A feeding strategy of combining tropical grass species for stall-fed dairy cows

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Abstract

An experiment was carried out to determine dry matter (DM) yield and frequency distribution of tropical grass species and to investigate the effects of feeding various combinations of these species on the performance of dual-purpose cows managed under a zero-grazing system in semi-arid areas of central Tanzania. *Cenchrus ciliaris*, *Cynodon plectostachyus* and *Rottiboeria exeltata* had the highest yields, while *Chloris gayana* and *Heteropogon contortus* yielded the least. Combinations of these grass species in a 50:50 ratio comprised of 4 rations tested: R1, *Cenchrus ciliaris* (CC) and *Panicum maximum* (PM); R2, CC and *Cynodon plectostachyus* (CPL); R3, PM and CPL; and R4, CPL and *Rottiboeria exeltata*. Eight cows in a double 4 × 4 Latin square design were fed rations R1-R4 ad libitum supplemented with concentrate (33% sunflower seed cake and 67% maize bran), that accounted for about 40% of DM intake. Total DM intakes of all rations were similar. R2 had the highest digestibility and metabolisable energy and crude protein concentrations. Cows produced more milk (5.3 kg/d, excluding milk suckled by the calves) on R2 than on R3, R1 and R4, which resulted in 4.6, 4.9 and 4.8 kg/d, respectively. Milk components were similar. Combining *Cenchrus ciliaris* and *Cynodon plectostachyus* provided good quality hay for milk production.

Introduction

Semi-arid areas of central Tanzania are more suitable for livestock production than any other form of agriculture, being characterised by extremely seasonal conditions with relatively low rainfall, a long dry season and high seasonal temperature fluctuations which cannot reliably produce food and cash crops.

These areas are largely dominated by natural grasslands with pastures which grow and mature rapidly during periods of heavy rainfall producing material with high concentrations of cell wall constituents. Common pasture species found in natural grasslands include: *Cenchrus ciliaris*, *Panicum maximum*, *Chloris gayana*, *Cynodon plectostachyus*, *Heteropogon contortus* and *Rottiboeria exeltata*. The nutritive value of these pastures decreases rapidly with maturity, and during the dry season the available feed is of low digestibility and total nitrogen concentration.

A dense population of ruminant livestock subsist on these forages, leading to over-grazing and land degradation. Zero grazing was introduced in order to arrest land degradation and has been shown to be a sustainable livestock management system for such areas (Shayo et al. 1993). The system necessitates provision of an alternative source of feed for dairy cows apart from the natural tropical grass species, which can include sown pastures in the form of short-term pastures or leys, temporary or annual pastures (fodder) and cultivated browses (Mbwile 1991).

In this regard, pasture species have been evaluated to identify the most productive and adapted species in central Tanzania and this was reviewed and documented by Mero and Masaoa (1991). They highlighted the importance of improved pastures in producing high yields of highly nutritious forage per unit area compared with natural pastures. Therefore, a system of feeding based on improved pastures is a step towards semi-intensive farming for dairy production.
Feeding grass to dairy cows

Herbaceous legumes, browses, oil seed cakes and grain brans could be used as supplements. The experience has been that small-holder farmers readily adopt cut-and-carry systems based on natural tropical grasses and are unable to set aside land for the establishment of pure stands of improved pastures.

The objective of this study therefore was to investigate appropriate tropical grass combination feeding strategies to optimise voluntary intake of dry matter (DM), energy and protein for stall-fed, dual-purpose cows.

Materials and methods

Location and general features of the experiment
The experiment was carried out at the Livestock Production Research Institute (LPRI), Mwapwa (36° 32' E, 6° 21' S; 1100 masl) in the semi-arid zone of central Tanzania. The area is characterised by low and erratic rainfall, averaging 660 mm annually with temperature ranging from 24–29°C. The experiment consisted of a field forage evaluation and a feeding trial.

