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Nutrition of beef breeder cows in the dry tropics. 2. Effects of time of weaning and diet quality on breeder performance

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Abstract. In the seasonally dry tropics the effects of three times of weaning and three nutritional regimes on the changes in liveweight (LW) and body condition score (BCS) of grazing *Bos indicus* × *Bos taurus* breeder cows (n = 210) and their calves were examined through an annual cycle, commencing in the early dry season in April 1998. Most of the cows (n = 180) were lactating initially, and were weaned in April (W1), July (W2) or September (W3) to represent the expected early, mid and late dry season. In addition, cows that had not lactated for 11 months before the experiment commenced (NOCALF treatment; n = 30) were examined. The seasonal break occurred in late August, 3.5 months earlier than average for the site. The nutritional regimes consisted of a native pasture (LOW), another native pasture augmented with *Stylosanthes* spp. legumes (MEDIUM), or this latter pasture supplemented during the dry season with molasses-urea (HIGH). These nutritional regimes were imposed from the commencement of the experiment in April 1998 until February 1999, except that for the HIGH treatment the supplement was fed only during the dry season. Near-infrared reflectance spectroscopy of faeces (F.NIRS) was used to estimate the contents of non-grass, crude protein (CP) and DM digestibility of the diet selected, and also DM intake and metabolisable energy (ME) intake. Diet quality was in accord with the expected seasonal cycle, and was consistently lower (P < 0.05) for the LOW than for the MEDIUM treatment. Concentrations of CP and CP/MJ ME in the diet, and of N in faeces, indicated that the cows grazing the LOW treatment were deficient in rumen degradable protein during the dry season. There was no interaction (P > 0.05) between the nutritional regime and the time of weaning on changes in conceptus-free liveweight (CF.LW) or BCS during the dry season. Weaning increased breeder CF.LW, relative to lactating breeders, by 0.42 kg/day in the early dry season (April–July; the difference between the W1 and W2 treatments), and 0.18 kg/day in the usual mid dry season (July–September; the difference between the W2 and W3 treatments). The NOCALF treatment cows were initially 79 kg heavier than lactating cows, and lost more LW during the dry season. Microbial CP synthesis was 21 and 29% greater (P < 0.05) in lactating than in non-lactating cows in the late dry season and shortly after the seasonal break (August and September), respectively. Calf growth was not affected (P > 0.05) by nutritional regime during the early dry season (April–July), but was lower for the LOW nutritional regime during the usual mid dry season (July–September); this indicated that the LOW nutritional regime cows mobilised sufficient additional body reserves to maintain milk production during the former, but not the latter, interval. All cows that were lactating at the commencement of the experiment gained CF.LW rapidly from September 1998 following the seasonal break. In conclusion, although nutrition affected LW change of both cows and calves, there was a much larger effect of weaning than of the nutrition treatments examined on conservation of body reserves in breeder cows during the dry season. The observation that the effects of weaning on conservation of cow body reserves were similar across a wide range of nutrition is important for management to achieve appropriate targets for breeder cow body reserves.

Additional keywords: body condition score, faecal near infrared spectroscopy, liveweight, microbial crude protein, molasses supplement.

Introduction

In the seasonally dry tropics the quality and availability of pasture is generally high only for a brief interval during the rainy season, and during the dry season intake of nutrients from pasture may be insufficient for maintenance of liveweight (LW) even of non-lactating animals (Winks 1984). In such regions seasonal cycles are usually observed in LW and body reserves of growing cattle, and are accentuated in reproducing cows by the high nutritional demands of pregnancy and lactation. From experimentation in temperate and subtropical climates, predominantly with *Bos*

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taurus cattle, it is clear that cow body reserves and nutrition, particularly near parturition, have important effects on milk output, weaning weight and reconception (Wiltbank *et al*. 1964; Randel 1990; Short *et al*. 1990; Quintans *et al*. 2010). Cow body reserves and nutrition have similar effects in *Bos indicus* cattle in the seasonally dry tropics, although mortality associated with undernutrition may also be important (Lamond 1970; Entwistle and McCool 1991; Dixon 1998; Savage 2005).

