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Supplementation with *Gliricidia sepium* and *Leucaena leucocephala* on voluntary food intake, digestibility, rumen fermentation and live weight of crossbred steers offered *Zea mays* stover

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Abstract

Twenty intact and five fistulated crossbred steers were used in two experiments to examine the effect of supplementing maize stover with *Gliricidia sepium* or *Leucaena leucocephala* forage on intake, rumen fermentation, microbial protein supply and live weight changes. The basal diet plus 1 kg maize bran was offered alone or supplemented with 7.5, 15, 22.5 or 30 g DM/kg $W^{0.75}$ of gliricidia (experiment 1), and with either 15 or 30 g DM/kg $W^{0.75}$ of gliricidia or leucaena forage (experiment 2). Supplementation increased total dry matter intake (TDMI) ($P < 0.001$). DMI of stover was depressed ($P < 0.001$) in experiment 1 from 2.1 to 1.3 kg/day, but increased at the lower levels of supplementation in experiment 2. Diet digestibility was only significantly increased in experiment 2. Supplementation increased the rumen ammonia from 53 to 106 mg/l and from 31 to 111 mg/l in experiment 1 and 2 respectively, and tended to improve the degradation characteristics of the basal diet. The efficiency of microbial N supply ranged between 21.0 and 27.7 g N/kg DOMR. The live weight gains from supplementation were greater, and the responses to gliricidia and leucaena did not differ significantly. It is concluded that the supplementation improved dry matter intake and live-weight gains, and that *Gliricidia sepium* could be an alternative supplement to *Leucaena leucocephala*. © 1997 Elsevier Science B.V.

Keywords: Cattle; Intake; Rumen; Live weight; Gliricidia; Leucaena; Legume forages; Rumen fermentation; Growth performance

1. Introduction

A major constraint to cattle performance in the tropics is the inadequacy of feeds, particularly during the dry season when the quality and quantity of natural pasture declines resulting in lower intakes and reduced cattle productivity. Crop by-products such as maize stover are an important source of dry season feed in Africa, yet because they are fibrous and generally low in nitrogen and digestible nutrients, supplementation is required to achieve reasonable levels of cattle production. Tree legumes, which

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persist during the seasons of pasture scarcity can contribute protein-rich forage for cattle production (Devendra, 1993). In a previous work (Abdulrazak et al., 1995 and Muinga et al., 1995), it was shown that supplementing napier grass fodder with foliage from the tree legumes, *Leucaena leucocephala* and *Gliricidia sepium*, improved the dry matter intake and live-weight gain of young cattle and lactation performance of dairy cows. The recent infestation of leucaena in Africa by the pest *Heteropsylla cubana* (Reynolds and Bimbuzi, 1993) and its poor performance in acid soils, calls for alternative tree legumes to leucaena. Gliricidia may meet these requirements (Bennison and Paterson, 1993; Coates, 1995).

The objective of this study was to evaluate the effects of incremental supplementation with leucaena and gliricidia on the intake, rumen fermentation, microbial N supply and live weight of steers offered a diet of maize stover *ad libitum*. The estimates of rumen parameters and animal performance will contribute towards the development of feeding systems that utilise optimal levels of the legume forages for tropical cattle production.

2. Material and methods

2.1. Production environment

The experiments were conducted at the Kenya Agricultural Research Institute's Regional Research Centre at Mtwapa (3°56′S, 39° 44′E) in the coastal lowlands of Kenya. The total rainfall and the mean temperature and relative humidity during each experiment were 87.6 mm, 26.6°C and 0.74 (experiment 1) and 2.6 mm, 27.6°C and 0.67 (experiment 2), respectively.

2.2. Animals

Twenty *Bos taurus* (Ayrshire/Brown Swiss) × *Bos indicus* (Sahiwal) steers of known breed composition were used for both experiments measuring the intake, digestibility, microbial N supply and rumen kinetics. Weekly live-weight changes were recorded to estimate the average daily gains (g/day). Five fistulated steers of similar breed composition to the 20 steers were used for the studies in which the rumen pH, ammonia(NH_3–N) and *in sacco* tion characteristics of the feeds were deter the start of the experiments the mean live the twenty steers and the fistulated steers kg (s.d. 9.0) and 428 kg (s.d. 53.3) (exper and 168 kg (s.d. 9.6) and 417 kg (s.d. 54.9) ment 2), respectively.

