Utilization of low-quality roughage by *Bos taurus* and *Bos indicus* cattle

1. Rumen digestion

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1. Six Hereford and six Brahman steers were fed *ad lib.* Pangola grass (*Digitaria decumbens*) and Spear grass (*Heteropogon contortus*) hay alone and supplemented with rumen-degradable nitrogen and sulphur and minerals. The rumen digestion of the two feeds was determined by reference to the disappearance of substrate from nylon bags suspended in the rumen and withdrawn after intervals ranging from 8 to 120 h.

2. The digestion of the unsupplemented Pangola grass diet occurred more rapidly in Brahmans than in Herefords and was associated with higher rumen ammonia concentrations in Brahmans (40 *v.* 16 mg/l). The rumen NH_3 concentrations were increased to over 100 mg/l by supplementation. The digestion rate increased in both breeds after supplementation and the breed difference disappeared. Increases in digestion rate were not achieved above NH_3 concentrations of 60–80 mg/l.

3. Spear grass, especially the cell-wall-constituent fraction, was more resistant to digestion than Pangola grass. Digestion of the unsupplemented Spear grass diet proceeded more rapidly in Brahmans than in Herefords. The digestion rate in Brahmans were similar irrespective of whether the diet was supplemented or not. Supplementation increased digestion rate in Herefords.

There is conflict regarding the relative abilities of *Bos taurus* and *Bos indicus* cattle to digest feedstuffs (See Moran & Vercoe, 1972; Warwick & Cobb, 1976). Part of this conflict may have arisen because a wide variety of diets have been fed at a range of intakes and only digestibility in the whole tract measured. Generally, no attempts have been made to partition rumen and post-rumen digestion or to assess the relative importance of rumen digestion and clearance between diets and between genotypes. These factors have a controlling effect on the residence time of feed particles in the rumen and therefore the time available for digestion. Voluntary food intake of forage diets also depends on the rate of reduction of particles, by digestion and comminution, to a size that permits escape through the reticulo-omasal orifice. Differences in digestion rate or clearance rate or both between genotypes may alter transit times of digesta through the tract and therefore the time available for digestion. Differences in intake that have been recorded between genotypes (Frisch & Vercoe, 1969, 1977) may also be related to different abilities of the breeds to remove organic matter from the rumen. As part of a comparative study of nutritional physiology, the rate of rumen digestion in nylon bags of two tropical-grass hays has been studied in Hereford (*Bos taurus*) and Brahman (*Bos indicus*) steers. Each hay was incubated in the rumen of steers eating that hay. In addition, to determine possible between-genotype differences in effects of limiting nutrients, the incubations were repeated with the same steers offered hay plus rumen-soluble nitrogen and sulphur and minerals.

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MATERIALS AND METHODS

Animals and diets

Six Hereford and six Brahman steers, initially 20 months of age and all of approximately 300 kg live weight, were housed in individual pens in an animal house. The cattle were kept free of internal and external parasites and were dosed regularly with vitamins A, D and E. Rectal temperature recorded regularly indicated that the animals were not heat-stressed. All steers had a fistula established in the dorsal sac of the rumen. They were given the following long-chaffed diets *ad lib.*: (1) Pangola grass (*Digitaria decumbens*) hay; (2) Pangola grass hay supplemented with 100 g casein, 106 g urea, 4·8 g S in dilute sulphuric acid and mineral mixture; (3) Spear grass (*Heteropogon contortus*) hay; (4) Spear grass hay supplemented with 60 g urea, 2·7 g S in dilute H_2SO_4 and mineral mixture. All steers were given the one diet at the one time. Each species of hay was first given unsupplemented then, after the requisite number of days, the supplement added. Between feeding the different species of hay the steers were given a restricted quantity of lucerne (*Medicago sativa*) hay to allow them to regain the body-weight lost.