Grass species percentage composition and dry matter yield estimation
A 15 ha area, which is representative of the semi-arid conditions of central Tanzania at the LPRI farm, was selected for estimation of percentage composition and yield of the grass species. The area was divided into 15 permanent transects, each 50 m long. Each transect consisted of 4 permanent quadrats placed 10 m apart, thus making a total of 60 quadrats. Within a quadrat, a permanent mark was established by using an iron bar, where forage species composition and frequency were determined. Forage species composition was determined by cutting a 0.25 m² quadrat per sward to ground level. The number of occurrences of a particular species in a 0.25 m² quadrat in proportion to the total number of species in the quadrat multiplied by 100 was the frequency of that particular species. DM yield was estimated randomly throughout the selected area by throwing a 0.25 m² quadrat several times, and the grass species were then clipped at ground level. Grass samples for determination of chemical composition and digestibility were collected during DM yield estimation by cutting the grasses to ground level. Based on percentage composition and DM yield, the following grass species were selected for inclusion in rations in the feeding trial: Panicum maximum, Cenchrus ciliaris, Cynodon plectostachyus and Rottboeria exeltata. The selected grass species were cut manually at the flowering stage in order to get pure stands of the respective species, allowed to sun-dry and then baled separately to make hay bales that were used in the feeding trial.

Cow management
Dual-purpose Mwapwa cows in their second and greater lactations were selected for the experiment during the second week of lactation.

The feeding experiment started towards mid-dry season and continued for 2.5 months. Eight lactating cows ranging in weight from 282–325 kg were penned and stall-fed individually according to liveweight. The cows were drenched to control endo-parasites before commencement of the experiment. They were also dipped weekly to control ticks and vaccinated against Black Quarter and Anthrax using Blantyr vaccine. Restricted suckling was practised as the calf management system whereby the calves were allowed to suckle their dams for about 30 seconds before hand milking to stimulate milk let-down. After hand milking of 3 teats, the calves were allowed to socialise with their dams and suckle the milk in the fourth un-milked teat and residual milk in the other 3 teats. The calves were weaned at 45 days post-partum. After weaning, all teats were milked during the remaining experimental period of about 4 weeks.

Feeds and feeding of experimental cows
Four hay rations (R1-R4) were formulated from combinations of grass species selected during field forage evaluation. The combinations were: R1, 50% Cenchrus ciliaris (CC) + 50% Panicum maximum (PM); R2, 50% CC + 50% Cynodon plectostachyus (CPL); R3, 50% PM +50% CPL; and R4, 50% CPL + 50% Rottboeria exeltata (RE). The total voluntary dry matter intake (TDMI) was assumed to be equal to 3% of live-weight with basal diet (hay) accounting for 70% of the TDMI. The hay rations (R1-R4) were fed ad libitum at 30% above expected voluntary basal intake and a concentrate mixture of sunflower
seed cake (33%) and maize bran (67%) was fed at 30% of the expected TDMI of about 3 kg DM/100 kg body weight. The amounts offered ranged between 2.6–3.1 kg DM/cow/d depending on the liveweight of the cow. Half of the concentrate was fed in the morning during milking at 07.30 h and the remaining half was given during evening milking at 16.00 h. Hay was apportioned and fed 3 times a day at 08.00 h, 12.00 h and 16.30 h to avoid spill-over from the feeding troughs. All cows had access to mineral blocks placed in individual feeding troughs and water was supplied daily on an *ad libitum* basis.

**Experimental design and data collection**

Experimental cows were blocked according to body weight and then assigned to the treatments and individual feeding stalls at random (Snedecor and Cochran 1980) in a double 4 × 4 Latin square design. Each period consisted of 14 days, a 7-day preliminary period and a 7-day collection period. Feeds were weighed prior to feeding and refusals were collected and weighed the following morning. Ten percent of the refusals collected in a period were bulked for 7 days and later subsampled for chemical analysis. Total dry matter intake (TDMI) was the sum of voluntary grass hay intake and concentrates offered. Milk yield was recorded daily, at the morning and evening milking sessions. Milk samples for determination of milk composition were taken on the last day of the second week of each period.