All steers were confined in individu ventilated stalls, and each week they were and sprayed with an acaricide. Before the each experiment, the steers were drenched anthelmintic and blood was sampled from the vein to screen for trypanosomes.

2.3. Diets

Pwani hybrid maize was planted at the re centre for the production of stover. During p triple superphosphate fertilizer was applied rate of 46 kg P_2O_5/ha. During weeding the was top dressed with calcium ammonium fertilizer at the rate of 60 kg N/ha. After the was harvested, the stover was cut 5 cm fro ground; tied in bundles and stored in a shed used in the experiments.

Gliricidia and leucaena had been establishe pure stands with spacing of m between and within the rows. During the experiments, the le forages were harvested daily at approximate weeks of regrowth. Stems thicker than 5 mm removed to ensure uniform forage composition.

2.4. Experimental design and procedures

In each experiment the twenty steers were di into five groups on the basis of their live-weight allocated to five diets in a randomised design; measurements were recorded for seven weeks. five fistulated steers were offered the same ments in a 5 × 5 latin square design in which period consisted of a 10-day adaptation and a data collection period.

The five experimental diets were as follows: stover plus 1 kg of maize bran (control), or co plus 7.5, 15, 22.5 or 30 g DM/kg $W^{0.75}$ of glirici (experiment 1), or control plus 15 or 30 g DM/ $W^{0.75}$ of gliricidia or leucaena forage (experiment Whole dry maize stover was chopped with an el

chopper to pieces of about 40–60 mm and offered ad libitum. The legume forage and 1 kg of maize bran were offered separately in two equal meals at 06:00 and 15:00 h. The forage was harvested in the morning for the afternoon feed and in the evening for the following day feed. Refusals were removed and recorded before offering new feed the next day. Animals with refusals of the basal diet of less than 1 kg fresh weight were offered 1 kg more than the amount offered the previous day. The forages offered were sampled once per week for DM determination. The live-weights recorded at the end of each week of each experiment were used to calculate the amount of legume forage to be offered during the subsequent week. Water and a mineral lick which contained 189 g Ca, 110 g P, 130 g Na, 4 g S and 1.6 g Cu per kg, were on offer at all times.

2.5. Rumen pH, NH_3 and in sacco degradation

To determine the in sacco degradation characteristics of the forages, five grams of dry (at 85°C) sample milled through a 3.5 mm screen were placed in nylon bags (140 × 75 mm, pore size 40 to 60 μm). During the last four days of each experiment period, nylon bags in duplicate containing stover and gliricidia (experiment 1), or stover, gliricidia and leucaena (experiment 2), were placed in the rumen. The bags were removed after 6, 12, 24, 48, 72 and 96 h for legume forages and up to 120 h for stover samples. All the bags were then stored in a freezer. The zero-hour measurement was obtained by soaking the bags in warm water (37°C) for about 15 minutes. At the end of the degradability trial the bags were hand-washed under running water until the water coming out of the bags was clear. The samples were then dried in an oven at 85°C to determine DM disappearance. The DM disappearance values were fitted to the exponential equation of McDonald (1981). The degradation curve is described as: within the lag time T, $y = A$, i.e. the initial washing loss; beyond the time T, $y = a + b(1 - e^{-ct})$ where a, b and c are degradation constants. During the last two days of the degradability study, about 100 ml rumen liquor were collected at 0, 1, 2, 3, 4, 6, 8, 10 and 12 h after the morning portion of supplement was offered. The pH of the sample was determined immediately, using a pH stick. The sample was strained using a clean cotton cloth and the liquid fraction acidified with HCl acid and stored at −20°C for later analysis of rumen ammonia.