The mineral mixture was similar to that of Siebert & Kennedy (1972) and given at the rate of 20 g/kg dry matter (DM). The urea and S supplements were mixed with water and the resultant solution kept refrigerated. The volume of solution necessary to give the required level of supplementation was added to the hay each day. The Spear grass diets were given once daily and the Pangola grass diets twice daily because the feed troughs were not large enough to hold the amount of Pangola grass offered daily with sufficient ease to avoid spillage by the steers. Only five Herefords were used in the experiment when the diet was Pangola grass as one steer had an injured leg and was not eating normally. Sometimes occurrences such as loss of rumen cannulas or sudden reduction in feed intake during an experiment prevented the results from all animals being included. The casein was added directly to the rumen through the fistula immediately after the morning feed was offered, to avoid differences in casein intake, and the urea and S solution mixed with the afternoon feed so that ingestion of N was more evenly spread through the day. The amount of N supplement was calculated from the incorporation of N into microbial protein (30 g N/kg digestible organic matter; Agricultural Research Council, 1980), assuming that a proportion of the microbial N requirement was provided by each diet and that recycled N accounted for any inefficiencies associated with N transactions in the rumen. The amount of feed offered was arranged so that the daily refusal was between 1·0 and 1·5 kg. Diets were given for 21 d (7 d preliminary feeding, 6 d during which digestion of feed was measured by reference to disappearance of a sample of that feed from nylon bags suspended in the rumen, and the final 8 d during which intake was measured daily). At the conclusion of each feeding period, weights of the steers after a 48 h fast were obtained. The intake values are reported in the second paper (Hunter & Siebert, 1985).

Nylon bags

The bags (164 mm by 90 mm) were made from nylon satin with French seams sewn (2 mm wide stitches) with nylon thread. The nylon satin had approximately 13×10^4 holes mm^{-2} of 20 μm average diameter. The thread diameter was 208 μm. A sample (5·0 g) of air-dry hay that had been milled through a 1·5 mm screen without subsequent sieving was weighed into the bag and the bag secured to a 900 mm length of nylon cord by a strong rubber ring. The cord was attached to a rubber rumen bung at one end and to a cylindrical steel weight at the other. Six nylon bags were attached at intervals along each nylon cord within 150 mm of the steel weight, ensuring that bags were kept near the bottom of the rumen. The bags were sealed by the strong rubber ring so that the substrate was confined to the bottom half of the bag.

The particle size distribution of substrate was determined by the wet sieving technique described by Poppi *et al.* (1980).

Digestion procedure

For each diet, six bags were suspended in the rumen of each animal. One bag from each animal was removed after the following times: 8, 24, 48, 72, 96, 120 h. On removal, bags were washed briefly under running cold water, squeezed to aid removal of rumen fluid, then washed again under running water for 30 min and squeezed again. Bags and contents were then dried at 80° and weighed before being subjected to a second-stage digestion with acid-pepsin solution (Tilley & Terry, 1963) for 48 h at 39°. Bags and solution (0·5 litres/bag) were placed in plastic containers which were held in a thermostatically controlled incubating oven. Bags were stirred periodically during the 48 h. On removal from acid-pepsin, bags were washed thoroughly under running water with repeated squeezing for 30 min, dried, reweighed and stored for chemical analysis.

When a bag was removed (except at 8 h) each morning before feeding, except when the diet was unsupplemented Spear grass, a sample of rumen fluid was strained through nylon gauze and collected. A fixed volume was acidified with H_2SO_4 then bulked with other such portions in store at −15°. Rumen fluid was collected from steers fed on unsupplemented Spear grass 2 weeks after nylon-bag incubations when the steers were in metabolism stalls and fed at hourly intervals. The rumen was sampled at four-hourly intervals for 48 h and the fluid treated as described previously. Venous blood samples were collected into heparinized tubes at the end of each period during which Pangola grass was fed. Plasma was obtained immediately and stored at −15° for urea determinations.

Calculation of water-soluble and particulate matter loss

Six bags containing 5 g of each feed were each placed in 0·5 litres demineralized water and stirred frequently for 48 h. The bags were dried, weighed and the total loss of weight of the sample determined. Feed particles which passed into the water were removed by filtration, dried and weighed. DM lost as particulate matter was calculated, and measured digestibility corrected for this loss. Water-soluble loss was also calculated.