In harsh environments of the seasonally dry tropics the nutritional management of the breeder herd often involves strategies to achieve substantial cow body reserves at the end of the wet season, to conserve cow body reserves through the dry season, and to achieve appropriate target body reserves at the commencement of the following wet season for the next reproductive cycle (Herd and Sprott 1986; Dixon 1998). Severe undernutrition during the dry season can cause prolonged cessation of ovarian activity (Fordyce *et al*. 1997). Time of calving and the quality and quantity of the pasture available through the wet season clearly have major effects on the body reserves of the breeder at the commencement of the dry season. Weaning greatly reduces the demand by the breeder cow for nutrients, and thus has large effects on breeder body reserves (Holroyd *et al*. 1988; Schlink *et al*. 1994). The timing of weaning in relation to the stage of the dry season is usually chosen, with consideration of the prevailing seasonal conditions, as a compromise between the adverse consequences for the nutrition of the calf and the benefits for the cow. In addition, in cows with low body reserves and suboptimal nutrition postpartum, weaning may lead to earlier return to oestrus and reconception (Williams 1990; Yavas and Walton 2000).

Optimal and cost-effective management of weaning and nutrition for breeder herd productivity in the seasonally dry tropics, particularly in relation to timing and the manipulation of the nutrition from pasture and supplements, clearly requires a quantitative understanding of the consequences of these management options on nutrient intake, cow body reserves and reproductive performance. Knowledge of nutrient intake, combined with information on cow body reserves, expected calving dates, and expectations of future pasture quality and quantity, allow improved decision-making on the implementation of strategies for the nutritional management of breeder herds. Near-infrared reflectance spectroscopy of faeces (F.NIRS) has been developed recently to estimate the quality and quantity of dietary metabolisable energy (ME) and crude protein (CP) ingested by grazing cattle (Lyons and Stuth 1992; Coates 2004; Dixon 2008; Dixon and Coates 2009), including by breeder cows (Dixon *et al*. 2007). This provides a technology to estimate nutrient intake of grazing breeder cows and thus facilitate effective nutritional management, including in the context of management for weaning, manipulation of body reserves and reproductive performance.

A previous study (Dixon *et al*. 2011) examined the effects of weaning early or late in the dry season, and of providing a non-protein N supplement during the dry season, on the conservation of cow body reserves and other consequences through the annual cycle in *Bos indicus* × *Bos taurus* cows and calves in a seasonally dry tropical environment. The present study further examined the effects of weaning and nutrition on the intake of nutrients, cow body reserves and the performance of breeder cows and their calves through an annual cycle, but with a greater range in nutrient supply and an additional intermediate time of weaning. The nutritional regimes were expected to lead to maintenance or moderate loss of body reserves of non-lactating cows, and substantial loss in body reserves of lactating cows, through the dry season. The consequences of the dry season treatments on the body reserves and the reproductive performance of the cows and their calves during the following wet season were also measured.

Materials and methods

Pastures and cattle

The experiment was carried out at the Swan's Lagoon Research Station situated 100 km south-southeast of Townsville (20°4′S, 147°15′E) in the seasonally dry tropics of northern Australia. About 80% of the annual average rainfall of 871 mm occurs during summer from October to March. The pastures grazed comprised tropical grasses native or naturalised to the open eucalypt woodlands of the speargrass region of coastal north-eastern Australia, or such pastures augmented with *Stylosanthes scabra* cv. *seca* and *S. hamata* cv. *verano* legumes growing on low fertility duplex soils. Major grass species were black speargrass (*Heteropogon contortus*) and other tropical tall grasses and medium grasses including *Chrysopogon fallax* and *Bothriochloa pertusa.*

