Faecal near infrared reflectance spectroscopy (F.NIRS) measurements of non-grass proportions in the diet of cattle grazing tropical rangelands

D. B. Coates and R. M. Dixon

Abstract. Frequent faecal near infrared reflectance spectroscopy (FNIRS) analyses of faeces from cattle grazing a range of tropical pastures were used to measure the non-grass component, and other aspects, of their diets. Seasonal profiles of non-grass and crude protein in the diet are presented for nine sites from the speargrass, Aristida–Bothriochloa, and Mitchell grass dominated pasture regions, and for three shrubland sites where browse was plentiful. In grass-dominated native pastures of the speargrass and Aristida–Bothriochloa pasture regions of Queensland where little browse was available, non-grass was usually only 5–15% of the diet. Diet non-grass was even lower for a buffel grass pasture. In unclipped eucalypt woodland in the speargrass region, browse may have contributed up to 20% of the diet in the late dry season when grasses were senesced. In regions with abundant browse (e.g. munga lands and desert upland systems) cattle preferentially selected actively growing grasses and forbs when they were available. With diminishing availability or declining quality of the forbs and grass due to grazing selection and dry conditions, browse increasingly contributed to intake. In Mitchell grass dominated pastures, forbs often comprised more than 50% of the diet, and there appeared to be strong selection for forbs during the dry season. Where browse was available in association with Mitchell grass dominated pastures, it appeared to contribute to intake only in the late dry season. Dry season sampling in monsoonal tallgrass and Mitchell grass dominated pastures indicated dietary crude protein to be linearly correlated with diet non-grass, demonstrating the importance of non-grass in the prevention or alleviation of dry season protein deficiency in cattle. Changes in diet selected by cattle in relation to season and rainfall were generally in accord with the previous limited information, largely with sheep, in comparable vegetation systems. The results demonstrate the value of FNIRS technology to assist understanding of diet selection by grazing cattle in northern Australia.

Additional keywords: Aristida–Bothriochloa, browse, diet selection, Mitchell grass, speargrass.

Introduction
Since cattle grazing the rangelands of northern Australia depend primarily on the vegetation on offer for their nutritional requirements, an understanding of the forage selected is obviously important for sound nutritional management. However, diet selection by cattle grazing the rangelands of northern Australia is poorly understood, largely because of the variety and complexity of the vegetation and herbivore selection, and the inadequacy of experimental methods. Nevertheless, it is clear that cattle grazing native vegetation systems do select a wide variety of plant species and morphological components, and that this selection has important implications for managing cattle for production and rangelands for sustainability (Squires 1980; Holechek 1984; Wilson and Harrington 1984; Vololesy and Coleman 1996). Measurement of the botanical composition of diets selected by grazing cattle and sheep has until recently depended on techniques employing oesophageally-fistulated animals, histological examination of undigested plant material in faeces, disappearance of plant components from pasture over defined intervals, and observation of grazing animals. Each of these techniques may involve large inaccuracies and require substantial experimental resources (Holechek et al. 1982; Coates et al. 1987; Gordon 1995). Information is particularly lacking for cattle grazing the unimproved rangelands of northern Australia. Studies on diet selection by sheep (Wilson 1976; Lorimer 1978; Graetz and Wilson 1980; Harrington 1986; McMeniman et al. 1986; Orr et al. 1988) can provide additional information but extrapolation of diet selection from measurements with sheep to cattle may be misleading (Dudzinski and Arnold 1973; Wilson 1976; Squires 1980; Graetz and Wilson 1980).