2.6. Urine and faeces collection

The total daily faecal output and spot urine samples of the 20 steers were collected by stationing an attendant with a bucket by each animal to collect all excreta voided during the last 7 days of the trial. The spot urine samples were collected between 09:00 and 13:00 h. Urine samples were measured daily and 100 ml of urine were stored in small plastic bottles containing 7 ml of 10% H_2SO_4 to give a pH below 3. The urine samples were stored at −20°C to be analyzed for purine derivatives (allantoin and uric acid) and creatinine. After recording the weight, a proportion (0.10) of the 24 h faecal collections was stored at 4°C. At the end of the collection period the faecal samples were bulked, mixed and a sub-sample obtained for DM and ash determinations.

2.7. Solid outflow rate

Chromium-mordanted stover was prepared according to the method of Uden et al. (1980). All the twenty steers were dosed orally with 130 g Cr-mordanted stover, and grab samples were taken at 6, 12, 20, 25, 30, 46, 54, 70, 94, 102 and 118 h post-dosing, and stored at 4°C for analysis of chromium oxide.

3. Analytical methods

DM of feeds and of faeces were determined by drying the samples in an oven at 105°C for 24 h, ash by ashing at 550°C for 8 h, and crude protein (CP) by the official methods of the Association of Official Analytical Chemists (Association of Official Analytical Chemists, 1984). Neutral detergent fibre (NDF) and lignin were determined by the method of Goering and Van Soest (1970). Rumen NH_3–N was determined as described by Preston and Leng (1987), and purine derivatives according to the method of Chen et al. (1990a). Faecal sample for the determination of particulate passage were digested with a combination of sulphuric, perchloric and nitric acid.

Chromium concentration was assayed with an atomic absorption spectrophotometer (Perkin-Elmer 2380).

Microbial purine absorbed (MPA) by the animals was estimated from the daily excretion of purine derivatives (PD) based on the model described by Chen et al. (1990b). The ratio PD:C (mmol:mmol) concentration in the spot urine samples was corrected for metabolic body weight ($W^{0.75}$), since daily creatinine excretion in urine appears as a function of the metabolic weight of the animal. The calculation was made as

$$\text{PD:C} = \text{PD concentration} / \text{creatinine concentration } W^{0.75-1}$$

Calculation of PD excretion from spot samples of urine was based on the findings of Mejia (1992) that the ratio of PD to creatinine concentration was positively related to daily output of PD.

$$\text{PD:}(\text{C}\,W^{0.75-1}) = 1.79X + 4.51 \ (r^2 = 0.84), \quad (1)$$

where X = daily excretion of PD (mmol/day).

The supply of microbial N (i.e., entering the small intestine) was calculated from MPA using the following factors (Chen, 1989) that, digestibility of microbial purine is 0.83 and the ratio of purine-N to total microbial-N ratio is 0.116:1.00. Thus microbial N supply (g/day) = MPA × 70/0.83 × 0.116 × 1000 = 0.727 × MPA, where 70 is the N content (mg/mmol) of purine.

3.1. Statistical analysis

Data from the experiments were subjected to analysis of covariance using the General Linear Model (GLM) of the SAS computer package (Statistical Analysis Systems, 1987). In experiment 1 orthogonal polynomial contrasts were used to estimate the effect of the level of supplement (Snedecor and Cochran, 1980). The model also evaluated the effect of breed (0.25–0.42 or 0.50–0.67 Sahiwal genes), and in experiment 2 the type and levels of legume. Initial live-weight was a covariate in the analysis of DM intake and live-weight change. In the analysis of the Latin square experiments, the effects of diet, period and animal were fitted. The fractional rates of particulate passage were derived by fitting the model of Grovum and Williams (1973).

4. Results

The animals remained healthy throughout the experiments. The chemical composition of feeds are presented in Table 1; the legume results are presented as means of seven observations. The legume forages had a higher CP and lower DM and NDF than maize stover. In experiment 2, gliricidia contained relatively more NDF (427 vs 394 g/kg DM) than leucaena. Crude protein content of gliricidia was similar in the two experiments, and slightly lower than that of leucaena.

