats and sheep are reviewed. These suggest variable responses depending on the type and level of feeding the forage. The presence of the toxic amino acid mimosine and its breakdown product DHP (3-dehydroxy - H pyridone) are deterrents, but both adaptational and thresholds of tolerance enable relatively high levels of feeding depending on the ruminant species. The economic implications rest firstly, with increasing evidence that urea pretreatment compared to supplementation with leucaena gave approximately similar production levels, and secondly, that dried leucaena leaf meal has a lower cost per tonne of crude protein. These advantages are also associated with the added benefit of income earned from meal production for small farmers. Encouraging wider utilisation of leucaena represents therefore an important development strategy in promoting improved feeding systems for ruminants.

I INTRODUCTION

While energy, protein, minerals and vitamins are used as supplements, proteins are by far the most important. Urea, which is the most popular chemical used for upgrading the quality of rice straw, does not achieve much more than improve the quality of the feed to support maintenance needs. This means that in order to provide the necessary requirements for production, supplementation with specific requirements are essential. The inadequacies need to be corrected to provide additional nutrients. It is an important means to alleviate nutrient limitations and improve the efficiency of feeding systems.

Dietary protein is of three categories :- (i) rumen degradable protein (RDP) which is used for microbial protein synthesis, (ii) undegraded dietary protein (UDP) which escapes digestion in the rumen and is absorbed in the small intestines, and (iii) undigested UDP which escapes fermentation and absorption in the intestines. It has been estimated (Leibholz and Kellaway, 1984) that the minimum required crude protein of a poor quality diet with a digestibility of organic matter of 50% would be between 6.1 - 7.4%. With most crop residues with low nitrogen content, and especially cereal straws with 4% crude protein, protein supplementation is clearly necessary.

Of the forages that are traditionally used by ruminants (buffaloes, cattle, goats and sheep) and particularly of use as a protein supplement, in the Association of South East Asian Nations (ASEAN) region, leucaena (Leucaena leucocephala) is the most popular and widely used forage. This is perhaps best exemplified by the Philippines where the forage is very commonly fed as a supplement in practical diets for ruminants either as a green forage, as a leaf meal or even as a slop. The forage has been used widely with various crop residues such as cereal straws or even in sugarcane based diets (Alvarez and Preston, 1984).

The benefits of using this and other forages in small farm systems are many, and have been enumerated (Devendra, 1984). These include inter alia availability in the farm; accessibility; provision of variety in the diet; source of dietary nitrogen (N), energy, minerals and vitamins; have a laxative effect on the alimentary system; reduction in the requirement of purchased concentrates and reduced cost of feeding. The forage is associated with such additional advantages as multi-purpose use (wood and as a fence line), ability to withstand dehydration and therefore act as a protein reserve especially during droughts. These various aspects have been discussed in detail (I.D.R.C., 1983).

The intent in this paper is to review the value of the forage as a supplement in diets for ruminants. The focus will be mainly on its role as a feed supplement, utilisation by ruminants, effects on performance especially when it is used in conjunction with fibrous crop residues such as rice straw, and issues of overcoming practical problems within feeding systems. In view of the emerging importance of the forage, including its value as a leaf meal, the relevance and prospects for further developing this feed resource in the ASEAN region is considered.

II QUALITY OF FORAGE

The benefits of supplementation rest largely on the quality of the forage. This refers to age of the forage, leafiness, mimosine content and relative proportions of leaves, stems and twigs. Some idea of the significance of this is seen in Table 1. It can be seen that the leaves had a higher N content than the leaves plus stems and pods. The latter also had a higher crude fibre content. (Table 1 here)

III SUPPLEMENTAL EFFECTS OF DIETARY LEUCAENA

A number of studies have been reported on the effects of supplementing leucaena in various diets for ruminants (Devendra, 1985).

