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Diet quality and liveweight gain of steers grazing *Leucaena*–grass pasture estimated with faecal near infrared reflectance spectroscopy (F.NIRS)

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Abstract. Three drafts of *Bos indicus* cross steers (initially 178–216 kg) grazed *Leucaena*–grass pasture [*Leucaena leucocephala* subspecies *glabrata* cv. Cunningham with green panic (*Panicum maximum* cv. *trichoglume*)] from late winter through to autumn during three consecutive years in the Burnett region of south-east Queensland. Measured daily weight gain (DWG_{Actual}) of the steers was generally 0.7–1.1 kg/day during the summer months. Estimated intakes of metabolisable energy and dry matter (DM) were calculated from feeding standards as the intakes required by the steers to grow at the DWG_{Actual}. Diet attributes were predicted from near infrared reflectance spectroscopy spectra of faeces (F.NIRS) using established calibration equations appropriate for northern Australian forages. Inclusion of some additional reference samples from cattle consuming *Leucaena* diets into F.NIRS calibrations based on grass and herbaceous legume–grass pastures improved prediction of the proportion of *Leucaena* in the diet. Mahalanobis distance values supported the hypothesis that the F.NIRS predictions of diet crude protein concentration and DM digestibility (DMD) were acceptable. F.NIRS indicated that the percentage of *Leucaena* in the diet varied widely (10–99%). Diet crude protein concentration and DMD were usually high, averaging 12.4 and 62%, respectively, and were related asymptotically to the percentage of *Leucaena* in the diet ($R^2 = 0.48$ and 0.33, respectively). F.NIRS calibrations for DWG were not satisfactory to predict this variable from an individual faecal sample since the s.e. of prediction were 0.33–0.40 kg/day. Cumulative steer liveweight (LW) predicted from F.NIRS DWG calibrations, which had been previously developed with tropical grass and grass–herbaceous legume pastures, greatly overestimated the measured steer LW; therefore, these calibrations were not useful. Cumulative steer LW predicted from a modified F.NIRS DWG calibration, which included data from the present study, was strongly correlated ($R^2 = 0.95$) with steer LW but overestimated LW by 19–31 kg after 8 months. Additional reference data are needed to develop robust F.NIRS calibrations to encompass the diversity of *Leucaena* pastures of northern Australia. In conclusion, the experiment demonstrated that F.NIRS could improve understanding of diet quality and nutrient intake of cattle grazing *Leucaena*–grass pasture, and the relationships between nutrient supply and cattle growth.

Introduction

Leucaena leucocephala is a leguminous shrub utilised extensively as forage in the tropics, providing high yields of leaf and edible stem of high nutritional quality and palatability (Norton *et al*. 1994; Garcia *et al*. 1996). The development of understanding and knowledge to overcome agronomic constraints (Dalzell *et al*. 2006) and dihydroxypyridine (DHP) toxicity (Jones and Megarrity 1986; Klieve *et al*. 2002) has led in recent years to an increasing adoption of *Leucaena* for cattle production in northern Australia. In rainfed systems in central and southern Queensland, growth rates of steers are typically 0.5–1.2 kg/day and 240–280 kg/annum and may range up to ~1.5 kg/day and 330 kg/annum (Rakuita *et al*. 1992; Middleton *et al*. 1994; Dalzell *et al*. 2006). In irrigated systems, cattle growth rates appear similar, but higher production per ha has been reported (Petty 1997).

Despite these successful developments there has been little published research investigating grazing management and productivity of cattle grazing *Leucaena*–grass pastures in circumstances where productivity was clearly not constrained by DHP toxicity. An understanding of the selection by grazing cattle and the nutritive value of the various pasture components, and the factors limiting voluntary intake, are clearly required. Information is limited primarily to observation and anecdotal information, to the studies of Petty (1997) and Galgal (2002), and to extrapolation from other pasture systems. The major resources required and the difficulties associated with such research are well known (Holechek *et al*. 1982; Gordon 1995). Faecal near infrared reflectance spectroscopy (F.NIRS) has been developed to estimate the diet selected by grazing ruminants, including the composition as crude protein (CP) concentration, dry matter digestibility (DMD) and non-grass proportion, and functional properties such as metabolisable energy intake (MEI) and liveweight (LW) gain. Calibration equations, which are central to NIRS technology, have been developed for conventional temperate (Lyons and Stuth 1992; Stuth *et al*.

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1999) and tropical grass and grass–herbaceous legume pastures (Coates 2004; Dixon and Coates 2005). Also, F.NIRS has been developed to estimate the grass to non-grass proportions in the diet selected by cattle grazing a variety of pasture systems in northern Australia (Coates and Dixon 2007).

The present study investigated the application of F.NIRS, based on current and modified calibration equations, to measure diet quality and LW gain of cattle grazing a *Leucaena*–grass pasture at a specific site.