Chemical analysis

DM was determined after oven drying at 80° to constant weight and N concentration by the autoanalyser procedure of Logsdon (1960) after a Kjeldahl digestion. Similarly, ammonia concentration in rumen fluid was determined using an autoanalyser after acidification with H_2SO_4. Cell-wall-constituents (CWC) were determined by the method of Van Soest & Wine (1967), lignin by the method of Van Soest (1963) and S by the method of Mottershead (1971).

Statistical analysis

The data from individual animals for relations between disappearance of substrate with time were fitted by an iterative process to the exponential equation

$$y = A - Be^{-kt},$$

where y is the disappearance or digestibility (g/kg) at time t, and A, B and k are constants. A is the digestibility at infinite time and is termed potential digestibility; k is a rate constant and is a measure of the change in the rate of digestion per unit time. A computer package of Health Sciences Computing Facility (Brown, 1977) was used. The model chosen was based on the supposition that the rate of digestion at any time is a constant multiplied by the amount of digestible material remaining. Although theoretically digestion is zero at time zero, in practice this point is subject to sampling and measurement error, so the fitted curve

Table 1. *Chemical composition of feeds (g/kg organic matter except where otherwise shown)*

	Pangola grass (*Digitaria decumbens*)	Spear grass (*Heteropogon contortus*)
Organic matter (g/kg DM)	924	931
Nitrogen	7·9	6·2
Sulphur	1·2	1·0
Cell-wall-constituents (CWC)	770	837
Cell soluble fraction (1000 − CWC)	230	163
Lignin	65	99
Water-soluble content (g/kg DM)	189	190

DM, dry matter.

Table 2. *Particle size distribution of substrates (% of dry matter retained on sieves)*

	Sieve pore diameter (mm)					
	4·0	2·8	1·0	0·6	0·3	< 0·3
Pangola grass (*Digitaria decumbens*)	0·1	0·2	7·0	23·9	19·0	49·8
Spear grass (*Heteropogon contortus*)	0·02	0·01	0·9	15·9	37·4	45·8

was allowed to deviate from the origin. $A-B$ is the intercept on the y-axis and represents the deviation from the time origin of the predicted digestion at time zero. It can be seen from the curves shown in Figs. 1–3 and Fig. 5 that the intercepts were near zero. Across all diets and treatments the intercepts for the equations describing DM digestion ranged only from 9·9 to 50·4 g/kg.

The significance of differences between groups for the estimated values of A and k were determined by Student's t test.

RESULTS

The chemical compositions of the feeds are shown in Table 1. The water-soluble contents of both feeds were not substantially different from the measured DM disappearance from the bags (g/kg DM) at 8 h, being 156 and 262 for Brahmans and 176 and 236 for Herefords for unsupplemented Spear grass and Pangola grass respectively. The loss of particulate matter from the bags amounted to 25 and 19 g/kg DM for Spear grass and Pangola grass respectively.

There was little difference in particle size distribution of the two substrates (Table 2).

Digestion of Pangola grass

The values for k, the rate-constant, in the equation which described rumen digestion of DM, digestion after second-stage treatment with acid-pepsin and digestion of CWC after pepsin treatment of the unsupplemented diet, were significantly less ($P < 0.01$) in Herefords than in Brahmans (Table 3). When the diet was supplemented with N and S there was a significant increase ($P < 0.01$) in values of k over the unsupplemented state in each breed and the difference between breeds disappeared. Comparisons between the unsupplemented and

Table 3. *Values for* k* *and potential digestibility* (A)† *(g/kg) predicted from the exponential model for digestion of Pangola grass* (Digitaria decumbens), *unsupplemented or supplemented, by Hereford* (Bos taurus) *and Brahman* (Bos indicus) *steers*

(Means with their standard errors)