**Laboratory chemical analysis of the feeds, milk samples and energy estimation**

Dry matter, ash, ether extract (EE), crude fibre (CF), crude protein (CP) and nitrogen free extract (NFE) concentrations in the concentrate mixture and grass species were determined according to the procedures of AOAC (1985). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the procedures of Goering and van Soest (1970), while *in vitro* digestibility was done using the procedure of Goering and van Soest (1970) modified by Mbwile and Udén (1991). The energy concentration of the concentrate mixture was estimated by procedures in MAFF (1975) where:

\[
\text{ME (MJ/kgDM)} = 0.012 \text{CP} + 0.031 \text{EE} + 0.005 \text{CF} + 0.014 \text{NFE},
\]

where CP, EE, CF and NFE are in g/kgDM. To determine the energy concentrations in the hay rations, they were subjected to an *in vitro* technique to determine dry matter digestibility (DMD%) which was then converted to digestible organic matter in the dry matter (DOMD%) according to MAFF (1975):

\[
\text{DOMD\%} = 0.98 \times \text{DMD\%} - 4.8
\]

and

\[
\text{ME (MJ/kgDM)} = 0.15 \times \text{DOMD\%}.
\]

Crude protein, ash, butterfat and total solids of milk samples were determined according to the procedures of AOAC (1985).

**Statistical analysis**

Mixed models procedures in the Statistical Analysis System (SAS 1999) was used to analyse the data. The class variables included in the model were cow, treatment, period, block, period × treatment and carry-over effects. When carry-over effects were found not to be significant, the following model was used:

\[
y_{ijkl} = \mu + \beta_i + \gamma x_{ij} + \alpha_k + \pi_l + \alpha \pi_{kl} + d_{ij} + e_{ijkl},
\]

where:

- β represents block with \( i = 1, 2 \),
- \( x \) is the covariate initial weight with regression coefficient (γ),
- \( \alpha \) represents treatment with \( k = 1..4 \),
- \( \pi \) is period with \( l = 1..4 \) and \( \alpha \pi \) is the treatment by period interaction. The random factor animals within blocks (d) and the residual (e) were assumed independent and normally distributed.

When interaction between period and treatment was not significant, data were analysed by considering fixed effects only in a reduced model:

\[
y_{ijkl} = \mu + \beta_i + \alpha_k + \pi_l + \alpha \pi_{kl} + d_{ij} + e_{ijkl},
\]

where:

- β represents block with \( i = 1, 2 \),
- \( \alpha \) represents treatment with \( k = 1..4 \), and
- \( \pi \) represents period with \( l = 1..4 \). The random factor animals within blocks (d) and the residual (e) were assumed independent and normally distributed.

Initial weight was used as a covariate in the analysis of hay intake and total dry matter intake (hay + concentrates). Pairwise comparison between least square means was done according to the procedure of Tukey-Kramer in SAS (1999). Results are reported as least square means ± standard error (s.e.).
Results

Botanical composition, dry matter yield, chemical composition and digestibility of the major grass species

Data for botanical composition, frequency distribution, estimated dry matter yield, chemical composition and digestibility of the natural grasses are shown in Table 1. *Rottiboeria exeltata* was the most common grass species, followed by *Cynodon plectostachyus*, *Panicum maximum* and *Cenchrus ciliaris* which were more common than *Chloris gayana* and *Heteropogon contortus*. The remaining 12% not shown in the table consisted of browses. *Cenchrus ciliaris* produced the most DM followed by *Cynodon plectostachyus* and *Rottiboeria exeltata*. The nutritive value in terms of crude protein (%) and *in vitro* OMD was fairly low, with most species having CP less than 5% and IVOMD less than 60%. *Cynodon plectostachyus* had the highest nutritive value. The concentrate mixture contained 13.2% crude protein, 5.1% ash, 16.0% crude fibre, 16.0% ether extract and 44.5% nitrogen free extract, and had a metabolisable energy concentration of 13.5 MJ/kgDM.