Materials and methods

Pasture, steers and sampling

Three herds of growing steers grazed an established *Leucaena*–grass pasture at Brian Pastures Research Station in the southern speargrass region near Gayndah, Queensland (25°40′S, 151°45′E). The 11-ha paddock comprised a brown clay-black earth soil of basaltic origin. *L. leucocephala* (subspecies *glabrata* cv. Cunningham) had been established in 1976 with rows spaced 3 m apart. During the 25 years before the present experiment commenced, the paddock had been utilised by grazing cattle in a variety of trials. The *Leucaena* had tended to spread from the original rows, and some areas of the *Leucaena* in the drainage lines had been severely damaged by frost. The grass between the *Leucaena* rows was principally green panic (*Panicum maximum* cv. *trichoglume*).

The three drafts of steers used were ~5/8 *Bos indicus* × 3/8 *Bos taurus* (>F_2) crossbreds from a research station herd. Draft 1 of the experiment commenced on 4 July 2002 with 14 steers 14–17 months of age and averaging 216 (±s.d. = 12) kg LW. Because of lower than average rainfall during September–December 2002, six steers were removed from the paddock in December to reduce the grazing pressure. The draft was continued through to 7 March 2003. Draft 2 steers commenced on the 19 August 2003 with seven steers [8–11 months of age and average LW 197 (±s.d. = 2) kg], and continued until 3 June 2004. Draft 3 steers commenced on the 12 August 2004 with eight steers [8–11 months of age and average LW 178 (±s.d. = 5) kg], and continued until the 26 May 2005. When each new draft of steers was introduced to the *Leucaena*–grass pasture they shared a water trough with a group of steers adapted to grazing *Leucaena* in an adjacent paddock; this was adopted as a generally effective management practice to avoid DHP toxicity (Jones and Megarrity 1986; Quirk *et al*. 1990; Hammond 1995). In addition, draft 3 steers were inoculated with specialist rumen microorganisms, including *Synergistes jonesii*, able to break down DHP. No symptoms of mimosine or DHP toxicity were observed during the experiment. Steers were mustered and weighed monthly. Faeces were obtained by rectal sampling at weighing, and also from fresh dung pats in the paddock midway between musters.

NIRS scanning and chemometrics

Faecal samples were oven-dried (65°C) and then ground (1-mm screen, Model 1093 Cyclotec mill, Foss Tecator AB, Hoganas, Sweden). Before analysis, samples were redried (65°C) and scanned (400–2500 nm range) using a monochromator fitted with a spinning cup module (Foss 6500, NIRSystems, Silver Spring, MD, USA) located in CSIRO Davies Laboratories. Chemometric analysis used ISI software (Infrasoft International, Port Matilda, PA, USA).

Diet CP concentration and DMD were predicted from spectra of faeces using the Coates (2004) calibration equations. The percentage of *Leucaena* in the diet and daily weight gain (DWG) were predicted using modified versions of the Coates (2004) calibrations. Of the > 300 diets in the dataset of the Coates (2004) calibrations for diet CP and DMD, five contained *Leucaena*. The percentage of *Leucaena* in the diet was calculated from the $\delta^{13}C$ of faeces, and the calibration for $\delta^{13}C$ was based on reference values of faecal $\delta^{13}C$ measured by mass spectrometry. The Coates (2004) calibration dataset for $\delta^{13}C$ ($n = 1756$) included 187 samples from cattle grazing *Leucaena*, but these were from one season at a single site (Galgal 2002). Since additional $\delta^{13}C$ reference samples were available from cattle grazing *Leucaena* from the present study ($n = 15$), that of Streeter (2005) ($n = 12$), and an unpublished study (P. Shotton, unpubl. data) ($n = 42$), these data were combined with the Coates (2004) data to form an expanded dataset ($n = 1825$). This calibration equation, based on a modified partial least-squares model (MPLS) [700–2500 nm range, standard normal variate (SNV), detrend and 1,4,4,1 data transformations] provided satisfactory calibration statistics [$R^2 = 0.92$, s.e. of cross validation (SECV) = 0.91 $\delta^{13}C$ units, ratio of the s.e. of prediction (SEP) to the s.d. of the reference data (RPD) = 3.5]. Although the inclusion of additional samples from cattle grazing *Leucaena* into the calibration dataset resulted in negligible improvement in the calibration statistics, the latter modified calibration was considered more appropriate and was thus used to predict the $\delta^{13}C$ and the percentage of *Leucaena* in the diet.

The Coates (2004) ADG1441 general calibration equation for predicting animal DWG was developed from a dataset which did not contain any *Leucaena* diets. Since actual DWG of steers was measured regularly during the present study, these results were used to develop a modified calibration equation for DWG which included data from cattle grazing *Leucaena*–grass pastures. Two approaches were used. For the first approach, predictions of DWG were made from a dataset which included all of the LW measurements in the present study. The faecal NIR spectra collected from drafts 1, 2 and 3 ($n = 56$) were, with their respective animal DWG reference values, included with the dataset used to calculate the Coates (2004) ADG1441 calibration ($n = 1191$) to form an expanded dataset ($n = 1247$). A modified DWG calibration ($DWG_{F.NIRS\_Leuc\_A}$) was calculated based on a MPLS model (700–2500 nm range, SNV, detrend and 1,4,4,1 data transformations) and calibration statistics were acceptable ($R^2 = 0.82$, SECV = 0.21 kg/day units, RPD = 2.2). This $DWG_{F.NIRS\_Leuc\_A}$ calibration was then used to predict the DWG of the steers at each sampling time, and to calculate the cumulative LW of the steers at each sampling time during each draft. For the second approach, predictions of DWG were made from datasets which were independent for each draft of steers in the present study. Three modified calibrations were calculated by inclusion of reference samples from: (i) drafts 1 and 2; (ii) drafts 2 and 3; and (iii) drafts 1 and 3 with the Coates (2004) ADG1441 dataset. The statistics were $R^2 = 0.83$ and