Faecal NIRS has been developed to provide a practical and inexpensive tool to measure various dietary and faecal attributes (e.g. diet crude protein concentration, digestibility, neutral detergent fibre and acid detergent fibre, faecal N and faecal ash) in free ranging ruminants (Brooks et al. 1984; Lyons and Stuth 1992; Leite and Stuth 1995; Coates 2004). It has also been used to measure the proportions of specific plant species, or groups of plant species, in the diet (Walker et al. 1998, 2002; Decuypere et al. 2004; Landau et al. 2004). One difficulty with this approach is that major experimental resources would...
be required to develop calibration equations for even a few plant species in a few well defined grazing systems. To avoid this latter constraint in developing FNIRS calibrations, Coates (2004), following Clark et al. (1995), utilised FNIRS to measure faecal \( ^{13}C \) together with the observation that, in the tropics and subtropics, pasture grasses are predominantly \( ^{13}C \) species (Hattersley 1983), whereas most of the non-grass species are \( ^{12}C \), and the proportion of grass to non-grass in the diet of ruminants grazing these communities is linearly related to the \( ^{13}C \) of faeces (Jones et al. 1979). The calibration equations developed by Coates (2004) enable faecal \( ^{13}C \) to be measured by FNIRS analysis and the proportion of non-grass in the diet can be calculated from predicted faecal \( ^{13}C \) as reported by Jones (1981). Determining diet non-grass proportions (DNG) using FNIRS can, therefore, be done concurrently with the prediction of other dietary and faecal attributes without additional cost, since all predictions are derived from the same faecal NIR spectra.

In this paper we present faecal profiles of DNG from a range of primarily native pasture systems in northern Australia to demonstrate the practical application of the technology in providing reliable information on the contribution of non-grass to dietary dry matter (DM) intake, and the effect of seasons, years and rainfall patterns on DNG. We also present data on the influence of DNG on the nutrient status of the diet. The results are discussed in terms of the perceived importance of non-grass to cattle production and FNIRS as a research, an educational and a decision support tool.

Materials and methods

Faecal sampling, processing and analysis

Diet non-grass was measured from NIR spectra of dry, milled faecal samples using the calibration equations developed and described by Coates (2004). The equation measured faecal \( ^{13}C \) and was derived from a calibration set of 1501 faecal samples from three commercial properties were chosen to illustrate a variety of pasture systems. The sites encompassed a range of environments, particularly with respect to the amount and distribution of rainfall, soil types, and vegetation communities. Nine were research sites where there was good control over the experimental cattle and where faecal sampling was carried out on a regular, predetermined schedule. The other three sites were paddocks located on commercial properties. Except where otherwise stated, each site was stocked with young Bos indicus or B. indicus \( \times \) B. taurus cattle, or at one site, Longreach Pastoral College (LPC), Bos taurus cattle adapted to the region. Stocking rate on all 12 sites was moderate by regional industry standards, except one additional high stocking rate treatment at Glenlulloch. However, because of low rainfall in some years at some sites, pasture on offer was sometimes reduced to low levels.

In addition to the sites described in Table 1, measurements from three commercial properties were chosen to illustrate the influence of DNG on dry season diet quality, and in particular, on protein concentration. At these sites, herds from several paddocks were sampled at the same time so that the correlation between diet CP and DNG could be determined. The three properties were Newcastle Waters (17\(^{\circ}\)22\(\,'\)S, 133\(^{\circ}\)23\(\,'\)E), ~100 km south of Daly Waters, NT, Carltoon Hill Station.
of merino sheep. Woolthorpe pastures on less fertile red soils, and Carlton Hill has timbered grass country on black clay soils and timbered tropical tallgrass pastures similar to those at Rosebank but rainfall at Toorak is highly summer dominant in contrast to more even distribution in central-western Queensland. The northern and southern speargrass regions: pasture of Queensland bluegrass ( Dichanthium sericeum (R. Br.) A. Camus), pitted bluegrass ( Bothriochloa decipiens var. decipiens C.E. Hubb.) and other native perennial grasses on texture contrast soils of surface loam over dense yellow clay. Pastures with significant browse species: commercial padock of 'hard' mulga country east of Cunnamulla with mulga the dominant browse species together with wiregrasses, annual grasses ( mulga oats) and forbs following rainfall events. Fenced NIRS profiles of DNG (Figs 1, 2) show that, when stocking rate was moderate, non-grass proportions were low at all sites, generally in the range of 0–20%, although exceeding 30% on rare occasions and averaging between 9 and 12% except for the soven buffel grass pasture at Frankfield where the average was 4%.