	Unsupplemented				Supplemented			
	Hereford		Brahman		Hereford		Brahman	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Rumen digestion of DM:								
k	0·023[a]	0·003	0·045[b]	0·003	0·066[c]	0·005	0·066[c]	0·004
A	709[a]	29·1	651[a]	9·5	659[a]	8·7	671[a]	18·6
Residual standard deviation (RSD)	4·46		3·13		3·48		3·07	
Correlation coefficient (r)	0·98		0·99		0·99		0·99	
$t_{\frac{1}{2}}$ (h)	26·2[a]	1·75	14·5[b]	0·55	9·8[c]	0·65	9·8[c]	0·47
df	32		32		32		38	
Digestion of DM after pepsin treatment:								
k	0·031[a]	0·004	0·061[b]	0·005	0·086[c]	0·006	0·087[c]	0·005
A	691[ab]	24·1	665[a]	11·3	682[ab]	8·3	696[b]	7·1
RSD	5·57		4·40		3·58		3·38	
r	0·97		0·98		0·99		0·99	
df	32		32		32		38	
Digestion of cell walls:								
k	0·013[a]	0·002	0·036[b]	0·002	0·060[c]	0·005	0·068[c]	0·004
A	848[a]	72·6	651[b]	11·1	671[bc]	9·4	686[ac]	8·2
RSD	4·27		3·05		3·60		3·57	
r	0·98		0·99		0·99		0·97	
df	32		32		32		38	
Digestion of cell soluble fraction:								
k	0·289[a]	0·031	0·295[a]	0·034	0·276[a]	0·024	0·237[a]	0·020
A	819[a]	8·5	796[ab]	8·6	787[b]	7·0	782[b]	8·1
RSD	4·07		4·17		3·47		4·28	
r	0·99		0·99		0·99		0·99	
df	30		31		32		38	

DM, dry matter.
[a, b, c] Means with different superscripts within a row are significantly different ($P < 0·05$).
* k is a rate constant and is a measure of the change in the rate of digestion per unit time.
† A is the digestibility at infinite time.

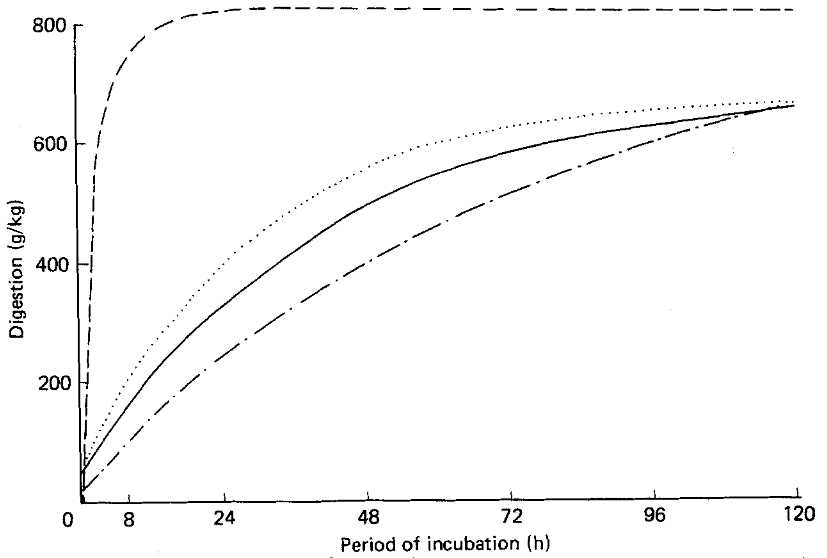

Fig. 1. Predicted curves for digestion of unsupplemented Pangola grass (*Digitaria decumbens*) by Hereford (*Bos taurus*) steers. ——, Rumen dry matter; . . . . . . , dry matter after pepsin treatment; –·–, cell-wall-constituents; – – –, cell soluble fraction.