From the commencement of the experiment on 28 April 1998 until 3 February 1999 the experimental animals grazed 15 trial paddocks and various nutritional and weaning treatments were imposed. Thereafter until 17 May 1999 the cattle grazed as a single herd in a 600-ha paddock. The cows (n = 210) used were ~5/8 *Bos indicus* × 3/8 *Bos taurus* (>F_2) crossbreds from the research station herd. There were three age cohorts of cows; 30 were lactating cows initially 5.0–5.5 years old (cohort 1), 82 (60 lactating and 22 non-lactating) were initially 4.0–4.5 years old (cohort 2), and 98 (90 lactating and 8 non-lactating) were cows initially 3.0–3.5 years old (cohort 3). The 30 non-lactating cows of cohorts 2 and 3 had calved between November 1996 and January 1997 and had been mated for 3 months from late January 1997, but did not become pregnant. These cows were weaned in May 1997, and mated again for 3 months from January 1998; at the commencement of the present experiment these cows had not lactated for 11 months and all were pregnant. The cohort 2 cows had been used in the study of Dixon *et al*. (2011) during the 12 months preceding the present study. For 3 months preceding the experiment the cohort 1 and 2 cows grazed as a single herd, while the cohort 3 cows grazed in several paddock groups. All the cows were mated from late January 1998 until the present study commenced. On 28 April 1998 the cows were mustered, weighed, evaluated for body condition score (BCS) and pregnancy diagnosed. The cows were allocated to 15 paddock groups by stratified randomisation, the strata being: (i) cow cohort, and (ii) pregnancy status. There were 14 cows in each paddock group consisting of two lactating cohort 1 cows, four lactating cohort 2 cows, six lactating cohort 3 cows, and two non-lactating cohort 2 or 3 cows. From this and subsequent pregnancy diagnoses, 57% of the cows were pregnant. Calves were included with their dams in designated paddock groups, and were 143 ± 25 (mean and s.d.) kg LW and 4–6 months of age. These calves were designated as cohort B; some were also the cohort B calves in the experiment of Dixon *et al*. (2011). All cattle were vaccinated against botulism, all cows against leptospirosis, and all calves against clostridial diseases and tick fever (*Babesia* spp. and *Anaplasma centrale*). Cows pregnant at the commencement of the experiment calved (cohort C calves) from October 1998 until February 1999, and the dates of parturition and dam-calf pairs were determined by frequent inspections. All cows were mated as a single herd with six bulls from 3 February until 17 May 1999.

Treatments

The 15 paddock groups of cattle were allocated to one of three nutritional regimes. The LOW nutrition regime consisted of five 40-ha native pasture paddocks that had soils of poor water-holding capacity and early senescence of pasture and that had comprised the site 1 paddocks in the previous study of Dixon *et al*. (2011). For the MEDIUM and HIGH nutritional regimes the cattle grazed 10 24-ha paddocks of moderate soil fertility where the native pasture was augmented with *Stylosanthes* spp. legumes. These 10 paddocks were, on the basis of soil type and vegetation, divided into five paddock blocks, and one paddock within each paddock block was randomly allocated to the MEDIUM and HIGH nutritional regimes. For the HIGH nutritional regime the cattle were offered molasses-urea supplement *ad libitum* during the dry season from 13 May 1998 until 7 September 1998. The urea content of the molasses was varied in an attempt to achieve voluntary intake of supplement of ~1 kg as-fed per cow per day. The concentration of urea was (g/kg as-fed) 74 during weeks 1 and 2, 107 during week 3, 138 during weeks 4–12, 74 during weeks 13–14, and 138 during weeks 15–16. From 8 September 1998 to 3 February 1999 the cows in the MEDIUM and HIGH treatments grazed nominally the same pasture and thus any differences were carryover effects from the previous supplementation.

Within each paddock group the six lactating cows from cohort 1 and 2, and the 6 from cohort 3, were randomly allocated to three times of weaning. These were: (i) W1, weaned early in the dry season (28 April 1998 at the commencement of the experiment), (ii) W2, weaned in the mid dry season (13 July 1998), or (iii) W3, weaned in the late dry season (8 September 1998). In addition, a NOCALF treatment consisted of two non-lactating cows per paddock from cohorts 2 and 3 as described above. Thus there were four treatments within each paddock group, with four cows in each of the W1, W2 and W3 treatments and two cows in the NOCALF treatment.

Measurements

The cows and calves were mustered each 4–6 weeks, weighed and BCS estimated (9-point scale; NRC 1996). Pregnancy status of the cows was determined by rectal palpation in April and June 1998, and May and July 1999.

Eight cows in each paddock group (two selected at random from cohorts 1 and 2, or 3, allocated to the W1 and W3 treatments) were sampled for blood, urine and faeces. Blood samples were obtained at the musters in June, July and August 1998, urine samples at the musters of August and September 1998, and faecal samples at each of the musters from June 1998 to February 1999. The procedures used for sampling and processing blood and urine were as described by Dixon *et al*. (2011). Faecal samples were obtained *per rectum*. Samples were pooled within weaning groups within paddocks for subsequent laboratory analysis. Plasma and urine samples were stored frozen pending analysis, while faeces were dried (70°C) immediately.