SECV = 0.20 kg/day for each of these calibrations. These three modified calibrations were then used to predict three validation datasets of the DWG of the steers for the draft not used for the calculation of the modified calibration. These latter predictions of DWG for the three drafts were then combined as the $DWG_{F.NIRS\_Leuc\_B}$ predictions, and the predicted cumulative LW of the steers calculated. Cumulative predicted LW estimated with F.NIRS was calculated from the mean steer LW at the commencement of the draft plus the summation of F.NIRS predictions of LWG in fortnightly increments through the measurement interval for each draft.

Calculation of estimated DM intake of the steers

DM intake (DMI) was calculated from the estimated MEI and the assumption that digestible DM contained 18.4 MJ ME/kg (DMI_{MEI}). The estimated MEI of the steers at each sampling time was calculated using equations given by Freer *et al*. (2007) as the ME required to achieve the measured DWG (DWG_{Actual}). The following assumptions were made: (i) standard reference weight was 550 kg; (ii) the ME required for maintenance was calculated following Eqn 1.19; (iii) the net energy content of LW change from Eqns 1.29 and 1.30 (iv) efficiency of utilisation of ME for LW gain was calculated following Eqn 1.37; (v) the ME concentration of the diet was calculated from the DMD measured by F.NIRS following Eqn 1.12A; and (vi) the animals walked 2 km per day on level terrain. The DWG_{Actual} of the steers at any specific time was calculated as the tangent to a polynomial regression of measured LW with time. The intake of *Leucaena* DM was calculated from the total DMI (DMI_{MEI}) and the percentage of *Leucaena* in the diet predicted with F.NIRS. In addition to the calculation of DMI_{MEI}, total DMI was calculated from the DMD predicted by F.NIRS and following the Freer *et al*. (2007) calculations of potential intake and relative intake (DMI_{DMD}).

Results

Rainfall and seasonal conditions

Rainfall in the 2002–03 summer (Table 1) from October to March for draft 1 (332 mm) was only 64% of average, but the effects of this low rainfall was compensated for by abnormally high rainfall in the preceding August (91 mm). Rainfall distribution and totals during drafts 2 and 3 were similar to the 35-year average. The amounts of *Leucaena* and grass forage varied widely with the stage of the seasonal cycle and grazing.

Growth of the steers

The draft 1 steers gained, on average, 0.76 kg/day for 8 months and were 398 kg at termination of grazing in March 2003. Drafts 2 and 3 steers gained on average 0.83 and 0.59 kg/day and weighed 436 and 348 kg, respectively, at termination of the drafts. In draft 1 steers, the increase in DWG_{Actual} from July to October 2002 was presumably a consequence of the August rain, and the large decline in DWG_{Actual} from over 0.9 kg/day in November 2002 to about maintenance in March 2003 (Fig. 1) appeared to be associated with a decline in the observed amounts of forage on offer. In draft 2 steers DWG_{Actual} was initially ~1 kg/day but declined steadily to ~0.7 kg/day at the end of the draft. In draft 3 steers, the increase in DWG_{Actual} from maintenance in September 2004 to 1.0–1.1 kg/day from December 2004 to February 2005, and subsequent decline through to May 2005, was consistent with low initial forage availability followed by growth of forage during the summer months and later low forage availability through into the autumn months.

Table 1. Rainfall (mm) and the date of the seasonal break at the experimental site
The seasonal break was defined as the first rainfall event of at least 50 mm over 3 days after 1 July

Month	2002–03	2003–04	2004–05	35-year mean
July	0	17	1	34
Aug.	91	41	1	29
Sept.	0	9	22	29
Oct.	64	60	92	61
Nov.	24	46	76	70
Dec.	58	179	182	105
Jan.	0	142	46	107
Feb.	113	91	68	96
Mar.	63	109	30	72
Apr.	61	28	10	38
May	43	11	44	39
June	10	5	96	30
Total	527	738	668	708
Break	22 Aug. 02	6 Dec. 03	18 Oct. 04	–

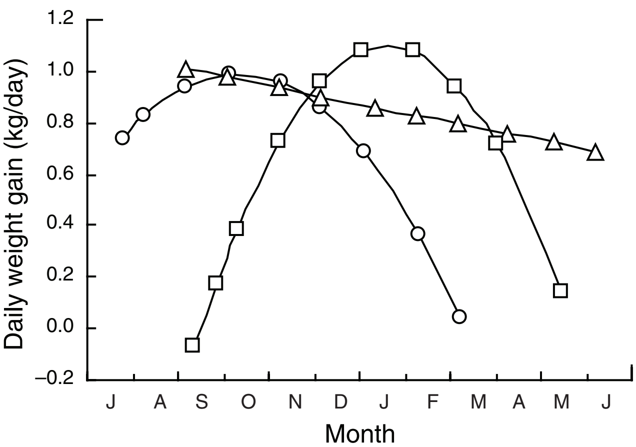

Fig. 1. The measured daily weight gain (DWG_{Actual}) of steers in draft 1 (2002–03) (○), draft 2 (2003–04) (△) and draft 3 (2004–05) (□).