DM intake, diet digestibility, live-weight gain and microbial nitrogen supply in experiments 1 and 2 are presented in Tables 2 and 3, respectively. During the first week of the experiment the steers refused some the of gliricidia offered, but all was

Table 1
Chemical composition of feeds used in experiments

	DM (g/kg)	Ash (g/kg DM)	CP (g/kg DM)	Lignin (g/kg DM)	NDF (g/kg DM)
Experiment 1					
maize stover	863	63	29	nd	768
gliricidia	254	79	192	nd	421
maize bran	870	37	98	nd	546
Experiment 2					
maize stover	867	77	34	50	741
gliricidia	258	86	196	119	427
leucaena	310	87	225	154	394
maize bran	875	37	95	nd	546

nd = not determined.

Table 2
Mean dry matter intake (DMI), digestibility, average daily gains (ADG) and microbial N supply in steers offered maize stover plus maize bran alone or with gliricidia forage

	Level of gliricidia(g DM/kg $W^{0.75}$)					s.e.d	Significance	
	0	7.5	15	22.5	30		L	Q
DMI (kg / day)								
stover	2.1	1.8	1.7	1.6	1.3	0.09	***	NS
gliricidia	0	0.3	0.7	1.0	1.3			
total	3.0	3.0	3.3	3.5	3.5	0.10	***	NS
Digestibility								
DM (g/kg)	516	471	513	525	529	24.9	NS	NS
OM (g/kg)	570	509	555	571	560	25.8	NS	NS
ADG (g/day)	203	179	434	373	352	40.1	**	NS
MN supply (g N/day) *	30.8	37.2	32.9	34.9	32.2	1.06	NS	*
MN supply (g N/kg DOMR)	23.4	27.7	22.7	24.5	21.0	1.46	NS	NS

DOMR = digestible organic matter fermented in the rumen, taken as 0.65 of the digestible OM intake (ARC, 1984).
* Calculated microbial N supply = 0.715 × estimated purine.
L = linear, Q = quadratic effect.

consumed subsequently. The incremental levels of gliricidia depressed linearly ($P < 0.01$) the intake of the maize stover diet, but increased linearly ($P < 0.01$) the total DMI by approximately 0.21 kg DM/day for every 10 g DM/kg $W^{0.75}$/day offered. In experiment 2, the steers consumed significantly ($P < 0.05$) more stover when 15 g DM/kg $W^{0.75}$ but not when 30 g DM/kg $W^{0.75}$ of either gliricidia or leucaena was offered. Supplementation with either of the legume forages increased the total DMI ($P < 0.001$). In experiment 2, but not in experiment 1, supplementation increased diet digestibility ($P < 0.01$).

In both experiments the unsupplemented steers gained weight. In experiment 1, the live-weight gains increased linearly ($P < 0.01$) with gliricidia supplementation: for every 10 g DM/kg $W^{0.75}$ increment, approximately 69 g/day live-weight was gained. In experiment 2, live-weight gains were approximately 700 g/day at the higher level of supplementation,

Table 3
Mean dry matter intake, digestibility, average daily gains and microbial N supply in steers offered maize stover plus maize bran alone or with gliricidia or leucaena forage

	Level of supplements (g DM/kg $W^{0.75}$)					s.e.d	significance			
	0	G15	G30	L15	L30		0 vs G,L	G vs L	2G	2L
DMI (kg / day)										
stover	2.3	2.5	2.3	2.7	2.2	0.05	*	NS	**	**
supplements	0	0.7	1.5	0.7	1.5					
total	3.2	4.1	4.6	4.3	4.6	0.05	***	NS	***	**
Digestibility										
DM (g/kg)	490	588	584	568	557	14.3	***	NS	NS	NS
OM (g/kg)	533	619	610	607	592	13.7	**	NS	NS	NS
ADG (g/day)	81	355	695	396	753	44.5	***	NS	***	***
MN supply (g N/day) *	23.1	39.8	47.8	37.6	43.4	4.39	**	NS	NS	NS
MN supply (g N/kg DOMR)	20.5	23.7	24.3	21.3	24.6	1.97	NS	NS	NS	NS

DOMR = digestible organic matter fermented in the rumen, taken as 0.65 of the digestible OM intake (ARC, 1984).
* Calculated microbial N supply = 0.715 × estimated purine.
G, L = levels of gliricidia and leucaena respectively.