Laboratory analyses, calculations and statistical analyses

The procedures described by Dixon *et al*. (2011) were used for analysis and calculation of urea N and inorganic phosphorus in plasma (PUN and PIP, respectively), microbial CP synthesis, and F.NIRS. The NIR calibration equations of Coates (2004) were used to predict the non-grass, CP and DM digestibility (DMD) contents of the diet, total N concentration of faeces, and voluntary DM intake. The estimated ME intake of the non-lactating non-supplemented cows was calculated from the F.NIRS estimates of DM intake and DMD, and with the assumption that digestible DM contained 15.5 MJ ME/kg DM (CSIRO 2007). Since F.NIRS predictions of diet quality attributes using the Coates (2004) calibration equations are not affected by lactational status, compensatory LW gain or small amounts of molasses supplement (Dixon and Coates 2005; Dixon *et al*. 2007), estimates of diet quality were made for each paddock group of cows. However, since even small amounts of supplementary molasses may lead to substantial error in the F.NIRS prediction of voluntary intake of forage DM (D. B. Coates, unpubl. data), no estimates of DM intake were presented for HIGH nutrition cows during the dry season when molasses supplements were fed.

Conceptus-free LW (CF.LW) of the cows was calculated as described by Dixon *et al*. (2011). Statistical analyses of treatment effects were evaluated for individual measurement dates using residual maximum likelihood (REML) with a split-plot error structure in which the effects of time and treatments were considered in a repeated-measures analysis and with an unstructured covariance undertaken using REML in GENSTAT release 11.1 (VSN International Ltd, Hemel Hempstead, UK). Because the LOW nutritional regime consisted of five similar paddocks in a different pasture system to the MEDIUM and HIGH nutritional regimes, the measurements for the LOW nutritional regime were analysed separately. The pooled s.e.d. was used to compare measurement means between the LOW and MEDIUM nutritional regimes. Linear regression was used to investigate relationships between F.NIRS predictions of diet attributes, and between these diet attributes and time. Reconception of cows during the 1998–99 wet season was analysed using a proportional hazards model which included the effects of lactation (Cox 1972).

Results

General

Rainfall during the wet season (October 1997–March 1998) preceding the commencement of the experiment on 28 April 1998 was 82% of the long-term average for the site (Table 1), and pasture availability was adequate. Rainfall during the 1998 dry season was greater than average with 101 mm in May and 274 mm on 30–31 August. The latter rain event caused the seasonal break 3.5 months earlier than expected, and substantial subsequent rain ensured continuing pasture growth.

Table 1. Monthly rainfall (mm) preceding (July 1997–March 1998) and during the experiment (April 1998–May 1999), and the 34-year average at the trial site

Month	1997–98	1998–99	34-year average
July	7	26	15
August	10	274[A]	19
September	9	7	9
October	27	56	30
November	0	142	67
December	302	46	123
January	161	201	195
February	85	101	187
March	21	140	114
April	53	2	44
May	101	7	40
June	9	0	18
Total	785	1002	871
Seasonal break[B]	15 December 1997	30 August 1998	17 December[C]

[A]30 and 31 August 1998.
[B]Defined as ≥50 mm rain in ≤3 days.
[C]Median.

All cows and cohort B calves were in good health throughout the experiment. The 57% of cows that were pregnant in April 1998 calved (cohort C calves) from 14 October 1998 through to 3 February 1999; distribution was 2, 40, 48, 9 and 1% in the respective months, and the mean calving date was 6 December 1998 (s.d. = 20 days). Eight cohort C calves died neonatally.

Supplement intake of cattle given the HIGH nutrition regime

Voluntary intake of molasses-urea supplements (Fig. 1) varied through the dry season. If the intake of supplement by the cows and calves was the same per kg LW (Earley *et al*. 1999; Dixon and Smith 2000), then supplement intake ranged from 0.5 to 1.9 kg as-fed/cow.day. Supplement intake could not be measured after 24 August 1998 due to rainwater overflowing the supplement feeders, but observations indicated that no supplement was consumed after the rain on 30 August 1998. Intake of supplement averaged 0.92 kg as-fed/cow.day and 6.5 MJ molasses ME/cow.day. Since ~30 g urea per kg molasses would have been required to balance the rumen fermentation, on average 76 (range between weeks 43 and 114) g supplementary urea/cow.day was available for rumen microbial digestion of pasture.