One of the earliest was that of Perez (1978) with grade feedlot bulls in the Philippines. Animals fed up to 50% of leucaena leaf meal with 40% rice straw and 10% concentrate mixture showed an average daily weight gain of 0.77 kg without any deleterious effect on the reproductive performance of the bulls. The animals also attained better feed conversion efficiency of 8.29 kg/kg feed over a feeding period of 126 days.

Lopez et al. fed varying levels of fresh leucaena leaves with sugarcane top cubes, with 40% concentrates in all diets. It was found that the 75% leucaena + 25% sugarcane top cubes gave the best daily gain of 1.20 kg/day (Table 2). All leucaena or sugarcane top cubes gave 1.04 and 0.78 kg/day respectively. (Table 2 here)

Also in the Philippines, leucaena leaves when fed with rice straw and/or dried poultry manure to crossbred dairy heifers showed no differences between treatments in daily live weight gain, but final live weights were different (Table 3).

Considering the feed costs, diet one was more expensive than diets two, three or four in the commercial system when leucaena had to be purchased as a dried meal. On the other hand if it can be easily cultivated at little or no cost in the backyard system, the cost of feeding diets one, two and three involving leucaena is substantially reduced. This is reflected in the cost/kg gain in the backyard system of 4.61, 4.42 and 4.26 P for diets one, two and three compared to 10.33 P for diet four which used up to 65% concentrates. (Table 3 here)

Similarly, several studies have demonstrated beneficial growth performance in cattle in Thailand. Veerasilp (1981) reported that a mixture of 1:2 fresh leucaena and gliricidia in a rice straw diet fed to sheep maintained body weight whereas feeding either forage alone produced live weight loss. Snitwong et al. (1983) fed dehydrate sugar cane tops with or without fresh leucaena leaves to young buffaloes and recorded a daily

Table 1. Chemical composition of the more important forages commonly used (% dry matter basis).

Constituent	Leucaena leaves	Leucaena leaves plus stems plus pods
Dry matter	30.0	30.1
Crude protein (N x 6.25)	22.0	17.4
Crude fibre	19.6	30.5
Ether extract	6.9	3.8
Ash	4.4	4.6
Nitrogen free extract	47.2	43.6
GE (MJ/Kg)	22.18	32.59
Ca	0.55	0.30
Mg	0.34	0.71
P	0.13	0.14
Cell wall (%)	31.2	34.6

Table 2. Average daily gain (kg) of cattle fed with varying Leucaena-sugarcane top ratio (Lopez *et al.*, 1981)

Treatment	Replication 1	2	3	4	5	Mean
I All Leucaena	0.96	1.31	0.93	0.98	1.04	1.04
I 75% Leucaena 25% SCT	1.26	1.18	1.03	1.10	1.41	1.20
I 50% L 50% SCT	1.01	1.25	0.90	1.06	1.06	1.06
V 25% L 75% SCT	1.02	0.93	1.09	1.12	1.04	1.04
V All Sugarcane top cubes	0.80	0.88	0.69	0.75	0.75	0.78

+ SCT - Sugarcane tops

Table 3. Effect of feeding rice straw diets supplemented with leucaena leucocephala and/or dried poultry manure to crossbred dairy heifers in the Philippines. (Adapted from Trung *et al*., 1983)

Parameter	Treatments 1	2	3	4
Average daily gain (kg)	0.58a	0.44a	0.53a	0.50a
Feed efficiency (kg)	15.6a	25.2a	15.2a	11.9a
Final weight (kg)	307a	241b	258b	272ab
Daily feed costs (P)				
Commercial +	8.41a	3.98b	4.98c	5.33c
Backyard ++	2.63d	1.90a	2.22a	5.09b

Treatments : 1 - 35% rice straw + 45% leucaena + 25% concentrates
2 - 35% rice straw + 30% leucaena + 15% dried poultry manure + 20% concentrates
3 - 35% rice straw, 22.5% leucaena, 22.5% dried poultry manure + 20% concentrates
4 - 35% rice straw + 65% concentrates

abc Means on the same row with different superscripts differ ($P < 0.05$).