Table 4
Rumen pH, ammonia, and in sacco degradation of feeds measured in steers offered maize stover plus maize bran alone or with gl... forage

	Level of gliricidia (g DM/kg $W^{0.75}$)					s.e.d	Significance	
	0	7.5	15	22.5	30		L	Q
Rumen pH	6.99	6.79	6.88	6.72	6.72	0.17	NS	NS
NH_3–N (mg/l)	53	81	87	91	106	28.2	**	NS
Degradation constants								
maize stover								
A	8.3	7.7	7.8	8.3	8.2	0.62	NS	NS
B	71.5	70.7	65.5	70.7	67.3	5.78	NS	NS
C	0.018	0.030	0.028	0.022	0.028	0.008	NS	*
gliricidia								
A	35.5	35.6	35.8	34.8	35.8	0.97	NS	NS
B	40.9	40.3	39.9	42.0	40.5	1.48	NS	NS
C	0.084	0.136	0.148	0.110	0.100	0.050	NS	0.06

A is the water soluble component and *B* the insoluble component; $B = (a + b) - A$.
a, b, and c are constants in the exponential $P = a + b(1 - e^{-ct})$.
L = Linear and Q = Quadratic effect.

approximately half that at the lower level, and only 80 g/day when no legume supplement was fed. Type of legume did not affect the response (Table 3). In experiment 1 gliricidia supplementation increased quadratically ($P < 0.05$) the calculated microbial N supply. When expressed proportionally to the d... gestible organic matter fermented in the rumen (DOMR), the efficiency of MN supply ranged be... tween 21.0–27.7 g N/kg DOMR. In experiment 2 the efficiency ranged between 20.5–24.6 g N/k...

Table 5
Rumen pH, ammonia, and in sacco degradation characteristics of feeds measured in steers offered maize stover plus maize bran alone or with gliricidia forage

	Level of supplements (g DM/kg $W^{0.75}$)					s.e.d	Significance			
	0	G15	G30	L15	L30		0 vs G, L	G vs L	2G	2L
Rumen pH	6.97	6.99	6.86	6.96	6.93	0.081	NS	NS	NS	NS
NH_3–N (mg/l)	31	80	101	95	111	20.4	***	NS	NS	NS
Degradation constants										
maize stover										
A	7.8	7.5	8.1	8.1	7.9	0.41				
B	73.2	69.6	64.8	66.5	69.4	5.27	0.06	NS	NS	NS
C	0.020	0.030	0.028	0.026	0.024	0.0084	NS	NS	NS	NS
gliricidia										
A	30.7	31.4	33.0	32.0	30.4	3.08	NS	NS	NS	NS
B	48.9	46.8	46.5	45.9	46.8	4.24	NS	NS	NS	NS
C	0.092	0.096	0.092	0.110	0.120	0.0448	NS	NS	NS	NS
leucaena										
A	30.2	31.9	30.8	31.1	30.0	1.86	NS	NS	NS	NS
B	44.7	42.7	42.7	42.3	42.5	2.10	NS	NS	NS	NS
C	0.072	0.084	0.076	0.075	0.094	0.0317	NS	NS	NS	NS

A is the water soluble component and *B* the insoluble component; $B = (a + b) - A$.
a, b, and c are constants in the exponential $P = a + b(1 - e^{-ct})$.
2G, 2L = levels of gliricidia and leucaena respectively.