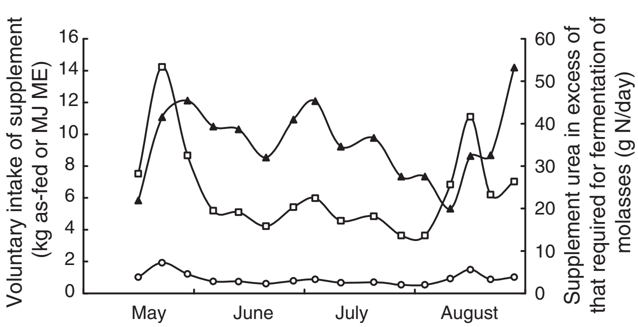

Fig. 1. Mean voluntary intake of molasses-urea supplement offered to the five paddock groups in the HIGH nutritional regime during the 1998 dry season. The intake of as-fed supplement (○, kg/cow.day), estimated metabolisable energy (ME) provided by the supplement (□, MJ ME/cow.day), and supplementary urea in excess of that required to ferment the molasses in the supplement (▲, g urea N/cow.day) are shown.

F.NIRS estimates of diet quality and intake

During the dry season the F.NIRS estimates of diet quality did not differ ($P > 0.05$) between the W1 and W3 cows within the respective nutritional regimes during the dry season (Table 2) or subsequently. In the absence of differences between the W1 and W3 treatments in the F.NIRS estimates of diet non-grass, CP and DMD, the mean values for these two treatments are shown (Fig. 2*a–c*). Because the F.NIRS calibrations used do not directly estimate voluntary intake of lactating cows, and the W3 cows were lactating until September, the F.NIRS estimates of DM intake, ME intake, and CP/ME (Fig. 2*d–f*) are presented only for the W1 cows. Diet quality as CP concentration and DMD, and voluntary intakes of DM and ME, decreased as the dry season progressed from June to July 1998, tended to remain the same from July to August 1998, and then increased after the seasonal break on 30 August 1998 and through the 1998–99 wet season. Diet non-grass, which likely consisted principally of native herbaceous forbs in the LOW treatment and stylo legume in the MEDIUM and HIGH treatments, was on average much lower ($P < 0.001$) in cows grazing the LOW than the MEDIUM

Table 2. Faecal near-infrared reflectance spectroscopy estimates during the dry season of mean diet crude protein (CP), DM digestibility (DMD), non-grass and CP per MJ metabolisable energy (ME) in the ingested diet, voluntary DM intake and faecal N concentration in cows given LOW, MEDIUM or HIGH nutritional regimes, and weaned in either April 1998 (W1) or September 1998 (W3)
The W1 cows were not lactating, and the W3 cows were lactating, during the dry season. Each mean represents five paddock groups sampled in June, July and August 1998. W, weaning; N, nutritional regime. The W × N interactions were not significant ($P > 0.10$). The estimates of diet quality and voluntary intake represent the forage component of the diet. n.s., not significant

Prediction	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
Sig.		*Diet CP (%)*			*Diet DMD*	
W1	4.2	5.4	5.6	50.7	52.2	53.1
W3	4.3	5.3	5.5	50.6	52.4	53.1
s.e.d.	0.22	0.40		0.55	0.75	
W	n.s.	n.s.		n.s.	n.s.	
N	–	n.s.		–	n.s.	
Sig.		*Diet non-grass (%)*			*DM intake (g/kg liveweight.day)*	
W1	7.2	18.3	19.0	15.5	16.5	–
W3	8.0	16.1	17.6	15.7	17.1	–
s.e.d.	0.56	2.42		0.67	0.63	–
W	n.s.	n.s.		n.s.	n.s.	–
N	–	n.s.		–	–	–
Sig.		*Diet g CP/MJ ME*			*Faecal N (%)*	
W1	5.3	6.6	–	0.94	1.05	1.11
W3	5.4	6.5	–	0.91	1.04	1.12
s.e.d.	0.22	0.40	–	0.03	0.05	
W	n.s.	n.s.	–	n.s.	n.s.	
N	–	–	–	–	n.s.	