\+ 15 cows

++ 2-3 cows

gain of 0.70 kg compared to 0.23 kg for the unsupplemented group, reflecting again the benefit due to increased energy and protein intakes. Snitwong, Mangmeechai and Manidool (1983) fed up to 60% leucaena leaf meal in combination with 1% urea and 34% cassava chips to buffaloes and recorded a daily gain of 0.48/head. The negative results with DHP (3-dehydroxy-H-pyridone) suggested that buffaloes were able to tolerate high levels of leucaena leaf meal (Table 4). Cheva-Isarakul and Potikanond (1984) compared feeding urea treated rice straw versus untreated straw plus leucaena leaves and reported growth responses of 0.48 kg and 0.42 kg/day, emphasising the value of leucaena. By comparison, Promma *et al*. (1984) reported positive production responses in crossbred Holstein-Friesian dairy cattle fed urea treated rice straw and leucaena. (Table 4 here)

In Indonesia, 0.0, 0.5, 1.0 and 2.0 kg of leucaena leaf supplementing a basal Napier grass (*Pennisetum purpureum*) diet in sheep increased daily growth rate significantly ($P<0.05$). However, increasing dietary leucaena leaves decreased apparent digestibility of dry matter and crude protein (Semali and Mathius, 1984). Utomo *et al*.(1984) fed 100, 175, 250 or 325 kg of leucaena leaf meal with corn stalks which were provided *ad libitum*, but found no significant differences in growth rates in growing goats. Soedomo-Reksohadiprodjo (1984) fed a basal diet of corn stalks or sorghum stalks or sugarcane tops fed with groundnut vines and cassava leaves with supplemented leucaena leaves (16.8, 20.6 and 25.7%) but found no differences in growth responses in goats.

In Malaysia, two trials investigated the nutritive value of leucaena forage (stems and leaves) when fed *ad libitum* to livestock. The forage was harvested at 2 month intervals at a cutting height of about 60 cm. Adult goats and sheep of similar live weight (25-26 kg) were also used in an assessment of comparative digestibility.

Goats had an average daily dry matter intake of 51.0-60.9 g/$W^{0.75}$ and sheep 39.4-53.7g/$W^{0.75}$kg. The digestibility of dry matter for goats was 53.9-56.4%, organic matter for goats was 53.9-56.4%, organic matter 54.1-57.0%, crude protein 44.8-45.0%, and crude fibre 38.5-68.4%. The figures for sheep were dry matter 50.0-50.5%, organic matter 51.1%, crude protein 40.5-46.3%, and crude fibre 31.2-60.2%. Nitrogen retention as a percentage of intake was 22.8-36.3 for goats and 8.7-18.4 for sheep; these differences were significant (Table 5) (Devendra, 1982). By comparison in India, the nutritive value for goats has been reported (Upadhay, Rekib and Pathak, 1974) to be 16-7% digestible crude protein (DCP) and 70.2% total digestible nutrients (TDN). (Table 5 here)

A 77-day growth trial was conducted with 40 Katjang x Etawah goats, about 1 year old. The trial had four treatments, replicated twice for males and females in a randomized, block design. The treatments, based on total dry matter intake (DMI), were napier (*Pennisetum purpureum*) grass (control); 75% grass, 25% leucaena; 50% grass, 50% leucaena; and 25% grass, 75% leucaena.