Chemical composition, digestibility and metabolisable energy of grass hay rations (*R1-R4*)

Data for chemical composition, energy estimation and *in vitro* organic matter digestibility of the grass combinations (*R1-R4*) fed to the cows, and hay refusals of the rations are shown in Table 2.

Table 1. Frequency of occurrence, dry matter yield (DMY), chemical composition and *in vitro* organic matter digestibility (IVOMD) of the main grass species in the study area.

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency (%)</th>
<th>DMY (kg/haDM)</th>
<th>Ash (%)</th>
<th>CP (%)</th>
<th>ADF (%)</th>
<th>NDF (%)</th>
<th>IVOMD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rottiboeria exeltata</td>
<td>33</td>
<td>1220</td>
<td>0.2</td>
<td>3.1</td>
<td>57.2</td>
<td>80.1</td>
<td>53.6</td>
</tr>
<tr>
<td>Cynodon plectostachyus</td>
<td>25</td>
<td>1250</td>
<td>9.5</td>
<td>5.4</td>
<td>43.2</td>
<td>77.9</td>
<td>61.5</td>
</tr>
<tr>
<td>Cenchrus ciliaris</td>
<td>13</td>
<td>1850</td>
<td>8.4</td>
<td>4.9</td>
<td>56.6</td>
<td>79.4</td>
<td>58.4</td>
</tr>
<tr>
<td>Panicum maximum</td>
<td>12</td>
<td>540</td>
<td>9.8</td>
<td>4.0</td>
<td>46.0</td>
<td>75.5</td>
<td>57.9</td>
</tr>
<tr>
<td>Heteropogon contortus</td>
<td>3</td>
<td>250</td>
<td>8.4</td>
<td>3.3</td>
<td>58.8</td>
<td>79.4</td>
<td>51.2</td>
</tr>
<tr>
<td>Chloris gayana</td>
<td>2</td>
<td>90</td>
<td>8.3</td>
<td>3.5</td>
<td>52.1</td>
<td>80.8</td>
<td>55.0</td>
</tr>
</tbody>
</table>

Table 2. Chemical composition, energy concentration and *in vitro* organic matter digestibility (IVOMD) of hay rations and hay refusals.

<table>
<thead>
<tr>
<th>Composition</th>
<th>CP (%)</th>
<th>Ash (%)</th>
<th>ADF (%)</th>
<th>NDF (%)</th>
<th>IVOMD (%)</th>
<th>ME (MJ/kgDM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay ration1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1 (CC/PM)</td>
<td>4.50</td>
<td>9.20</td>
<td>51.35</td>
<td>78.60</td>
<td>57.40</td>
<td>7.27</td>
</tr>
<tr>
<td>R2 (CC/CPL)</td>
<td>5.30</td>
<td>8.96</td>
<td>50.00</td>
<td>75.12</td>
<td>60.20</td>
<td>8.13</td>
</tr>
<tr>
<td>R3 (PM/CPL)</td>
<td>4.80</td>
<td>9.67</td>
<td>44.70</td>
<td>76.90</td>
<td>59.40</td>
<td>8.01</td>
</tr>
<tr>
<td>R4 (CPL/RE)</td>
<td>4.30</td>
<td>9.90</td>
<td>51.90</td>
<td>79.66</td>
<td>55.30</td>
<td>7.41</td>
</tr>
<tr>
<td>Hay refusals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>2.90</td>
<td>5.70</td>
<td>55.86</td>
<td>84.90</td>
<td>42.92</td>
<td>5.58</td>
</tr>
<tr>
<td>R2</td>
<td>3.00</td>
<td>5.60</td>
<td>53.86</td>
<td>83.50</td>
<td>45.50</td>
<td>5.97</td>
</tr>
<tr>
<td>R3</td>
<td>2.20</td>
<td>8.20</td>
<td>56.83</td>
<td>88.90</td>
<td>38.40</td>
<td>4.92</td>
</tr>
<tr>
<td>R4</td>
<td>3.00</td>
<td>8.10</td>
<td>55.90</td>
<td>87.80</td>
<td>40.27</td>
<td>5.20</td>
</tr>
</tbody>
</table>