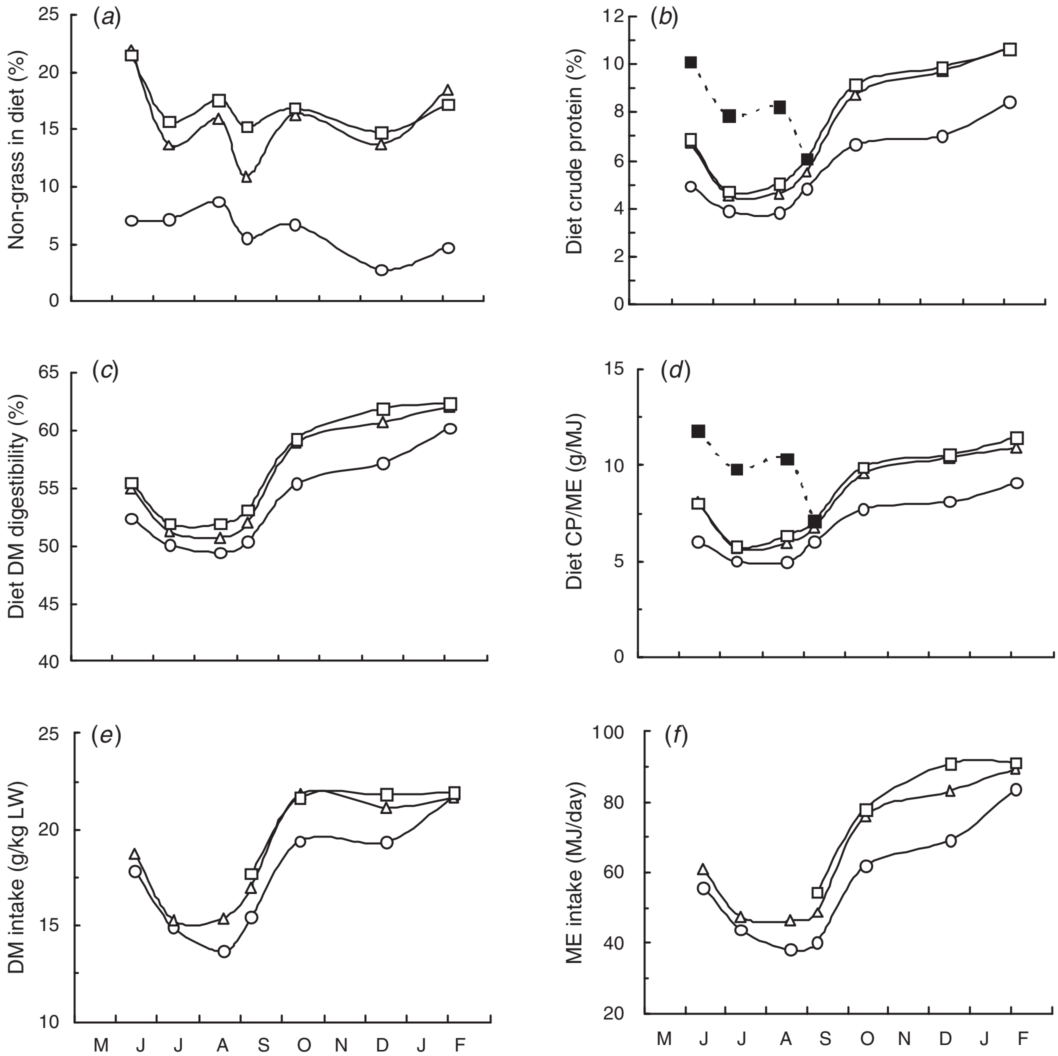

Fig. 2. Faecal near-infrared reflectance spectroscopy (F.NIRS) estimates of the mean concentrations in the forage component of the diet of (*a*) non-grass, (*b*) crude protein (CP), (*c*) DM digestibility of grazing cows weaned in April (W1) or September (W3) in LOW (○), MEDIUM (△) and HIGH (□) nutritional regimes. The calculated values for the HIGH regime following adjustment for the contribution of the supplement to diet CP and intakes of DM and metabolisable energy (ME) are shown (■). In addition, the (*d*) diet CP/MJ ME intake, (*e*) the voluntary DM intake (g/kg liveweight.day), and (*f*) the ME intake (MJ/day) for the non-lactating W1 treatment cows are shown. ME intake was estimated from F.NIRS estimates of voluntary DM intake and DM digestibility. Molasses-urea supplement was fed to the HIGH treatment cows from May to late August, and no estimates were made of the DM intake in these cows during this interval.

and HIGH regimes (means 6, 16 and 17%, respectively). In the MEDIUM and HIGH nutritional regimes the diet non-grass appeared to be higher in June 1998 than later in the dry season, or through the following wet season (Fig. 2*a*).