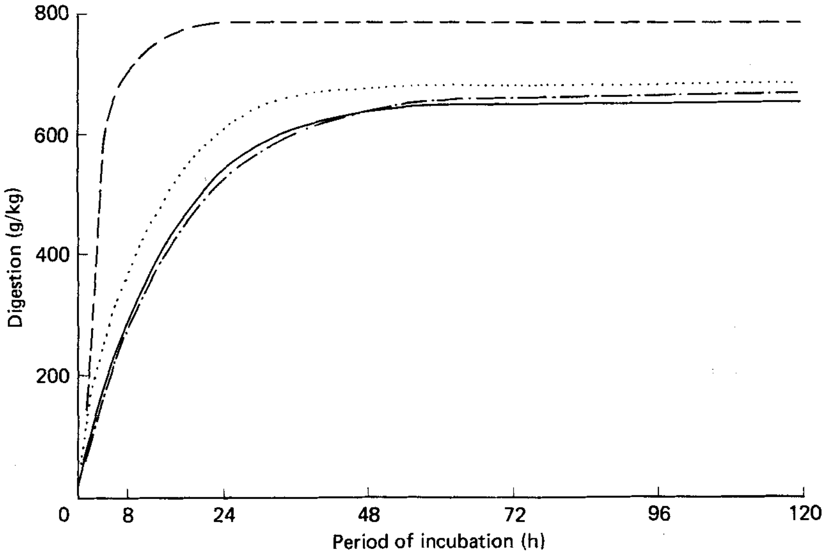

Fig. 2. Predicted curves for digestion of Pangola grass (*Digitaria decumbens*), supplemented with nitrogen and sulphur, by Hereford (*Bos taurus*) steers. ——, Rumen dry matter; . . . . . . , dry matter after pepsin treatment; –·–, cell-wall-constituents; – – –, cell soluble fraction.

supplemented diets are confounded with time. However, as the period during which the supplement was given followed immediately after the period of feeding the unsupplemented diet, it can be concluded with reasonable certainty that the observed effects were due to treatment.

Neither supplementation nor breed had any significant effect on the *k* values for digestion of cell solubles which were at least ten times greater than those for other indices.

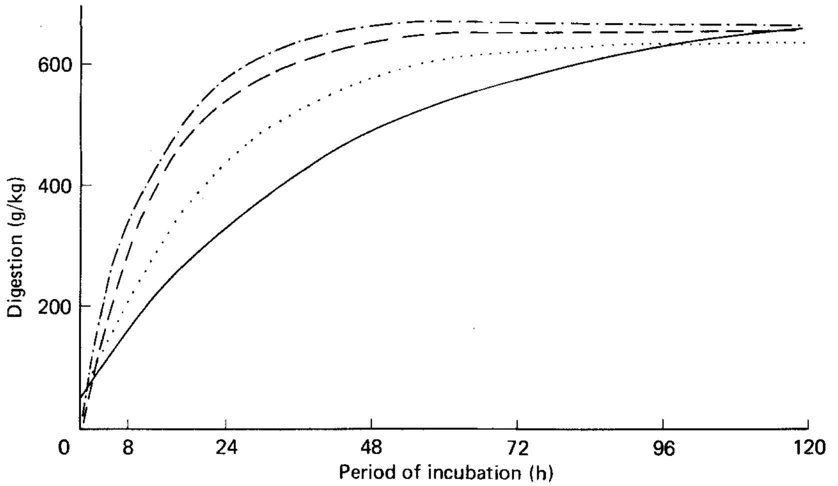

Fig. 3. Predicted curves for ruminal dry matter digestion of Pangola grass (*Digitaria decumbens*), unsupplemented or supplemented, by Brahman (*Bos indicus*) and Hereford (*Bos taurus*) steers. ——, Unsupplemented, Hereford; . . . . . ., unsupplemented, Brahman; – – –, supplemented, Hereford; –·–, supplemented, Brahman.

Table 4. *Mean rumen ammonia concentrations (mg/l) in Hereford* (Bos taurus) *and Brahman* (Bos indicus) *steers given Pangola grass* (Digitaria decumbens) *or Spear grass* (Heteropogon contortus) *unsupplemented or supplemented*

(Mean values with their standard errors)

Diet	Hereford Mean	Hereford SE	Brahman Mean	Brahman SE
Pangola grass: unsupplemented	16	2·4	40	2·9
Pangola grass + supplement	112	6·9	101	11·9
Spear grass: unsupplemented	14	1·5	29	6·0
Spear grass + supplement	85	9·0	78	11·5

The potential digestibility of DM, which was essentially the 120 h value, was not significantly different between the unsupplemented and supplemented diet or between breeds, and varied between 651 and 709 g/kg. Differences between potential digestibility of the four groups after pepsin treatment and for CWC digestion were sometimes statistically significant. However, in general, values were similar to those for rumen DM digestion. The potential digestibility for the cell-soluble fraction was near 800 g/kg for all groups, i.e. 20% of this fraction remained undigested.