The kinetics of particulate matter along the digestive tract of steers offered maize stover plus maize bran alone or with gliricidia or leucaena

	Level of supplements (g DM/kg $W^{0.75}$)				s.e.d	Significance			
	G15	G30	L15	L30		0 vs G, L	G vs L	2G	2l
Fractional outflow rate from rumen (k_1/h)	0.0212	0.0352	0.0220	0.0211	0.0262	0.0020	NS	NS	*	NS
Fractional outflow rate from hind gut (k_2/h)	0.0851	0.1068	0.1592	0.2051	0.1754	0.0575	NS	NS	NS	NS
Retention time in the rumen RTR	47.5	29.3	48.0	47.7	43.0	5.33	NS	NS	*	NS
Retention time in hind gut RTH /h	13.8	10.2	7.8	6.5	9.2	1.42	NS	NS	NS	NS
Mean gut retention time MRT /h	61.4	39.5	55.9	54.2	52.2	4.94	0.059	NS	*	NS

G, L = levels of gliricidia and leucaena respectively

DOMR; with the level tending to increase with supplementation ($P > 0.05$).

Tables 4 and 5 present the results of rumen pH, NH_3–N and in sacco degradation characteristics of the forages in experiments 1 and 2, respectively. In both experiments, rumen pH was unaffected by supplementation. In experiment 1, rumen NH_3–N increased linearly ($P < 0.01$) by approximately 16 mg/l for every 10 g DM/kg $W^{0.75}$ of gliricidia offered. In experiment 2 legume supplementation, but not its type or level, increased rumen NH_3–N ($P < 0.001$). Rumen NH_3–N levels in the unsupplemented animals were lower in experiment 2 than in experiment 1 (31 vs 53 mg/l). Supplementation did not significantly improve ($P > 0.05$) the degradation parameters of the forages, but the rate of degradation of maize stover was lowest in the unsupplemented animals.

Table 6 presents from experiment 2 the results of the kinetics of particulate matter along the digestive tract. The fractional outflow rate from the rumen was not changed by supplementation, except when 15 g DM/kg $W^{0.75}$ of gliricidia was offered. Supplementation tended to reduce mean gut retention time (MRT), the highest value for which was recorded in the unsupplemented animals.

5. Discussion

5.1. Effect of supplements on forage digestion and food intake

The stover in these trials had a similar chemical composition to that reported by Getachew et al. (1994) and Shem et al. (1995). The high lignocellulose and low N contents of stover result in low intakes by cattle, and when stover is offered alone, nutrient intakes are generally insufficient for maintenance requirements. Consequently maize bran was offered to all the animals in these experiments to minimise any possible live-weight loss.

Tree legume forages have several effects when offered as supplements to such poor quality feeds; they supply nutrients such as N and S (Egan, 1986), which improve the rumen environment and the degradation characteristics of the feeds, and generally they result in increased dry matter intake. In this study, supplementation with gliricidia and with leucaena significantly improved total DMI, and in both experiments the improvement could be attributed to a reduction in the particulate retention time in the gut. The MRT was higher in the unsupplemented than supplemented animals (61.4 vs 54.1/h), in agreement with the results of Bamualim et al. (1984). The increase in total DMI is consistent with the results of Bonsi et al. (1994) who studied legume supplementation of a teff straw diet.

Supplementation with gliricidia forage in experiment 1 depressed the intake of maize stover even at the lower levels of inclusion. By contrast, in experiment 2 when gliricidia and leucaena were offered at 15 g DM/kg $W^{0.75}$, more stover was consumed than when unsupplemented. Supplementation of low quality diets have been reported both to improve the intake of the basal diet (Minson and Milford, 1967; Pathirana et al., 1992), and to depress intake (Mosi and Butterworth, 1985; Getachew et al., 1994).

Smith and van Houtert (1987) indicated that when gliricidia is readily consumed it distends the rumen, restricting the intake of the basal diet, while Tjandraatmadja et al. (1993) associated the lower intake

of gliricidia forage to its distinctive odour. In these studies, gliricidia was offered after wilting for about 7 h post-harvest; it was readily consumed; and, it was extensively degraded in the rumen. As the degradation of stover was not depressed, it is unlikely that the substitution of stover in experiment 1 was due to decreased cellulolysis.