Table 1. Description of the 12 experimental faecal profiling sites showing coordinates, mean annual rainfall (MAR), pasture type and soil type

<table>
<thead>
<tr>
<th>Site Description</th>
<th>Non-grass component of cattle diet in tropical rangelands</th>
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<td>Newcastle Waters and Carlton Hill Station are located within the monsoon tropics and were stocked with R. indicus or R. indicus cross breeders. Newcastle Waters has a mixture of Mitchell grass country on black clay soils and timbered tropical tallgrass pastures on less fertile red soils, and Carlton Hill has timbered tropical tall grass pastures and marine plains. Woolthorpe is on the eastern edge of the Mitchell grass country of southern Queensland, and measurements were made with flocks of merino sheep.</td>
<td>Fenced NIRS profiles of DNG (Figs 1, 2) show that, when stocking rate was moderate, non-grass proportions were low at all sites, generally in the range of 0–20%, although exceeding 30% on rare occasions and averaging between 9 and 12% except for the soven buffel grass pasture at Frankfield where the average was 4%.</td>
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Fig. 1. Faecal NIRS predictions of diet non-grass proportions (•) and crude protein concentration (△) and monthly rainfall, over several years at (a) Swans Lagoon in the northern speargrass region, (b) Brian Pastures in the southern speargrass region, (c) Frankfield north of Clermont, and (d) Forest Home east of Charters Towers.

The results from Swans Lagoon (Fig. 1a) revealed that DNG tended to be highest during the wet season and lowest during the mid-dry season of each year (July–August in 2001, September–October 2002, July 2003, and May–July 2004) and then to rise again before effective opening rains to the wet season (September–October 2001, December–January 2002–03, ...
Predicted diet CP levels also rose with the increase in DNG in the late dry. We propose that the decline in DNG from the wet season into the dry season was due to cattle eating browse in this open eucalypt woodland at a time when protein concentration in the dry standing grass was very low.

Between-year differences were apparent, with an appreciable increase in DNG during years 2003 and 2004 (means of 16.5 and 16.1%, respectively) compared with 2001 and 2002 (means of 6.7 and 7.7%, respectively). This was probably due to the cumulative adverse effect of well below average rainfall in 2001–02 and 2002–03 on the vigour and competitiveness of grass and an increase in the availability of forbs. There was a highly significant and positive correlation between diet CP and DNG ($P < 0.001, R^2 = 0.32$), but this was probably due, at least in part, to DNG being highest in the wet season when pasture quality overall was highest.

At Brian Pastures rainfall was more evenly distributed than at the northern sites. DNG averaged $\sim 10\%$ for the entire sampling period (range 0–24%), and we could not discern any consistent pattern between DNG and season or rainfall (Fig. 1b) whereas diet CP concentrations always declined during intervals of low or nil rainfall. Since no browse was available except for scattered ironbark and bloodwood trees, the non-grass in the diet was presumably due to ingestion of native legumes or other forbs, and it is likely that low DNG was the result of low availability of the non-grass pasture components. There was a positive correlation ($P < 0.001, R^2 = 0.25$) between diet CP and DNG.

At Frankfield (Fig. 1c) DNG was lower than at all the other sites, averaging only 4% and never exceeding 20%. Since the cattle grazed within a cell system the temporal fluctuations in predicted DNG were probably influenced mainly by availability as cattle moved from one paddock to another or one block of paddocks to another block. Diet CP was not correlated with DNG over the sampling period ($P = 0.42$).

At Forest Home (Fig. 1d) DNG averaged 11% and varied within only a narrow range of 5–15%. There was no discernable pattern between DNG and season or rainfall. In particular, the results indicated that DNG did not increase during the long dry season of 2002, despite the low diet CP concentrations and the availability of the native Indigofera, currant bush, and eucalypt trees and seedlings. Although there was a significant and positive correlation between diet CP and DNG ($P < 0.05$), the correlation was weak ($R^2 = 0.15$). Since grass was the dominant dietary component, diet CP was determined primarily by grass quality which in turn was dependent on rainfall.