Selection of Leucaena *and the CP and DMD of the diet estimated with F.NIRS*

The percentage of *Leucaena* in the diet (Fig. 2) fluctuated through a wide range, which generally appeared to reflect the amount of *Leucaena* forage observed to be on offer and the expected growth from rain. The percentage of *Leucaena* was, on average (±s.d.), 48% (±20), 60% (±20) and 51% (±29) for draft 1, 2 and 3 steers, respectively. In draft 1 steers, the percentage of *Leucaena* was initially high but declined steeply through August with reducing availability. Warmer temperatures and the August rain apparently promoted sufficient new growth for

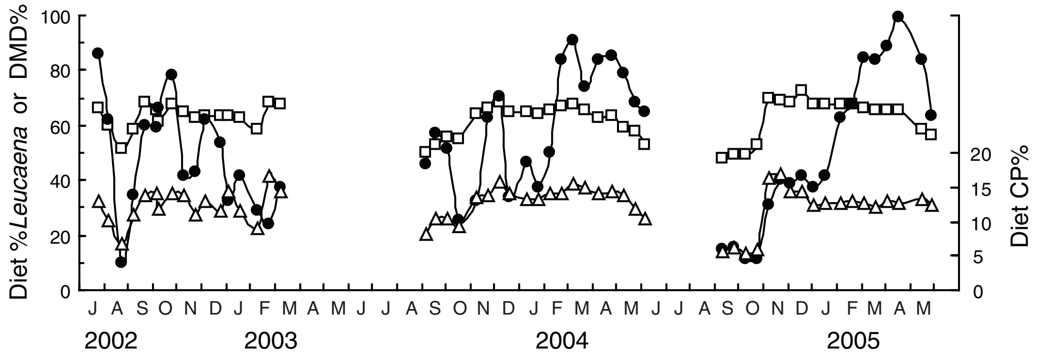

Fig. 2. The percentage of *Leucaena* (●), crude protein concentration (△) and the dry matter digestibility (□) of the diet selected by draft 1 (2002–03), draft 2 (2003–04) and draft 3 (2004–05) steers.

the percentage of *Leucaena* to increase through September to peak in late October, but thereafter there was a decline. In draft 2 steers, the percentage of *Leucaena* in the diet from late February to early May 2004 was high and averaged 83%. Draft 3 steers initially selected a low percentage of *Leucaena* (11–15%) in September–October 2004, most likely because there was little *Leucaena* forage available when this draft commenced. However, with rain and summer growth the percentage of *Leucaena* in the diet increased progressively and averaged 84% of the diet from March to May 2005.

Early in draft 1, the CP% and the DMD of the diet selected declined as the percentage of *Leucaena* declined (Fig. 2). Through September 2002 in draft 1, and also during the early months of drafts 2 and 3, the CP increased to average between 13.0 and 16.7%, and DMD to average between 65 and 69%, in November. These higher values tended to be maintained through the summer months, and from December through to March the CP averaged between 12.9 and 14.4%, and the DMD averaged between 64 and 68%, across the three drafts. Dietary CP% (Y_1) and DMD% (Y_2) were asymptotically related to the percentage of *Leucaena* in the diet (X) as follows:

$$Y_1 = 13.2 - 27.1\,e^{-0.115X} \quad (n = 55,\ R^2 = 0.48,\ P < 0.001,\ \text{r.s.d.} = 1.98) \qquad (1)$$

$$Y_2 = 63.9 - 48.9\,e^{-0.113X} \quad (n = 55,\ R^2 = 0.33,\ P < 0.001,\ \text{r.s.d.} = 4.95) \qquad (2)$$

However, the CP% and the DMD were correlated ($R^2 = 0.78$) and thus not independent. The ratio of the diet DMD to diet CP (DMD : CP) was <8 throughout the experiment except for ~6 weeks early in draft 3 when availability of *Leucaena* forage was low.

Intakes of total DM, Leucaena *DM and grass DM*

The intakes (DMI_{MEI}) of *Leucaena* and total DM by the steers in each of the three drafts calculated from DMI_{MEI} are shown in Fig. 3, while the difference represented intake of grass DM. Total intake exceeded 30 g DM/kg LW.day early in drafts 1 and 2, but declined rapidly and was usually in the range 20–25 g DM/kg LW.day. Total intake was less than 15 g DM/kg LW.day during the last month of drafts 1 and 3. *Leucaena* intake exceeded 15 g DM/kg LW.day for short intervals during the early months of drafts 1 and 2, and the late summer-autumn months of drafts 2 and 3.