Diet CP and DMD were consistently lower ($P < 0.05$ or $P < 0.01$) in the LOW than the MEDIUM nutritional regime (Table 2; Fig. 2*b*, *c*). In June 1998 the diet CP concentrations were 4.9 and 6.8%, and DMD 52 and 55%, respectively, and declined as the dry season progressed to 3.8 and 4.7% CP, and 49 and 51% DMD, respectively, in August 1998 (Fig. 2*b*, *c*). During the dry season the diet CP/ME (g/MJ) was lower ($P < 0.05$) for the LOW than for the MEDIUM regime (means of 5.4 and 6.5, respectively from June to August) (Table 2; Fig. 2*d*). Following the seasonal break, both diet CP concentration and DMD increased progressively from September 1998 so that by February 1999 the CP was 8.4 and 10.7%, and DMD 60 and 62%, in the LOW and MEDIUM regimes, respectively. DM intake of the W1 cows in the LOW nutritional regime was generally lower than in the MEDIUM nutritional regimes (Fig. 2*e*), and was 18–19 g DM/kg LW in June 1998, declined to 14–15 g DM/kg LW in July and August 1998, but after the seasonal break increased progressively to 22 g DM/kg LW in February 1999. In the LOW and MEDIUM regimes the estimated ME intake declined from 56 and 61 MJ ME/day in June 1998 to 38 and 46 MJ ME/day in August 1998, respectively, and then increased progressively to 84 and 90 MJ ME/day in February 1999 (Fig. 2*f*). On average the DM intake was 7% higher, and ME intake 16% higher, in the MEDIUM than in the LOW nutritional regime.

F.NIRS estimates of the diet quality of the cows in the HIGH nutrition during the dry season were similar to those for the MEDIUM nutrition (Table 2). This was expected because the F.NIRS calibrations estimated the forage component of the diet, and the cattle grazed nominally the same pasture in these two nutritional regimes; differences would be expected only if the molasses supplement modified diet selection. The concentrations of diet CP and CP/MJ ME, as calculated from the F.NIRS estimates of the forage component of the diet plus the CP and ME from the molasses supplement, were all substantially greater for the HIGH than for the MEDIUM nutritional regime during the dry season when supplement was provided. On average during the dry season the diet ingested was increased to 8.7% CP and 10.6 g CP/MJ ME.

Faecal N concentrations followed a similar pattern to diet CP concentration. The DMD and the faecal N concentration were related to the CP concentration in the forage component of the diet as follows:

$$\text{Diet DMD}(\%) = 1.89\,(\text{Diet CP}\%) + 42.5$$
$$(n = 209;\ R^2 = 0.95;\ P < 0.001;\ \text{r.s.d.} = 1.02)$$

$$\text{Faecal N}(\%) = 0.106\,(\text{Diet CP}\%) + 0.49$$
$$(n = 209;\ R^2 = 0.94;\ P < 0.001;\ \text{r.s.d.} = 0.0643)$$

Cow liveweight and body reserves

At the commencement of the experiment in April 1998 the mean CF.LW of the NOCALF and the lactating cows were 450 and 371 kg, respectively, while mean BCS were 7.1 and 5.1, respectively. In general the lactating cows (W2 and W3) in the MEDIUM and HIGH nutritional regimes lost, while respective non-lactating cows (W1 and NOCALF) gained, CF.LW and body reserves during the dry season (Fig. 3). In the LOW nutritional regime the non-lactating cows lost some CF.LW during the interval from April to August 1998. In all treatments there was a large decrease (mean 26 kg, s.d. 9 kg) in the cow CF.LW from 19 August to 8 September 1998 (i.e. from 11 days before to 9 days after the seasonal break), presumably due principally to decreases in digesta load and body water. Following the seasonal break, cows in the W1, W2 and W3 treatments progressively gained CF.LW and BCS from September 1998 to February 1999. The NOCALF cows were variable in their response. The changes in BCS of the cows were generally similar to the changes observed in CF.LW.