The rainfall distribution at Glentulloch (Fig. 2), with registrations of 27 mm or more in every month for the period October 1997–June 1999, was, like that at Brian Pastures, in marked contrast to the highly seasonal distribution at the northern sites. We could not discern any consistent pattern between DNG and seasons or rainfall, nor was diet CP correlated with DNG.
with DNG at either high or low utilisation rate ($P < 0.05$ and $0.60$ at the low and high utilisation, respectively). Diet non-grass and diet CP were higher in cattle grazing the high utilisation rate paddock compared with the low utilisation rate paddock with differences averaging $15$ and $2.15$% for DNG and diet CP, respectively. However, in the analysis of variance for the whole experiment which was a replicated factorial of three utilisation rates ($25$, $50$ and $75$%) by two timber treatments (trees alive and trees killed), the effect of utilisation rate on DNG was not significant ($P > 0.05$).

**Mitchell grass dominated sites**

At all Mitchell grass dominated sites (Fig. 3), DNG was appreciably higher than at the moderately stocked speargrass and *Aristida–Bothriochloa* sites, with mean values of $35$% at Rosebank, $32$% at LPC, $32$% at Toorak and $21$% at Morungle. Non-grass comprised a high proportion ($30$–$70$%) of the diet during the wet season. No data were available on the botanical composition of pasture during the wet season, but the results suggested that cattle did not select against non-grass, and may have selected for non-grass, during the wet season.

Rainfall at the Rosebank site during 1997–2000 was $30$% higher than the long-term mean of $434$ mm, and the seasonal distribution was generally favourable for growth of forbs. This occurred especially during 1998 and 1999 when DNG often exceeded $50$%. Mean diet CP was also high during most of that period, but diet CP was not correlated with DNG across samplings. In contrast to the Rosebank data, results from the other sites were obtained for only one year of experiments. In the wet season of 2000, DNG was appreciably higher in 2003 and 2004, such as in the early dry in May of both 2001 and 2002 indicated the decline in DNG, but with the lack of follow-up, the results did not support the observation of forage species. It is noteworthy that DNG in the early dry season was associated with depleted availability of forbs, while the subsequent increase was probably due to cattle utilising browse species. It is noteworthy that diet CP concentrations also fell sharply with the decline in DNG over the April–June interval and then rose by $>1$% with the late dry season increase in DNG.

**Pastures with substantial browse available**

Conditions were dry when sampling commenced at Ryandale and the observation that the diet consisted entirely of non-grass was consistent with the advice from the property owner that the cattle were being fed on pushed mulga (Fig. 4a). Predictions of over $90$% DNG continued through to June 2003, though some rain was received during the autumn and early winter. Following more substantial rain in July which clearly promoted some growth of grass there was a brief but substantial decrease in DNG to less than $80$% before it increased again. After nearly $100$ mm rain in January 2004, DNG decreased to $<30$% of the diet. Information on the relative contributions of browse foliage and herbage forbs to DNG was obtained from concurrent FNIRS measurements of faecal ash and the findings from an experiment where various proportions of mulga foliage and grass hay were fed to cattle in pens (M. Jeffery, personal communication). The pen trial results indicated that faecal ash concentration was negatively correlated with the proportion of mulga in the diet. The faecal ash profile for Ryandale (Fig. 4a) showed low faecal ash concentrations of $12$–$14$% for December 2002–April 2003, then an increase in faecal ash to $16$% in May–June 2003, followed by a further increase to at least $20$% for the remainder of the trial period. These faecal ash concentrations therefore indicated that the non-grass in the diet was principally mulga until the end of March 2003, that a lesser amount of mulga and an increased proportion of forbs was selected after the autumn–early winter rain in May–June, and that the non-grass was principally herbage forbs from July 2003 through to the end of the trial period. In February 2004, following the rain in January, DNG decreased to only $30$%, indicating that the cattle were consuming mainly grass rather than forbs. Diet CP predictions were consistent with forbs constituting the majority of the diet from July 2003 through to January 2004. At Croxdale (Fig. 4b), cattle selected $<15$% non-grass during the 2001–02 wet season (November–March) and up to only $20$% non-grass through the dry season from May to October 2002. There was a sharp increase in DNG to almost $80$% at the end of the dry season in January 2003, followed by a sharp decrease after the substantial rain in February 2003. It later increased to over $40$% in early June. We speculate that the cattle selected some browse during the dry season, that there was some increase in selection of browse in November 2002 and a major increase in January 2003 owing to the lack of alternative forages. Grass growth from the rain in February 2003 led to a sharp decrease in DNG, but with the lack of follow-up rain the cattle again changed their diet to include more browse. Faecal ash concentrations, which were low in late January and in June, provided supportive evidence for this change in diet selection. Dietary CP was highest following substantial rainfall during the 2001–02 wet season, and following the rain in February 2003, when cattle were apparently selecting for actively growing grasses.
Conditions were also dry at Oakley Station when sampling commenced in the middle of the dry season in July 2001 and DNG ranged between 50 and 70% through until December 2001 (Fig. 4c). A sharp decrease during January-March 2002 to <10% DNG in March was associated with substantial rain in January-February. Through the dry season the non-grass was...
probably principally browse. Forbs may have contributed to the diet after the rain in January–February 2002, though diet CP did not increase until March when the diet was principally grass.