Diet CP% (Y) was asymptotically related to the *Leucaena* intake (g DM/kg LW.day) (X), as follows:

$$Y = 13.0 - 20.5\,e^{-0.528X} \quad (n = 55,\ R^2 = 0.24,\ P < 0.001,\ \text{r.s.d.} = 2.40) \qquad (3)$$

but DMD was not related to the *Leucaena* intake. $\text{DWG}_{\text{Actual}}$ was poorly related to the percentage of *Leucaena* in the diet ($n = 55$, $R^2 = 0.12$, $P < 0.05$, r.s.d. = 0.27 kg/day units). High LW gains (>0.7 kg/day) occurred across a wide range (10–91%) of percentage of *Leucaena* in the diet, indicating that a high DWG could occur irrespective of the diet percentage of *Leucaena*.

Prediction of steer liveweight from F.NIRS

The cumulative LW of the steers at the end of the drafts, when predicted using the Coates (2004) ADG1441 calibration equation for DWG based on grass and grass–herbaceous legume pastures, was 129–193 kg greater than the measured LW of the steers, while the Mahalanobis distance values calculated during predictions from F.NIRS averaged 7.8. Thus, the Coates (2004) ADG1441 calibration to predict DWG was not useful for these *Leucaena*–grass diets. The $\text{DWG}_{\text{F.NIRS\_Leuc\_A}}$ calibration provided excellent predictions of cumulative steer LW (Figs 4 and 5*a*) while the average Mahalanobis distance (2.1) was satisfactory. However, the SEP of $\text{DWG}_{\text{F.NIRS\_Leuc\_A}}$ was 0.33 kg/day. The prediction of cumulative LW from the $\text{DWG}_{\text{F.NIRS\_Leuc\_B}}$ calibration, which was based on an expanded population and which included data from the present experiment but where each draft was predicted as an external population, was considered acceptable since cumulative steer LW was overestimated by only 19–31 kg at the end of the draft (Figs 4 and 5*b*). However, the SEP was high at 0.40 kg/day.

Discussion

Reliability and error of the estimation of intake, diet quality and steer growth from F.NIRS measurements

The estimated total DMI calculated as DMI_{MEI} were generally in the range expected for young cattle grazing high quality forage, except for the estimates exceeding 30 g DM/kg LW.day for two

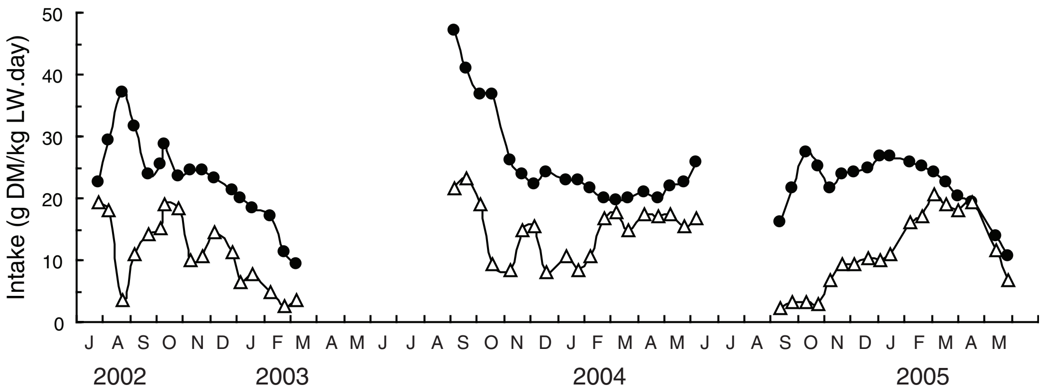

Fig. 3. The estimated intakes of *Leucaena* dry matter (DM) (△) and total DM (●) (g/kg liveweight per day) for draft 1 (2002–03), draft 2 (2003–04) and draft 3 (2004–05) steers. Total DM intake (DMI_{MEI}) was calculated from the metabolisable energy intake estimated to be required for the measured liveweight change and the DM digestibility of the diet, while the *Leucaena* intake was calculated from the total DM intake and the percentage of *Leucaena*. The difference between the intakes of total DM and *Leucaena* DM was grass DM.

samples near the commencement of draft 1, and during the first 2 months of draft 2 (Fig. 3). Such high intakes seem unlikely, but may have been an overestimation due to increased gut fill and compensatory growth in these steers being transferred from low quality winter native pasture to the high quality *Leucaena*–grass pasture; any increase in gut fill and body water would have led to overestimation of the true gains in body tissue and body energy, and thus caused overestimation of ME and DMI.