Table 4. Performance of buffaloes fed on rice straw with leucaena leaf meal and concentrate supplement (Snitwong, Mangmeechai, and Manidool, 1983)

Feed ingredients	Control	40% LM+	50% LM	60% LM
Cassava chips	47	45	43.5	34
Soybean cake	18	5	-	-
Leaf meal	0	40	50	60
Rice bran	20	-	-	-
Corn meal	15	9	5	5
Urea	-	1	1.5	1
Crude protein (%)	13.2	13.4	13.8	13.7
Mimosine (%)	0	1.28	1.60	1.92
Performance				
No. of buffaloes	5	5	5	5
Duration (days)	120	120	120	120
Initial wt. (kg)	317.3	316.9	342.6	326.5
Average daily gain (kg/head)	0.62	0.48	0.39	0.48
Feed intake (kg/head/day)	8.09	9.02	9.20	9.02
DHP++ test, urine	negative	negative	negative	negative
Weight of thyroid gland (g)	37	25	25	31

+ Leucaena leaf meal

++ 3 - dehydroxy - H pyridone

Table 5. Nutritive value of leucaena forage to goats and sheep (Devendra, 1982)

Parameter	Goats	Sheep
Digestible crude protein (%)	9.3-11.0	9.1-10.1
Total digestible nutrients (%)	46.9-67.8	46.7-54.2
Digestible energy (10^6J/kg)	8.66-12.62	8.62-10.00
Metabolizable energy (10^6J/kg)	7.10-10.35	7.07-820

Leucaena stimulated daily live weight gain, which was highest ($P<0.05$) for the animals fed 25% grass, 75% leucaena (Table 6). At this level, however, the mimosine's effects were apparent. No significant differences were distinguishable on the basis of sex, DMI, or body measurements (height at withers, heart girth, and body length). It was concluded that leucaena forage can constitute 50% of the diet of goats (Devendra, 1982), which is higher than the level (30%) advocated for steers by Jones (1979). (Table 6 here)

The beneficial effects of leucaena forage are dependent essentially on the quality of the forage, pods and stems. This explains why in some experiments supplementing leucaena had little effect on diet digestibility even when it comprised a significant portion of the diet (Devendra, 1983; Moran, 1983; Semali and Mathius, 1983; Sitorus, Van Eys and Pulungan 1985). This suggests that the quality of the forage supplements might not always be high, and for best results, leafy material in optimum amounts need to be fed to get the best results to take advantage of the relatively higher value (Table 1). Forage quality is thus important in getting the high nutrient uptake in terms of energy, N minerals and vitamins and for the best performance. Thus, when leucaena leaves were compared to leucaena leaves plus stems plus pods in balance trials with sheep, the best N retention and mineral retentions were recorded for the former (Table 7). Leucaena leaf meal when supplemented either alone or in combination with water hyacinth (Eichornia crassipes) improved organic matter and crude protein digestibility (Sirwattanosombat and Wanapat, 1984). (Table 7 here)

Recent studies in Mexico on the effect of tropical forages on rumen function and flow of nutrients to the duodenum in cattle showed that leucaena forage produced higher N flows than sweet potato, cassava banana or sugarcane leaves (Jodoy and Elliott, 1981). The forage protein was either material escaping rumen degredation or microbial protein due to greater synthesis stimulated by the amino acids present in leucaena. The biological value of leucaena protein is high and it has been reported that the forage supported similar growth rates to groundnut cake (Hulman, Owen and Preston, 1978).

IV TOXIC COMPONENTS

One main constraint to its feeding value is the presence of the toxic amino acid mimosine, and its breakdown product in the rumen DHP (3-dehydroxy-H pyridone). Table 8 gives an indication of the mimosine content in different parts of the leucaena plant in the ASEAN region. Considerable differences are apparent due to strain and locational reasons. Young leaves however had the highest mimosine content. Tannins are also found in leucaena. Sheep unaccustomed to feeding leucaena, shed their wool between 7 and 14 days after leucaena feeding commences. Adaptation to leucaena diets is important to enable

Table 6. Effects on growth performance of goats fed L. leucocephala (L) and P. purpurum (G). (Devendra, 1982)