**Relationship between diet non-grass proportions and protein in the diet**

The linear relationships ($P < 0.05$) between diet CP and DNG for dry season samplings at Newcastle Waters and Carlton Hill Station (Fig. 5) indicated that the protein content of the non-grass was higher than that of the grass in each of these circumstances. The intercepts of the regressions indicated that the protein content of the grass selected ranged from 3.1–5.3%, and the slopes indicated that the protein content of the non-grass selected ranged from 12.0–15.1% for the Newcastle Waters and Carlton Hill sites. Thus, for every 10% increase in DNG, the CP of the entire diet increased by 0.8–1.1%. The regressions for the two sampling dates at Newcastle Waters suggested that CP of the grass selected decreased from 5.3 to 3.6%, and CP of the non-grass selected decreased from 15.1 to 12.5%, during the interval between samplings. Similarly, at Woolthorpe (Fig. 6) the CP contents of the selected grasses and non-grasses were 4.7 and 12.9% in June, and 4.5 and 15.5% in July, respectively. Also the DM digestibilities of the selected grasses and non-grasses at Woolthorpe were 53 and 73% in June, and 50 and 74% in July.

**Discussion**

Use of FNIRS technology to measure the proportion of non-grass in the diet selected by grazing cattle (or sheep), as in the present study, involved both advantages and limitations. The FNIRS technique allowed frequent, low-cost measurements of many dietary attributes in herds grazing many sites and a range of pasture systems over long periods, and DNG was but one such attribute. This would have been difficult to achieve with any other existing technology. Furthermore, since the measurement was based on faeces obtained from many animals grazing paddocks without restriction, many of the errors associated with use of
non-grass component of cattle diet in tropical rangelands

Non-grass component of cattle diet in tropical rangelands

Fig. 6. The relationship between (a) diet crude protein (CP) and diet non-grass and (b) DM digestibility and diet non-grass. Predictions represented sheep from three paddocks in June and four paddocks in July of 2003.