There was considerable evidence that F.NIRS provided reliable and acceptable predictions of the percentage of *Leucaena* and the diet quality in these steers grazing *Leucaena*–grass pasture in the present study. Since $\delta^{13}C$ was measured by mass spectrometry in 15 faecal samples from the present study, the error associated with F.NIRS prediction of $\delta^{13}C$ in these samples could be used to assess the error associated with the F.NIRS prediction of percentage of *Leucaena* in the present experiment. This relationship (Fig. 6) indicated that the F.NIRS calibration used underestimated the actual percentage of *Leucaena* by 4–10% units when the proportion of *Leucaena* in the diet was low, and overestimated the percentage of *Leucaena* by 8–14% units when the proportion of *Leucaena* in the diet was high. It would be possible to use this regression relationship to adjust the percentage of *Leucaena* values, but this was not performed for the present experiment. Additional evidence for the appropriateness of the F.NIRS calibration used in the present experiment was that the Mahalanobis distance averaged 2.2, less than the desirable maximum of 3.0 suggested by Shenk and Westerhaus (1993).

The errors associated with thxe F.NIRS predictions of diet CP% and DMD in the present study from the Coates (2004) calibration equations could not be evaluated using the approach described for the percentage of *Leucaena*, since no diet–faecal pair samples were available. The average (±s.d.) Mahalanobis distance for the predictions of diet CP% and DMD were 4.7 (±3.5) and 5.1 (±3.2), respectively, and indicated that some caution in the interpretation of the predicted values is warranted. However, the Coates (2004) calibration dataset included five diets containing 25% or 50% *Leucaena* each fed to 3–4 steers. The differences between the actual values and the F.NIRS predicted values (i.e. the bias) for these five *Leucaena* diets were small, being on average 0.09 (±0.96) for diet CP% and 0.5 (±3.4) for DMD. These observations support the hypothesis that

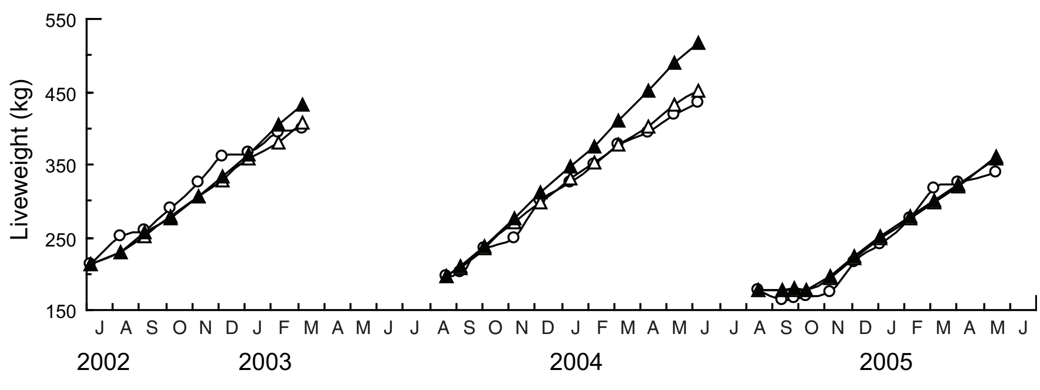

Fig. 4. The actual measured liveweight (○), and the cumulative liveweight predicted using the $DWG_{F.NIRS\_Leuc\_A}$ (△) and the $DWG_{F.NIRS\_Leuc\_B}$ (▲) faecal near infrared reflectance spectroscopy calibration equations in the three drafts of steers.