Typical curves which describe the pattern of digestion of substrate for the unsupplemented and supplemented Pangola grass diet are shown in Figs. 1–3. It can be seen from Fig. 1 that CWC were more slowly digested than total DM and that digestion of cell solubles was completed within the first 12 h. From a comparison of the curves for unsupplemented and supplemented Pangola grass (Figs. 1 and 2) it is obvious that digestion proceeded more quickly when the diet was supplemented, to the extent that the plateau or potential digestibility for DM and CWC was approached at approximately 48 h compared with more than 120 h when the diet was unsupplemented. Fig. 3 shows that at any time within the first 96 h for unsupplemented Pangola grass, digestion was quantitatively greater in

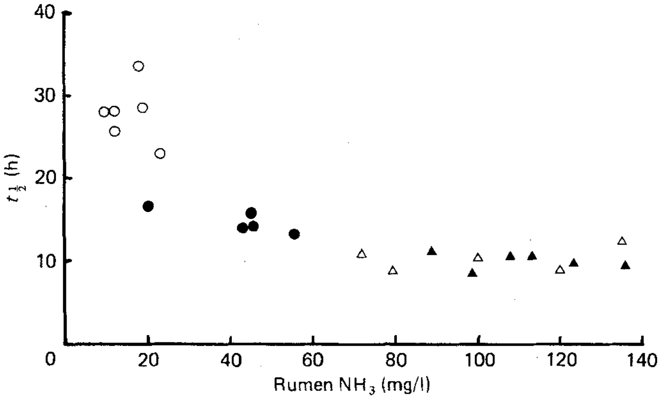

Fig. 4. Effect of rumen ammonia concentration on $t_{\frac{1}{2}}$ (time (h) for half the potential digestion of dry matter) for rumen digestion of dry matter of Pangola grass (*Digitaria decumbens*), unsupplemented or supplemented. ○, Unsupplemented, Hereford; ●, unsupplemented, Brahman; △, supplemented, Hereford; ▲, supplemented, Brahman.

Brahmans than in Herefords. On the other hand there was so little difference when the diet was supplemented that the curves could not be distinguished statistically.

Values of $t_{\frac{1}{2}}$ (time (h) taken for half the potential digestion of DM) are given in Table 3. These values, which are a function of the rate constant, k, and the potential digestibility provide a comparison of the relative rates of digestion between breeds and dietary treatments. The curves and the $t_{\frac{1}{2}}$ values show clearly that the rate of digestion of unsupplemented Pangola hay was faster in Brahmans than in Herefords. This was associated with higher concentrations of rumen NH_3 (Table 4). When Pangola was supplemented with N and S, and rumen NH_3 concentrations were in excess of 100 mg/l, the relative rate of digestion increased still further in both breeds. The $t_{\frac{1}{2}}$ values for both breeds were then approximately 10 h and were independent of NH_3 concentration (Fig. 4).

Digestion of Spear grass

The value of k for the unsupplemented Spear grass diet was significantly ($P < 0{\cdot}05$) lower in Herefords than in Brahmans (Table 5). The value significantly ($P < 0{\cdot}05$) increased in Herefords after supplementation. In Brahmans supplementation had negligible effect on the value for k which was similar to that in Herefords given the supplemented diet.

The potential digestibility for each of rumen DM digestion, digestion after pepsin treatment and CWC digestion was generally similar between breeds and treatments, although in particular instances differences were statistically significant. The mean values were approximately 150 g/kg lower than the corresponding values for Pangola grass. Similarly, the potential digestibility for cell-soluble fractions was approximately 150 g/kg lower than for Pangola grass. Curves which contrast the pattern of rumen digestion of DM for Spear grass and Pangola grass for both breeds are shown in Fig. 5. It can be seen that, quantitatively, more digestion had occurred at any time with Pangola grass than with Spear grass.

The concentrations of rumen NH were higher in Brahmans than in Herefords on the unsupplemented diets but similar in both breeds after supplementation (Table 4).