oesophageal fistulated animals to measure diet selection were avoided. With oesophageal-fistulated animals there are always concerns about whether the extrusa sampled is representative of the daily intake, whether the area grazed during sampling is representative of the paddock, and whether a few surgically modified animals introduced briefly to the specific grazing situation will accurately represent the diet selected by long-term resident animals (Coates et al. 1987; Jones and Lascano 1992; Clements et al. 1996). Microhistological analysis of plant cuticle in faeces to identify the plant species avoids many of the latter difficulties, but quantitative determination of the proportions of the various plant species selected in the diet often involves large errors and the technique is very laborious (Holechek et al. 1982). Estimates of the diet selected from observing grazing animals, or by measuring the disappearance of vegetation components, also involve major limitations. Alkane and other plant wax compounds have been used as markers to measure diet selection in temperate pastures (Dove and Mayes 1991, 2005; Ali et al. 2005), but the presently available methods cannot measure the botanical composition of the diet where animals may be selecting a substantial number of plant species. There are additional difficulties with the application of this marker technology to cattle grazing in the tropics, since the alkane concentrations are low and variable in many tropical pasture species (Laredo et al. 1991; Reich et al. 2000). An obvious limitation of using FNIRS to measure the $^{13}$C of the diet is that the diet can be divided into only two botanical classes, and the non-grass class may include browse species, leguminous forbs, and non-leguminous forbs. Estimation of the plant species which comprise the grass or non-grass classes must depend on other knowledge such as the measurement or observation of the plant species available and apparently being selected by the grazing animals. Furthermore some of the grass species available in the sub-tropics are C$_4$ (Hattersley 1983) and some forbs species in Mitchell grass dominated pastures are C$_4$ (Cobon and Carter 1994). However, as discussed by Coates (2004), the calibration equation he developed is probably measuring plant tissue characteristics rather than actual $^{13}$C/$^{12}$C ratios, and the predictions of DNG when these C$_4$ grasses and C$_4$ forbs contribute to the diet approximate the true values unless they are present in very high proportions. Despite these limitations FNIRS technology is extremely valuable in allowing frequent measurement of the diet, including grass and non-grass proportions, in circumstances where this would otherwise not be possible.

In the absence of ongoing, detailed information on the botanical composition of the vegetation on offer at the sites we sampled, we could not assign selection preferences to different classes of plants. However, measured DNG at the browse sites at Ryandale, Coonamble and Oakley Station appeared to be consistent with selection preferences of cattle on sheep grazing the arid rangelands of southern Australia as described by Wilson and Harrington (1984), who grouped plant species into four main categories according to the order in which they are selected by livestock during the usual seasonal progression from active pasture growth through to maturity and senescence. First preference during the period of active pasture growth was usually for some perennials and a wide array of ephemeral plants (annual grasses and forbs) when these were available (category 1). Second preference (category 2) was for the more palatable perennials when the ephemerals had either dried off or had been grazed down. Grazing then turned to lower palatability plants (category 3) that were eaten in increasing amounts when the availability of palatable plants was reduced and included browse species such as mulga and saltbush and a range of perennial grasses such as Mitchell grasses. The fourth category included species which are rarely or never eaten, usually because of the presence of antinutritional factors, protective physical features or extreme fibrousness. Similar results for sheep in semi-arid mulga woodland were reported by Freudenberger et al. (1999) who also emphasised preference for green grass leaf when it was available, and also for cattle as well as sheep for other Australian rangeland regions (Squires 1980, Squires and Siebert 1983; McMeniman et al. 1986; Squires and Low 1987).

Fecal profiles for DNG at the browse sites appeared to be consistent with these published selection sequences. At Ryandale the only feed available when sampling commenced was mulga and it constituted the entire diet. Rain was received through the autumn and winter months (Fig. 4a) but DNG remained very high throughout this period. As we explained in the results section we suggest there was a change in diet selection from mulga (category 3) to forbs (category 1) that germinated...
and grew in response to autumn-winter rain, and that rainfall was insufficient to maintain pasture growth until substantial rain fell in January, after which grass growth increased. At Croxdale DNG was around 10% during the pasture growing season November–March (Fig. 4) and we concluded that grass was either preferred to the available forbs or that low availability of palatable forbs prohibited high intakes. However, as the pasture dried off and grass protein concentrations declined there was an increase in non-grass consumption to alleviate the protein deficiency. We proposed that the increase in DNG (April–August) was not the result of cattle eating mulga (category 3) and that high intakes of mulga (reaching nearly 80% in January) only occurred late in the dry period when other more palatable sources of non-grass forage were depleted. Following substantial rain in February grass became the dominant dietary component. Similarly, browse was a major dietary component during the long dry season at Oakley Station but, with wet season rains, cattle reverted to a diet of grass.