5.2. Rumen ammonia concentrations

Tree legume contains considerable amounts of antinutritional factors like tannin which have depressed intake and digestion in ruminants (Makkar, 1991). Polyninylpolyrolidone (PVP) has been used to reverse tannin inhibition of digestive enzymes (Blytt et al., 1988) and to assess the phenolic-related antinutritive factors in these browse species (Khazaal and Ørskov, 1994). Incubating leucaena and gliricidia in vitro with or without PVP, resulted in no difference in gas production between the samples with or without PVP (Abdulrazak, 1995). This would indicate that tannin-like compounds were unlikely to have had any inhibitory effect, at least on the digestion in the rumen. The total extractable phenolics measured in gliricidia and leucaena were approximately 15.6 mg/g DM (Abdulrazak, 1995). Mean ammonia levels in the rumen liquor of the unsupplemented animals were relatively lower (31 vs 53 mg/l) in experiment 2 than in 1. The provision of ruminally degradable nitrogen from the legume forages in experiment 2 may have improved the N status in the rumen, resulting in an increase in the intake of the basal diet. The level of NH_3–N in the rumen depends on several factors, one of which will be the type of diet being fermented. While Satter and Slyter (1974) indicated that 50 mg/l was the minimum level required for the maximum microbial growth in the rumen, Mehrez et al. (1977) showed that with high energy diets, NH_3–N levels as high as 238 mg/l were required to maximize the digestion of fibre. In experiments 1 and 2, supplementation with legume forages increased rumen NH_3–N from 53 to 106 mg/l and 31 to 111 mg/l, respectively. Levels of 50–80 mg/l seemed to have been sufficient for fibre digestion because higher levels did not significantly increase the degradation characteristics of the feeds in the rumen.

Studies to estimate the changes in the microbial population in the rumen were not carried out. It could be speculated that the legume supplements alleviated nutrient deficiencies in the rumen and probably increased cellulolytic microbes in the rumen liquor (Silva and Ørskov, 1988). These effects would improve the invasion of the substrate by microbes and the degradation rate of feeds thus improving the intake of the basal diet. This increase in intake of basal diet was observed at the lower levels of legume supplementation in experiment 2, as also consistent with those reported by Minson and Milford (1967), Ash (1990) and Kimambo et al. (1991). At the higher levels of supplementation, the intake of the basal diet tended to decline, probably due to the bulk of the forage supplement.

Supplementation with legume forage only improved the digestibility of the diets in experiment 2 in which the digestibility of the control diet was lower than in experiment 1. Mosi and Butterworth (1985) and McMeniman et al. (1988) reported an improvement in digestibility when sheep were fed crop residue diet supplemented with legume straw and increasing levels of the legume *Trifolium subterraneum* (Clover), respectively. The improvement in digestibility could have resulted from reduced levels of ADF and lignin (Van Soest, 1982).

Microbial N supply tended to improve with supplementation. Differences in purine derivatives resulting from supplementation may not have been expected as the treatment differences were relatively small (Chen, personal communication). The estimated values were within the range 14 to 60 g N/kg DOMR suggested by Agricultural Research Council (1980), and were consistent with those reported in the previous experiments (Abdulrazak, 1995).

5.3. The effects of supplements on animal performance

Supplementation with the legume forages increased total N supply: it increased the supply to the rumen and the microbial N supply and it provided some rumen undegradable protein in the form of amino acids to the small intestine. These N sources would have contributed to the increased live-weight gains (Ørskov, 1992). The responses in experiment 1 were such that every 10 g DM/kg $W^{0.75}$ of gliricidia resulted in 69 g/day live-weight gain. In experiment

gains from supplementation were greater, and comparison of gliricidia and leucaena indicated although leucaena resulted in slightly higher the difference was not significant. These results are consistent with the conclusion of Simons and Stewart (1994) that for low quality basal diets, *Gliricidia sepium* protein is most effectively used when fed at about 30% level.

In conclusion, the results indicate that moderate levels (20–30%) of tree legume forage supplements to low quality diets can significantly improve the intake and performance of ruminants in the tropics, and contribute to protein rich forage particularly during the dry season. Since *Leucaena leucocephala* has been heavily attacked by the insect pest *Heteropsylla cubana* in many regions, it is also concluded that Gliricidia sepium could be an alternative supplement to Leucaena leucocephala. Research is required to evaluate other potential tree legumes as ruminant foods

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