Parameter	100%G	75%G + 25%L	50%G + 50%L	25%G + 75%L
Initial live weight (kg)	12.2	10.1	10.1	10.2
Final live weight (kg)	12.8	12.0	12.6	14.5
Live weight change (kg)	0.6	1.9	2.5	4.3
Mean live weight (kg)	12.5	11.1	11.4	12.4
Mean daily live gain (g)	11.7a	24.4a	32.9ab	55.8c
Dry matter intake/day (g)	393.9	404.9	505.3	550.3
Dry matter intake/$W^{0.75}$kg (g/day)	59.7	66.4	81.4	83.4
Dry matter intake as % of live wt.	3.4	4.0	4.8	4.7
Feed efficiency (DMI/gain)	30.3a	17.1b	15.9b	11.5b

[a] Results refer to the mean value for both males and females (10 goats total). Means in horizontal columns followed by different letters differs significantly ($P<0.05$).

Table 7. Intake and digestibility of chopped rice straw (RS) supplemented with either cassava leaves (CL), leucaena leaves (L), leucaena leaves plus stems plus pods (LSP) or gliricidia leaves (GL). (Devendra, 1983)

Parameter	RS+CL	RS+L	RS+LSP	RS+GL
Fresh intake (g/day)	1556.8a	1408.6a	1414.5a	1414.3a
DMI/kg$^{0.75}$(g/day)	65.9a	69.7a	64.7a	64.1a
DMI as % body weight	3.0a	3.2a	3.0a	2.7a
DM digestibility	53.5a	49.2a	48.0a	47.6a
OM digestibility	60.5a	56.9b	55.4b	55.4b
CP digestibility	49.7a	50.4a	44.3a	31.6b
Energy digestibility	54.7a	52.6a	45.7a	48.9a
N retention as % of intake	16.2a	34.8b	3.9c	9.2cd
Ca retention as % of intake	27.4b	22.9a	7.8a	21.2c
Mg retention as % of intake	30.2b	30.4b	26.2b	33.4b
P retention as % of intake	65.3a	56.8b	38.2c	39.4c

abc Means on the same row with different superscripts differ ($P<0.05$)

the rumen microorganisms to break down the mimosine as it increases. Goats fed mimosine have been shown to degrade the mimosine content from 60 to 0.3 mmg/g after 25 hours, and with pure mimosine, 98% was degraded by the rumen fluid after five hours (Shiroma and Akashi, 1976). In India, feeding the forage to adult Barbari goats over 33 days indicated that falling of hair was only noted in one animal during the last week. The mean intake was 2.16 kg/100 kg of live weight, and the DCP and TDN contents were 16.7% and 70.2% respectively. The goats were in positive N and Ca balance. The leaves alone were inadequate to meet the energy requirements for maintenance (Upadhay, Rekib and Pathadk, 1974). More recently, it has been reported that the enzyme system in leucaena leaf was more efficient in degrading mimosine than were the microorganisms in the rumen liquor of sheep (Tangendjaja and Lowry, 1984). The degradation of mimosine due to an endogenous enzyme resulted in a faster rate of degradation so that 50% of the mimosine present was degraded in two hours. (Table 8 here).

There is evidence that there are adaptational differences to the level of dietary leucaena. In some countries such as in Australia, ruminants develop signs of toxicity when they consume a high proportion of leucaena in the diet, whereas animals in other countries such as in Indonesia, Philippines and Hawaii do not. The reason for this difference appear to be related to the ability to degrade mimosine and DHP. Among the ruminants, goats in particular, appear to do this more efficiently, and consequently are able to utilise higher levels of the forage. There is also evidence that goats are unaffected (Kranveld and Djaenoedin, 1947; Owen, 1958; Jones, 1981; Lowry, 1983).

Mueulen and El-Harith (1985) suggest that except for cattle and sheep, the tolerable limit is 0.2 g mimosine/kg body weight/day. They calculate that with a 2% mimosine content in the dry matter, a cow of 200 kg body weight would require 2 kg of leaf meal or 8 kg of fresh forage, equivalent to 40% of its dry matter requirements.