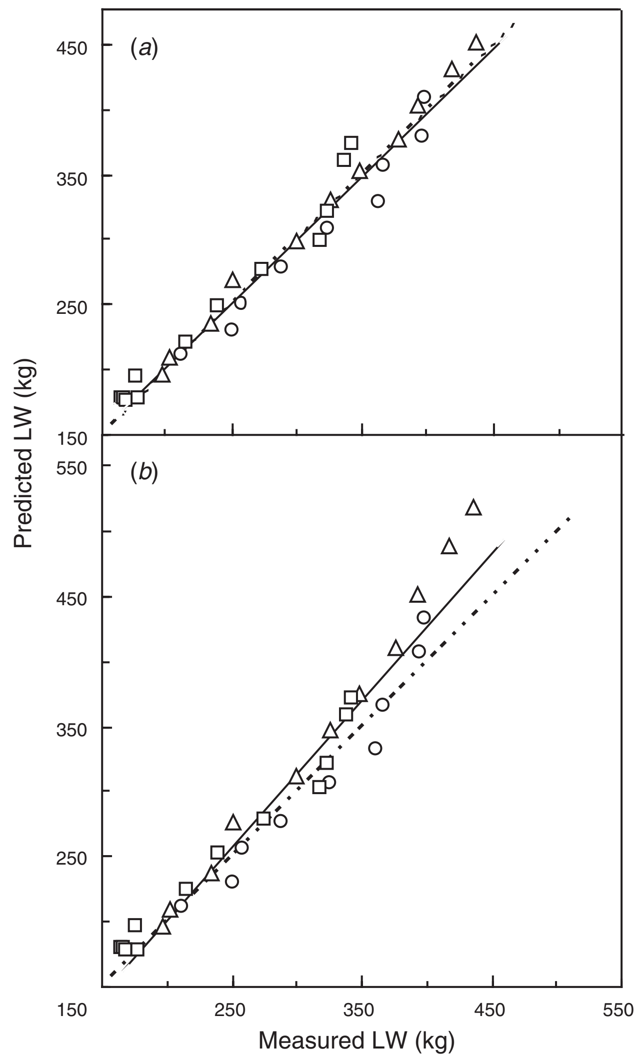

Fig. 5. Measured liveweight and the cumulative predicted liveweight at each sampling time calculated using (*a*) the $DWG_{F.NIRS\_Leuc\_A}$, and (*b*) the $DWG_{F.NIRS\_Leuc\_B}$ calibration equations for draft 1 (○), draft 2 (△) and draft 3 (□) steers. The regression relationships (±s.e.) are shown as (—) and the 1 : 1 relationship as (- - -). The equations were as follows: (*a*) $Y = 0.98\ (\pm\ 0.030)X + 7\ (\pm 9.0)$ ($n = 32$, $R^2 = 0.97$, $P < 0.001$, r.s.d. = 13.8), (*b*) $Y = 1.13\ (\pm\ 0.049)X - 26\ (\pm 14.6)$ ($n = 32$, $R^2 = 0.95$, $P < 0.001$, r.s.d. = 22.4). For 5 (*a*) the intercept did not differ from the origin and the slope did not differ from 1.0 (both $P > 0.05$). For (*b*) the intercept did not differ from the origin ($P > 0.05$) and the slope was greater than 1.0 ($P < 0.001$).

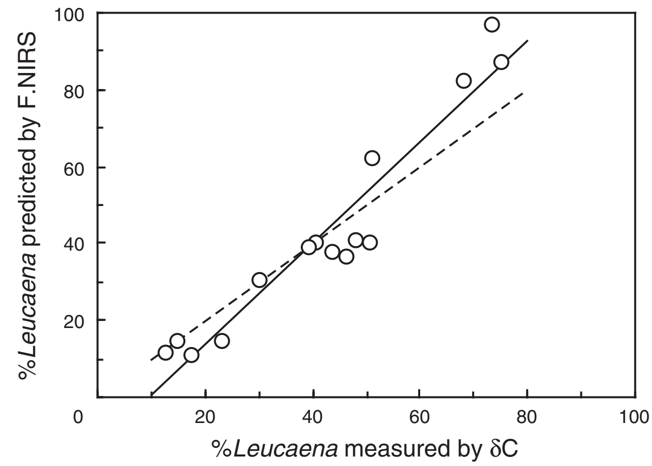

Fig. 6. The relationship between the percentage of *Leucaena* in the diet calculated from the $\delta^{13}C$ content of faeces measured by mass spectrometry, and the percentage of *Leucaena* in the diet calculated from the $\delta^{13}C$ content of faeces predicted from the faecal near infrared reflectance spectroscopy calibration equation used for the present study. The regression relationships are shown as (—) and the 1 : 1 relationship as (- - -). The relationship was as follows: $Y = 1.32X - 13$ ($n = 15$; $R^2 = 0.92$, $P < 0.001$, r.s.d. = 8.1). The intercept of the relationship differed from the origin ($P < 0.05$) and the slope was greater than 1.0 ($P < 0.05$).

the calibration equations used were acceptable for these *Leucaena*–grass pastures and that prediction errors were likely to be comparable with those for conventional pastures.

Because the experimental steers were weighed frequently, the errors associated with the calibrations for DWG could be examined directly. The Coates (2004) calibrations for DWG based on grass and grass-herbaceous legume pastures, and which did not contain any data from cattle grazing *Leucaena*–grass pastures, were not acceptable. Given the botanical dissimilarity between *Leucaena* and the conventional grass and herbaceous dicot species in northern Australia pastures, and experience with application of NIRS to analysis of forages and foods (Shenk and Westerhaus 1993), this was not unexpected. However, the inclusion into the Coates (2004) dataset of some faecal spectra from *Leucaena*–grass diets measured in the present experiment allowed the development of a modified calibration which substantially improved prediction of DWG and cumulative LW, at least for *Leucaena*–grass pasture at the experimental site and during the years of the study. The excellent prediction of cumulative LW by the $DWG_{F.NIRS\_Leuc\_A}$ calibration (Fig. 5*a*) demonstrated that F.NIRS spectra from cattle grazing *Leucaena*–grass pastures could be combined with those from conventional pastures and be described satisfactorily by a single calibration equation. These observations are consistent with studies with other agricultural products, which have shown that usually only a small number of samples from a new population are required to successfully modify an established NIRS calibration to describe the new population (Shenk and Westerhaus 1993; Guthrie *et al*. 2005). The good agreement between the F.NIRS predicted cumulative LW and the measured LW of the steers in the present experiment is comparable with excellent prediction of cumulative LW by F.NIRS in non-pregnant, non-lactating breeders grazing native tropical pasture (Dixon *et al*. 2007).