Table 5. *Values for* k* *and potential digestibility* (A)† *(g/kg) predicted from the exponential model for digestion of Spear grass* (Heteropogon contortus), *unsupplemented or supplemented, by Hereford* (Bos taurus) *and Brahman* (Bos indicus) *steers*

(Means with their standard errors)

	Unsupplemented				Supplemented			
	Hereford		Brahman		Hereford		Brahman	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Rumen digestion of DM:								
k	0·020[a]	0·004	0·031[b]	0·003	0·032[b]	0·002	0·032[b]	0·002
A	534[ab]	39·7	533[a]	12·1	471[b]	9·4	510[a]	10·0
Residual standard deviation (RSD)	5·47		3·06		2·24		2·39	
Correlation coefficient (*r*)	0·95		0·99		0·99		0·99	
df	38		38		32		32	
Digestion of DM after pepsin treatment:								
k	0·029[a]	0·006	0·040[a]	0·003	0·038[a]	0·003	0·039[a]	0·003
A	529[ab]	26·6	552[a]	10·9	509[b]	10·0	542[a]	9·7
RSD	6·36		3·52		2·89		2·87	
r	0·94		0·99		0·99		0·99	
df	38		38		32		32	
Digestion of cell walls:								
k	0·018[a]	0·006	0·028[a]	0·003	0·025[a]	0·002	0·027[a]	0·002
A	559[a]	75·2	545[a]	16·9	506[a]	12·9	539[a]	12·2
RSD	7·89		3·35		2·31		2·39	
r	0·91		0·99		0·99		0·99	
df	32		32		32		32	
Digestion of cell soluble fraction:								
k	0·154[a]	0·033	0·443[ab]	0·316	0·181[a]	0·018	0·392[b]	0·084
A	625[a]	19·3	651[a]	15·6	665[a]	9·8	676[a]	13·4
RSD	8·92		7·78		4·68		6·67	
r	0·94		0·96		0·98		0·96	
df	32		32		31		32	

DM, dry matter.

[a, b] Means with different superscripts within a row are significantly different ($P < 0.05$).

* *k* is a rate constant and is a measure of the change in the rate of digestion per unit time.

† *A* is the digestibility at infinite time.

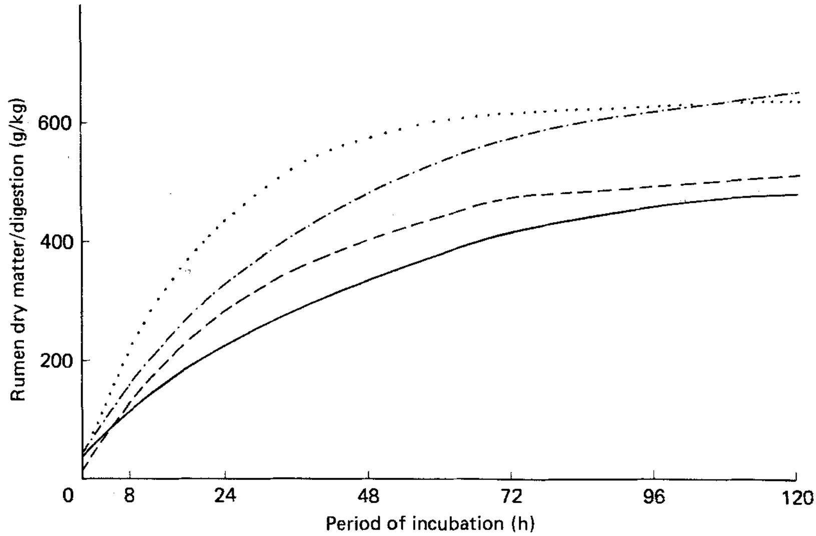

Fig. 5. Predicted curves for ruminal dry matter digestion of Spear grass (*Heteropogon contortus*) and Pangola grass (*Digitaria decumbens*) by Brahman (*Bos indicus*) and Hereford (*Bos taurus*) steers. ——, Spear grass, Hereford; – – –, Spear grass, Brahman; –·–, Pangola, Hereford; . . . . . ., Pangola, Brahman.