At the Mitchell grass dominated sites, with the exception of Morungle, the non-grass component was necessarily forbs due to the absence of browse. Lack of pasture composition data (except for early dry season and late dry season measurements at Toorak) again made it impossible for us to assign grazing preferences to the grass and non-grass fractions but high DNG was consistent with previous measurements in oesophageal-fistulated sheep grazing Mitchell grass dominated pastures (Lorimer 1978; McMenemy et al. 1986; Orr et al. 1988). We conclude that many forb species present in Mitchell grass dominated pastures are palatable and readily grazed by cattle during the wet season when green grass leaf is also available. Moreover, we propose that, where both green grass and young forbs are readily available, cattle prefer a mixed diet rather than a diet heavily biased towards either category. During the dry season the protein concentration in dry grass falls to low levels and cattle exhibit a strong preference for forbs. This was particularly well demonstrated at Toorak in 2002 when forbs accounted for less than 2% of the pasture on offer in May but cattle selected a diet averaging ~15% forbs throughout the long dry season. Forbs were more prevalent at Toorak in 2003 and 2004 and cattle again selected strongly for forbs during the dry season. Although sheep have a greater ability than cattle to select some vegetation components (Wilson 1976; Graetz and Wilson 1980; Squires 1980), these results from Toorak indicate that cattle also have the ability to select the forb component in Mitchell grass dominated pastures.

Non-grass levels in the diet of cattle grazing grasslands of the black speargrass and Aristida–Bothriochloa regions at moderate stocking rates were much lower than those of the Mitchell grass pastures and those that were measured at times in the browse communities. A range of factors contribute to diet composition but of primary importance are the species on offer and their availability. Since adapted perennial grasses dominate these grasslands when grazed at moderate rates, forbs generally only contribute ~2% of DNG in the diet of cattle averaged over the season. Forbs are readily available, cattle prefer a mixed diet rather than a diet heavily biased towards either category. During the dry season, the protein concentration in dry grass falls to low levels and cattle exhibit a strong preference for forbs. This was particularly well demonstrated at Toorak in 2002 when forbs accounted for less than 2% of the pasture on offer in May but cattle selected a diet averaging ~15% forbs throughout the long dry season. Forbs were more prevalent at Toorak in 2003 and 2004 and cattle again selected strongly for forbs during the dry season. Although sheep have a greater ability than cattle to select some vegetation components (Wilson 1976; Graetz and Wilson 1980; Squires 1980), these results from Toorak indicate that cattle also have the ability to select the forb component in Mitchell grass dominated pastures.