*R1*: 50% *Cenchrus ciliaris* (CC) + 50% *Panicum maximum* (PM); *R2*: 50% *Cenchrus ciliaris* (CC) + 50% *Cynodon plectostachyus* (CPL); *R3*: 50% *Panicum maximum* (PM) + 50% *Cynodon plectostachyus* (CPL); *R4*: 50% *Cynodon plectostachyus* (CPL) + 50% *Rottiboeria exeltata* (RE).
The ration R2 (50% CC + 50% CPL) had the highest CP and IVOMD followed by R3, R1 and R4. On the other hand, R2 had the highest ME followed by R3, R4 and R1. The hay refusals for all rations had lower CP and IVOMD and higher fibre concentrations (ADF and NDF) than the rations offered, indicating selective consumption of the more nutritious hay components.

Hay intake, total dry matter intake, milk yield and milk composition

Data for hay and total DMI (hay + concentrate) for cows on rations R1-R4 are shown in Table 3. There was no significant difference (P > 0.05) between treatments in hay intake and total DMI, although rations R2, R3 and R4 tended to have higher intakes than R1. The CP concentrations in the rations (based on calculated consumed hay and concentrates, not shown in the table) were 7.91, 8.57, 7.89 and 8.30% for rations R1, R2, R3 and R4, respectively. Daily milk yield differed between treatments (P < 0.05), with cows on R2 producing more milk than those on R3. Milk components were similar (P > 0.05) for all treatments (Table 3) except for ash (P < 0.05).

Discussion

Dry matter yields of the naturally growing tropical grass species in this study were lower than those of the sown or improved tropical grasses evaluated on-station in the same area by Shayo and Msangi (1989). This could be due to lack of improved management practices such as fertiliser application and weeding normally employed during on-station evaluation (Mero and Masaoa 1991). It could also indicate that the grasses on the rangeland were competing for nutrients, space and water. Apart from fertiliser application and weeding, harvesting time has a marked impact on forage production, and Shayo and Msangi (1989) and Mero and Masaoa (1991) showed that DM production increased with age up to maturity. Differences between grass species in DM production have been discussed previously (Shayo and Msangi 1989; Mero and Masaoa 1991) with Cenchrus ciliaris out-performing other grass species.

The merits of any pasture species depend on DM production, as well as the ability to maintain high nutritive value over long periods of the year. The individual grass species and the rations R1-R4 had CP concentrations below 8%, a level reported to be inadequate for optimum rumen function (van Soest 1982). This necessitates concentrate supplementation to raise CP concentration to the level required for optimum rumen function. With concentrate supplementation, CP % in the rations consumed in our study was about 8% for R1 and R3 and above 8% for R2 and R4. Improved pasture management with sown grass species could also increase CP concentration and digestibility, especially when the grasses are harvested early (Mero and Masaoa 1991). In their study, grasses harvested at an age of 112 days had CP values ranging from 7.8–12%, but with much lower values when the same species were harvested at an age of 202 days.

The estimated energy concentrations in our rations ranged from 7.3–8.1 MJ ME/kgDM, which is somewhat higher than the 6.8–6.9 MJ ME/kgDM reported by Mwilawa et al. (1998) for grasses in reserved grazing lands. The observed

Table 3. Daily dry matter intake of grass hay (HDMI) and total dry matter intake (TDMI), milk yield (MY), milk protein (MP), milk fat (MF), ash and total solids (TS) concentrations of cows on experimental diets.