DISCUSSION

The results show that the rate of chemical digestion in the rumen of low N, poor quality herbage is influenced by the innate characteristics of the herbage and the breed of animal to which it is fed. The animal effect was considered to be partially mediated via the supply of endogenous nutrients to the rumen micro-organisms. The decrease in the time for digestion to take place ($t_{\frac{1}{2}}$) with increasing NH_3 concentration up to 60–80 mg/l, and the constancy of $t_{\frac{1}{2}}$ at higher concentrations together with the disappearance of the breed effect at these higher concentrations, suggest that N was a nutrient limiting digestion of the unsupplemented diets. The faster digestion rate in Brahmans compared with Herefords on these diets may be explained in terms of their ability to maintain higher rumen NH_3 concentrations. It is likely that S was also limiting, as Siebert & Kennedy (1972) showed that on a low-N tropical roughage diet there was a requirement for supplements of S as well as N to stimulate intake.

To the best of our knowledge the breed difference in rumen NH_3, with Brahmans having higher concentrations than Herefords, has not been reported previously. Kennedy (1982) observed no differences in NH_3-N concentrations between Hereford and Brahman × Hereford crossbred steers fed on lucerne (241 *v.* 243 mg/l) but a small significant difference in favour of the Herefords when the diet was pasture hay (88 *v.* 73 mg/l). However, the pasture hay was given in restricted amounts well below *ad lib.* intake and contained 12 g N/kg organic matter. Thus it would have been doubtful if N supply to the rumen were sufficiently deficient to limit rumen function (Milford & Minson, 1966). It must be stressed that the substantially higher NH_3 concentrations in Brahmans compared with Hereford steers were recorded on diets that were deficient in N.

The characteristic of the herbage that had the greatest influence on the pattern of digestion was the CWC fraction. The cell-soluble fraction of both grasses was essentially digested within the first 12 h in the rumen. The CWC of Pangola grass were digested to a greater extent than those of Spear grass after 120 h of rumen incubation. With the lower lignin content of Pangola grass there would have been less resistance to micro-organisms gaining access to the more digestible parts of the cell. This is shown by the fact that (1) 20% of initial cell solubles of Pangola grass remained undigested compared with 35% for Spear grass and (2) when the digestion that had taken place after any time was expressed per unit of digestion that ultimately occurred, there was no difference between the two hays. Because the CWC of Pangola grass were innately more digestible than those of Spear grass, the rate of digestion of DM of Pangola grass was more responsive to an improvement of N and S conditions in the rumen. The inertia in the digestion rate of Spear grass gives little scope for marked improvement in the intake of roughages which have CWC of low potential digestibility by supplementation with rumen-soluble nutrients.

The degree of digestion of the cell soluble fraction, 0·8 for Pangola grass and 0·65 for Spear grass, was similar to that recorded by Playne *et al.* (1978) for mature tropical hays but considerably less than the value for temperate forages. Van Soest (1967) suggested that approximately 98% of cell solubles in temperate forages are truly digested in the ruminant. The reason for the differences is probably associated with the resistance of the cell walls of mature tropicals to digestion, making fracture of the cell wall by physical processes an important means of providing the micro-organisms with access to the cell contents. Presumably, a proportion of the cells escape being damaged by either digestion or comminution and their cell contents remain undigested. The substrates in the nylon bags were, of course, protected from physical breakdown. However, their particle size distribution showed that, on average, particles were finer than those which leave the rumen of sheep fed on tropical forages (Poppi *et al.* 1980). Thus, it is reasonable to expect that the substrates in the nylon bags were physically degraded to a greater degree than that which occurs by normal biological processes, and that estimates of cell-soluble fraction digestibility made from the incubations would not be an underestimate. The low digestibility of the cell-soluble fraction of mature tropical forages is obviously part of the reason for their low nutritive value.

The advantage in rumen digestive efficiency in favour of the Brahmans when the diet was deficient in N and S probably means that in other studies where there was no such advantage in apparent digestibility of the diet, there was either compensatory post-ruminal digestion in the *Bos taurus* type animals or that digesta was retained longer in the reticulo-rumen to enable the same degree of digestion to occur. The results of Hunter & Siebert (1985) which showed a lower mean retention time of digesta in Brahmans compared with Herefords given such diets suggest the latter to be the more likely. The similarity of digestion rate in both breeds when adequate N and S were supplied to the rumen in the present experiment is possibly the reason that differences in digestive efficiency between breeds have been found rarely on good quality diets.

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