The mimosine and tannin contents are presently a deterrent to the use of leucaena in poultry diets. The mimosine content can be treated with water at 60° C to convert it to DHP. Mimosine and DHP can be destroyed by auto-claving at 120°C after adding NaOH and macerating, but both methods are expensive and not practical. More recently, the problem has been resolved through the use of ferric sulphate (8.45 g/kg diet) and also polyetheleneglycol (PEG) is isoenergetic and isonitrogenous diets for poultry containing 150 g leucaena meal/kg. It has been reported that the combined supplements restored growth of leucaena-fed chicks to 90% of that obtained by birds fed a soybean meal-maize control diet (Acamovic and D'Mello, 1984).

V ECONOMIC IMPLICATIONS

There are important economic implications in the use of forages such as leucaena. There are three examples of good experimental evidence to demonstrate this. One concerns the results from the Philippines (Trung *et al.*, 1983) which has been summarised in Table 3. Tables 9 and 10 present two other sets of results from Thailand (Cheva-Isarakul and Potikanond, 1984;

Table 8. The mimosine content of young and mature leaves, pods and seeds in leucaena forage

Country	Mimosine content (%)					Reference
	Young leaves	Mature leaves	Stems	Pods	Seeds	
Indonesia	-	1.05	-	-	-	Lowry (1983)
Malaysia	2.09	0.26	0.10	1.21	-	Wong & Devendra (1983)
Philippines	6.83	3.42	-	3.66	7.12	Endrinal and Mendoza (1979)
Thailand	-	3.7	5.9	-	-	Manidool (1983)

Promma et al., 1984) for growing and lactating cattle. The latter studies for example showed that both urea pretreatment compared to supplementation with leucaena give approximately the same production levels. (Tables 9 and 10 here)

These results together demonstrate that utilising leucaena leaves is just as economical as the alternative method of chemical pre-treatment using urea and/or ammonia. For the reasons already given concerning the benefits of using forages such as leucaena already available on most small farm in the ASEAN region and elsewhere, it follows that encouraging wider utilisation of this forage is both realistic and logical, and indeed needs to be pursued as an important development strategy.

VI LEUCAENA LEAF MEAL PRODUCTION

Consistent with the increasing production and utilisation of leucaena throughout the ASEAN region, consideration is also now being given to its commercial production as a dried meal for use by the feedmilling industry as well as for possible export. The justification for this rests with the fact that preformed protein sources are in great demand and are increasing in cost. Since small amounts (up to about 8%) of the meal can also be used for feeding non-ruminants, the value of producing the meal is also attractive especially in relation to the cost per tonne of protein. When used at the 5% level, it is estimated that the annual requirements for the meal in the ASEAN region for non-ruminants done is about 405,000 mt.

Table 11 presents the relative costs per tonne of protein produced. The comparative advantage of leucaena leaf meal production in terms of cost of protein/tonne has been calculated using current (Jan 1986) costs of the ingredients. Similar calculations have also been made for the detoxified meal. Minimum differences can be expected in harvest, handling and transport costs of the forage. Processing costs are not expected to differ greatly other than energy costs associated with drying the green forage. Table 11 demonstrates that leucaena meal is about 23% cheaper than fish meal and about 7% cheaper than soyabean meal. Similar costs for the detoxified leaf meal are 2% and 5% respectively. (Table 11 here)

The economic production of the meal has such other advantages as reducing the cost of production, reducing the drain on foreign exchange and increasing the income of farmers. To this end, leucaena leaf meal production is becoming increasingly popular in the Philippines and Thailand. In the latter case, farmers now get a much higher return from leucaena leaf meal production than from rice cultivation, and is associated with the fact that there exist about 35 leucaena leaf meal producing feed mills today. In both the Philippines (Calub and Mendoza, 1984) and Thailand (Manidool, 1983) commercial feed millers use about 205% of leucaena leaf meal for pig and poultry diets.