<table>
<thead>
<tr>
<th>Ration</th>
<th>HDMI</th>
<th>TDMI</th>
<th>MY</th>
<th>Milk composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kg/d)</td>
<td>(g/d)</td>
<td></td>
<td>MP</td>
</tr>
<tr>
<td>R1</td>
<td>3.9</td>
<td>6.2</td>
<td>4.9 ab</td>
<td>1440</td>
</tr>
<tr>
<td>R2</td>
<td>4.2</td>
<td>6.9</td>
<td>5.3</td>
<td>1450</td>
</tr>
<tr>
<td>R3</td>
<td>4.1</td>
<td>6.8</td>
<td>4.6b</td>
<td>1380</td>
</tr>
<tr>
<td>R4</td>
<td>4.0</td>
<td>6.7</td>
<td>4.8ab</td>
<td>1300</td>
</tr>
</tbody>
</table>

R1, 50% Cenchrus ciliaris (CC) + 50% Panicum maximum (PM); R2, 50% (CC) + 50% Cynodon plectostachyus (CPL); R3, 50% PM + 50% CPL; R4, 50% CPL + 50% Rottiboeria exeltata (RE).

Means within a column followed by different letters differ significantly (P < 0.05).
differences in energy levels could be due to differences in time of harvesting, sampling or location.

The high fibre and low crude protein percentages in the hay refusals compared with those in the hay offered reflects the ability of ruminant animals to preferentially select for the most nutritious parts of the forage. This confirms what has been shown in several studies that cows select the most nutritious leafy materials and reject less nutritious or stemmy parts (Mbwile and Udén 1997; Mero and Udén 1998). Dry matter intakes of rations were similar despite differences in grass hay digestibilities. The reason could be that the supplements had a low ‘rumen load’ and left the rumen quickly with little effect on rumen distention (Preston and Leng 1987). As we did not have comparisons with and without concentrate supplementation in this study, we cannot say if differences in intake would have occurred for different grass combinations in the absence of concentrates.

The tendency for cows on R2 to eat more feed than those on the other rations could explain the increased milk production on this ration. The amount of milk produced on R2 was similar to the yields of cows of the same breed receiving high concentrate supplementation 8 weeks post partum, and continued on the same plane of nutrition for the remainder of the lactation (J.M.N. Bwire and H.Wiktorsson, unpublished data). Milk components were similar on the various rations, with results in agreement with a report of Shayo et al. (1997) of 2.98, 4.53, 0.72 and 13.38% for crude protein, butterfat, ash and total solids, respectively. In their experiment, cows of the same breed were fed Cenchrus ciliaris hay ad libitum and were supplemented with maize bran. Data on milk yield and composition indicate primarily the genetic limit and characteristic nature of the dual-purpose Mpwapwa breed.

Roughage: concentrate ratio has a marked influence on milk composition, and increasing the proportion of concentrates to above 60% of the total dry matter of the ration may result in situations of animals going off-feed, rumen acidosis, milk fat depression, reduction in forage digestibility and possibly increased incidence of displaced abomasum in high producing dairy cows (Clark and Davis 1980). In the present study, we planned that concentrates would be 30% of the expected voluntary dry matter intake. Since hay intake was lower than anticipated, the concentrate proportion approached 40% of the voluntary intake. However, this is far below the level which would produce changes in milk composition, especially butterfat content.

Conclusion

Tropical grasses are potentially nutritious basal feeds when harvested early at the blooming stage. Planting legume species will help in boosting the quality of these grasses. Delaying time of harvesting results in a decline in nutritive value and DM yields. Combining Cenchrus ciliaris and Cynodon plectostachyus was found to be a better feeding strategy than other grass combinations as it optimises crude protein, digestibility and energy concentrations for feeding dairy cows. Supplementation using conventional concentrates or browses is encouraged to further increase the crude protein and energy content of the rations for lactating dual-purpose dairy cows.

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References


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