Although the $DWG_{F.NIRS\_Leuc\_A}$ and $DWG_{F.NIRS\_Leuc\_B}$ calibrations provided estimates of cumulative steer LW during the 8–9 months of each draft which would be acceptable for many purposes, the SEPs were too large for DWG to be reliably predicted at a specific time from a single faecal sample. Because the calculation of cumulative LW involved F.NIRS predictions at fortnightly intervals during each draft, the error of cumulative LW would be expected to be much lower than for the estimates of DWG from a single sample, while the difference between the measured LW and the predicted cumulative LW would represent any bias in the prediction of DWG. The SEPs from the $DWG_{F.NIRS\_Leuc\_A}$ and $DWG_{F.NIRS\_Leuc\_B}$ calibrations were about twice the SEP observed in the Coates (2004) calibrations for DWG of cattle grazing conventional pastures. However, if a dataset for DWG of cattle grazing *Leucaena*–grass pastures were developed comparable in size and diversity with that for grass and grass-herbaceous legume pastures, then it is likely that a similar smaller SEP would also be observed.

Since the samples in the present study were limited to one site, the calibrations which were developed ($DWG_{F.NIRS\_Leuc\_A}$ and $DWG_{F.NIRS\_Leuc\_B}$) are probably not sufficiently robust to predict reliably across the variety of *Leucaena*–grass pastures which occur in northern Australia. However, the present study demonstrated that some faecal samples with DWG reference measurements substantially improved the F.NIRS calibrations. Thus, it should be possible to develop robust and reliable calibrations for *Leucaena* pastures in northern Australia if measurements similar to those in the present study were obtained in herds representing the variety of such pasture systems. In addition, experimentation to generate additional diet-faecal pairs for *Leucaena*–grass diets to improve the calibrations for diet CP and DMD would be highly desirable. The greatest need would seem to be for diets where the *Leucaena* is providing nitrogen (N) to balance low N forages. These are the circumstances where rumen degradable N may become limiting and a capacity to accurately and reliably measure diet CP% and DMD : CP ratio is likely to be most important.

Diet selected and LWG of the steers

The high proportion of *Leucaena* in the diet selected was expected given that *Leucaena* is usually highly palatable, and that only limited grass was observed to be usually available between the narrow *Leucaena* rows in the pasture used. It is also consistent with observations that even when *Leucaena* forage available varied widely, it usually comprised 35–60% of the diet selected in *Leucaena*–grass pastures (Petty 1997; Galgal 2002). In the present study, diet CP concentration and DMD were generally high (overall means 12.4 and 62%, respectively) compared with diets usually selected by cattle grazing tropical grass pastures, and this was presumably due to the high CP% and DMD of *Leucaena* leaf and edible stem (Norton *et al*. 1994; Garcia *et al*. 1996), and the likely effect of *Leucaena* to increase the N concentration of associated grasses (Quirk *et al*. 1990). The DMD : CP ratio of the diet exceeded 8 for only ~6 weeks during September–October 2004. Since rumen degradable N is likely to be limiting only when the DMD : CP ratio exceeds 8–10 (Dixon and Coates 2005), the present study confirms that *Leucaena*–grass pastures are rarely deficient in rumen degradable N, as indeed is to be expected for any pasture containing a high proportion of palatable legume.

Although in the present study, increases in percentage of *Leucaena* in the diet up to ~25–30% were associated with increases in diet CP% and DMD, high steer growth rates (>0.7 kg/day) occurred across a wide range of dietary grass : *Leucaena* proportions and DWG was poorly related to percentage of *Leucaena* in the diet. This contrasted with results reported by Petty (1997) and Galgal (2002). The absence of a general relationship between percentage of *Leucaena* in the diet and DWG in the present study was probably due to several factors. First, in this experiment the grass component would have provided high quality forage when growing conditions were favourable, especially during the early wet season. High steer growth rates would then be achieved regardless of the dietary grass : *Leucaena* proportions. Second, if forage intake is limited by low amounts of DM on offer, DWG is likely to be poor even if the diet selected contains a high proportion of *Leucaena*. This almost certainly occurred during the latter part of draft 3 when *Leucaena* comprised > 60% of the diet (Figs 2 and 3). Finally, in circumstances where diet DMD is on average greater than ~60%, voluntary DMI and animal growth is likely to be limited by either the physiological mechanisms which limit intake and the balance of absorbed nutrients or by the capacity of the animal to harvest forage. The observation that in the present experiment DMI_{MEI} averaged only 0.87 (s.d. = 0.29) of DMI_{DMD} suggested that the ability of the steers to harvest forage may have constrained intake and growth. This is consistent with the suggestion of Petty (1997) that the low bulk density of *Leucaena* forage may constrain its voluntary intake by grazing cattle. Regardless of the differences between experiments and the uncertainty about the factors limiting voluntary intake and DWG, we suggest that caution should be applied in any general recommendation for producers, such as that suggested by Dalzell *et al*. (2006), that cattle should be ingesting 30% of their diet as *Leucaena* to achieve high growth rates of > 1 kg/day.

In conclusion, the present study demonstrated that F.NIRS could predict the amount and quality of the diet selected by cattle grazing *Leucaena*–grass pastures, including the contribution of *Leucaena*, through the seasonal cycle. Such information is essential to understand the nutritional limitations of *Leucaena*–grass pastures, and to develop optimal grazing management strategies. Advantages of F.NIRS include its simplicity, low labour and low cost compared with alternative techniques to measure selection and nutrient intake of grazing ruminants.

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