The effect of grazing pressure on DNG in the Glentulloch experiment was substantial in one replicate but not significant overall. Nevertheless, the results presented in Fig. 2 demonstrate the benefits of ENIRS profiles of DNG and diet quality as an aid to interpreting paddock and treatment differences (or lack thereof) in both pasture and animal production traits. Although the difference was not significant at Glentulloch, Ash et al. (1995) reported higher DNG and higher diet quality as a consequence of prolonged high grazing pressures at sites near Charters Towers in the northern speargrass region and near...
The proportion of forbs. The effect has been recorded for speargrass, the palatable perennials, and an increase in the amount and proportion of forbs. The effect has been recorded for speargrass pastures (Ash and McIvor 1995), monosomial tallgrass pastures (McIvor et al. 1995), Mitchell grass dominated pastures (Orr 1988), and in rangelands of the Americas (Smith et al. 1994). The increases in DNG and diet CP during years 3 and 4 at Swans Lagoon, Katherine in the monsoonal tallgrass region. The underlying non-grass component of cattle diet in tropical rangelands importance of non-grass in the savannahs of northern Australia where perennial grasses dominate the pasture has often been either not recognised or underrated. Even in the Mitchell grass regions the importance of forbs in providing nutrients and energy to grazing livestock has probably not been fully appreciated. Faecal NIRS provides a practical and inexpensive means by which this type of information can now be made available to commercial operators and the information becomes all the more relevant when it applies to the operator's observations on their own properties. Predictions of diet non-grass by FNIRS can also be considered a decision support tool. Any technology that provides managers with a greater understanding of how their enterprises function is likely to help managers make better decisions. As an example, consider dry season N supplementation in the Mitchell grass areas where livestock obtain energy and protein from grass and forbs. Once grasses dry off in the dry season, protein levels will be low and, if forbs are not available to grazing livestock, they are likely to suffer a deficiency of rumen degradable protein. However, if forbs are available they can provide sufficient protein, thus avoiding the need for N supplementation. The results for diet non-grass from Toorak, where no browse was available, showed that cattle, as well as sheep, have an extraordinary ability to seek out forbs even when present in very low amounts and where they may not be apparent to the casual observer. Faecal NIRS predictions of diet non-grass in such situations can be a valuable tool to assist producers make economically important decisions regarding the need to supplement or not throughout the course of the dry season. Future opportunities As stated previously, a major limitation of FNIRS estimates of diet composition based on predictions of faecal δ¹⁵N is that the diet can only be divided into grass and non-grass. Although this two-class division is useful, an ability to distinguish between species or groups of species within either class would be highly desirable. Other work has shown that FNIRS calibration equations can be developed to measure the proportional composition of the diet, at least in defined circumstances (Walker et al. 1998, 2002; Landau et al. 2004). Evidence from our own research to date indicates that it is not likely that FNIRS has the capacity to distinguish between multiple species such as between many different grass species in a diet. However, early work to develop a calibration equation for predicting the dietary proportions of (i) mulla and (ii) Stylolanthus legume has been encouraging. Spectral analysis using advanced chemometrics may also enhance the discriminatory power of NIRS in general and FNIRS in particular. Similarly, combining FNIRS technology with other new technologies may lead to improved outcomes. For example, DNA analysis shows promise for the identification of plant species in faeces and the two technologies (FNIRS and DNA) combined may produce better outcomes than either technology separately. The results presented in this paper relate to northern Australia where most grasses are C₄ and most non-grasses are C₃. Our calibration equation and the calculation of diet non-grass cannot be applied as it currently exists to pastures in southern Australia where there are many native and introduced C₃ grasses.
and vast areas such as the Chenopod shrublands where a C₄ non-grass species (saltbush) forms a major component of the forage resource. Nevertheless, we believe that with appropriate research, FNIRS has the potential to provide useful information on the botanical composition of diets in southern Australia.

Conclusions

The contribution of non-grass to the diets of cattle grazing the rangelands of northern Australia can be easily and reliably estimated using FNIRS. The non-grass fraction can make a substantial contribution to the diet in terms of proportionial DM and protein status. Since the protein level of grass during the dry season is generally well below maintenance requirements for cattle, the edible non-grass components of the vegetation form an important part of the fodder resource, even where grasses dominate.

Acknowledgements

We thank Meat and Livestock Australia for partial financial support for this research. Also we thank Trevor Hall for access to results from the Clermont site, Desirée Jackson for access to the results from the Rossbank site, and Michael Jeffery (Cromdule), Rick Searer (Longreach Pastoral College), Bakh Schoo (Frankfield), Dick Cribb and John Mally and Don Robertson for assistance with sampling, and Kylee Wulk for technical assistance at the CSIRO Dairy Laboratory. Animal Experimentation Ethics Committee approval numbers: TSV-42/00, WLEAC07-01, ARJ/R05/2004, SLEAC DP0013, SEAE C00/01–38.

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Ash, A. J., and McIvor, J. G. (1995). Land condition in the tropical tallgrass season is generally well below maintenance requirements for cattle, the edible non-grass components of the vegetation form an important part of the fodder resource, even where grasses dominate.

Acknowledgements

We thank Meat and Livestock Australia for partial financial support for this research. Also we thank Trevor Hall for access to results from the Clermont site, Desirée Jackson for access to the results from the Rossbank site, and Michael Jeffery (Cromdule), Rick Searer (Longreach Pastoral College), Bakh Schoo (Frankfield), Dick Cribb and John Mally and Don Robertson for assistance with sampling, and Kylee Wulk for technical assistance at the CSIRO Dairy Laboratory. Animal Experimentation Ethics Committee approval numbers: TSV-42/00, WLEAC07-01, ARJ/R05/2004, SLEAC DP0013, SEAE C00/01–38.

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Manuscript received 20 November 2006; accepted 29 March 2007