Table 9. Economics of feeding untreated rice straw (RS) with leucaena leaf and urea-treated rice straw (UTS) by growing Holstein Friesian bulls+ (Cheva-Isarakul and Potikanond, 1984)

Item	UTS (6%)	RS + leucaena leaf
Total straw intake, kg/d	186.5	164
Leucaena leaf, kg/d	-	45.5
Concentrate, kg/d	91.	91.
Total cost, Baht/hd	475.9	477.8
Total weight gain, kg/hd	38.4	44.
Feed cost/gain, Baht/kg	12.4	10.9

+ Experimental period was 91 days

Table 10. The performance of lactating cow given 6% urea treated rice straw, 4% urea treated rice straw and untreated rice straw plus leucaena leaves (Adapted from Promma *et al*., 1984)

Parameter	6% urea treated straw	4% urea treated straw	Untreated straw + L
I. Performance			
Roughage DMI (g/kg $W^{0.75}$/day)	86.6	81.4	84.8
DMI as % of body weight	1.98	1.86	1.95
Concentrates DMI (kg/hd/day)	4.03[a]	3.9[a]	4.12[a]
Total DMI (kg/hd/day)	11.23	10.7	11.12
Feed efficiency (kg feed/ kg FCM milk)	1.28	1.27	1.31
Milk production (4% FCM) (kg/hd/day)	8.8[a]	8.4[a]	8.5[a]
Average fat (%)	3.7[a]	3.7[a]	3.4[a]
Milk protein (kg/hd/ 28 days)	9.03[a]	8.62[a]	8.9[a]
Average protein (%)	3.5	3.5	3.4
Weight changes (g/day)	+96.4[f]	+96.3[f]	+71.8[f]
II. Economic analysis			
Operating costs (Baht/kg milk)	4.22	4.12	4.18
Net income (Baht/head/month)	575.4	574.5	517.8

[a] No significant differences (P>0.25) were observed

Table 11. Relative costs of protein (US$/ton)

Ingredient	Cost ($/t)	Protein content (%)	Cost/tonne Protein ($/t)
Fishmeal	395	65%	608
Soyabean Meal	210	40%	525
Leucaena Leaf Meal	138	28%	493
Leucaena Meal (detoxified)	140	28%	500

VII PRACTICAL IMPLICATIONS

While leucaena leaf feeding is more beneficial than feeding the leaves plus stems, there is the disadvantage that the former has a higher mimosine content (Table 8). Clearly, a balance needs to be formed between the material fed, level of feeding and the choice of species. Present indications are that among the ruminants, buffaloes and goats appear to have a higher thresholds of tolerance than do cattle and sheep.

It has been recommended by Ranjhan (1983) that feeding straws with green fodders, whether these are grasses or legume in the ratios of 3:1 or 1:1 should meet the requirements for maintenance and growth respectively. On the other hand it has been suggested that green forages, preferably legumes, can be given up to a maximum of about 0.7% (dry matter basis) of live weight or about 25% of the diet (Preston and Leng, 1984).

VIII CONCLUDING COMMENTS

Based on current evidence and the extent of utilisation of leucaena forage by the various ruminants in the ASEAN region, there is no doubt that the forage is one of increasing economic importance in these countries and elsewhere. While several studies have reported beneficial effects when fed to buffaloes, cattle, goats and sheep, there is room for a lot more precision in the use of the forage in respect of leafiness, proportion of stems, level of feeding, and quality with reference to crude protein, mimosine and tannin contents. These issues need to be defined in relation to specific species use in view of different thresholds of tolerance. Buffaloes and goats for example, appear to have greater tolerance and possibly also increased ability to degrade mimosine than do cattle and sheep. Inadequate attention has been given to dehydrated leucaena leaf meal production and this is a potential that remains to be explored. Economic production of the meal can reduce the dependence on the need for imported preformed proteins at high cost. Accelerating the use of leucaena forage and improving the efficiency of feeding systems, thus represents an important development strategy.

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