The changes in CF.LW and BCS during the dry season were markedly influenced by both the weaning treatments and the nutritional regime ($P < 0.05$ to $P < 0.001$), but there was no interaction ($P > 0.05$) between these main effect treatments. In the early dry season from April to July 1998 when the W2 cows were weaned the W1 non-lactating cows gained on average 24 kg CF.LW, but the lactating cows (W2 and W3) lost 8 kg CF.LW. From July to September 1998 the non-lactating cows (W1 and W2) lost on average 32 kg CF.LW, whereas the lactating cows (W3) lost 44 kg CF.LW. On average across the nutritional treatments, the loss of CF.LW from April to September 1998 ranged from 8 kg in the W1 cows to 54 kg in the W3 cows. Weaning improved CF.LW by 0.42 kg/day during the April–July interval (the difference between the W1 and W2 treatments) in the early dry season, and improved CF.LW by 0.18 kg/day during the July–September interval (the difference between the W2 and W3 treatments), which would usually comprise the mid dry season.

Dry season changes in CF.LW and BCS were also influenced by reproductive performance of the cows before the experiment commenced. From April to July 1998 the W1 cows gained more ($P < 0.05$) CF.LW than the NOCALF cows (24 and 6 kg, respectively; Fig. 3), although there did not appear to be any difference between these groups from July to September. However, because the NOCALF cows were 79 kg heavier in April 1998, they were still 60 kg heavier than the W1 cows in September.

The changes in CF.LW from April to September 1998 were influenced by the nutritional regime. From April to July 1998 the LOW cows lost, on average, 5 kg CF.LW, while the MEDIUM and HIGH cows gained 7 and 8 kg CF.LW, respectively. From July to September 1998 the LOW cows lost 53 kg CF.LW while the MEDIUM and HIGH cows lost 32 and 25 kg CF.LW, respectively. Thus, the accumulated losses through the dry season from April to September 1998 ranged from 17 kg CF.LW in the HIGH nutrition to 58 kg CF.LW for the LOW nutritional regime. The CF.LW of the HIGH nutritional regime cows was on average 9 kg greater in September that the MEDIUM cows, but the difference was not significant ($P > 0.10$). The greatest CF.LW loss from April to September 1998 occurred in the LOW W3 cows that lost 80 kg CF.LW, whereas at the opposite extreme the HIGH W1 cows gained 8 kg CF.LW. The change in CF.LW from April to September, when expressed in proportion to the cow CF.LW in April, ranged from a 2% gain to a 9% loss for the W1 cows, a 6–16% loss in the W2 cows, and a 10–22% loss in the W3 cows.

From September 1998 shortly after the seasonal break through to February 1999 cows gained on average 83 kg CF.LW, and from February until May 1999 cows gained on average 9 kg CF.LW. However, these changes in CF.LW were influenced by the nutritional regime, previous weaning treatments, and previous and current reproductive status. From September 1998 to February 1999 the W1, W2 and W3 treatment groups of cows gained from 50 to 129 kg CF.LW, while during the same interval the NOCALF treatment gained 22–32 kg CF.LW. Lactation during the 1998–99 wet season when cows were suckling cohort C calves reduced ($P < 0.001$) cow CF.LW by 55 kg in February 1999 and by 50 kg in May 1999. From February to April the lactating W1, W2 and W3 cows lost CF.LW (–5 to –23 kg), while the non-lactating W1, W2 and W3 cows gained CF.LW (29–43 kg). The lactating NOCALF cows lost 11–26 kg CF.LW during the same interval. The cows that lost more CF.LW during the dry season because they were weaned later (W2 and W3) gained more CF.LW ($P < 0.05$) from September 1998 through to February 1999 (i.e. they exhibited compensatory LW gain relative to the W1 cows). Lactating cows compensated to a lesser extent than non-lactating cows through the 1998–99 wet season. The W1, W2 and W3 treatment cows differed in CF.LW within lactation status groups in February ($P < 0.05$), but not in May 1999 ($P > 0.05$). Among the cows lactating in 1998–99 the previous W1, W2 and W3 treatment cows were on average 47 kg lighter ($P < 0.05$) in February 1998, and 40 kg lighter ($P < 0.10$) in May

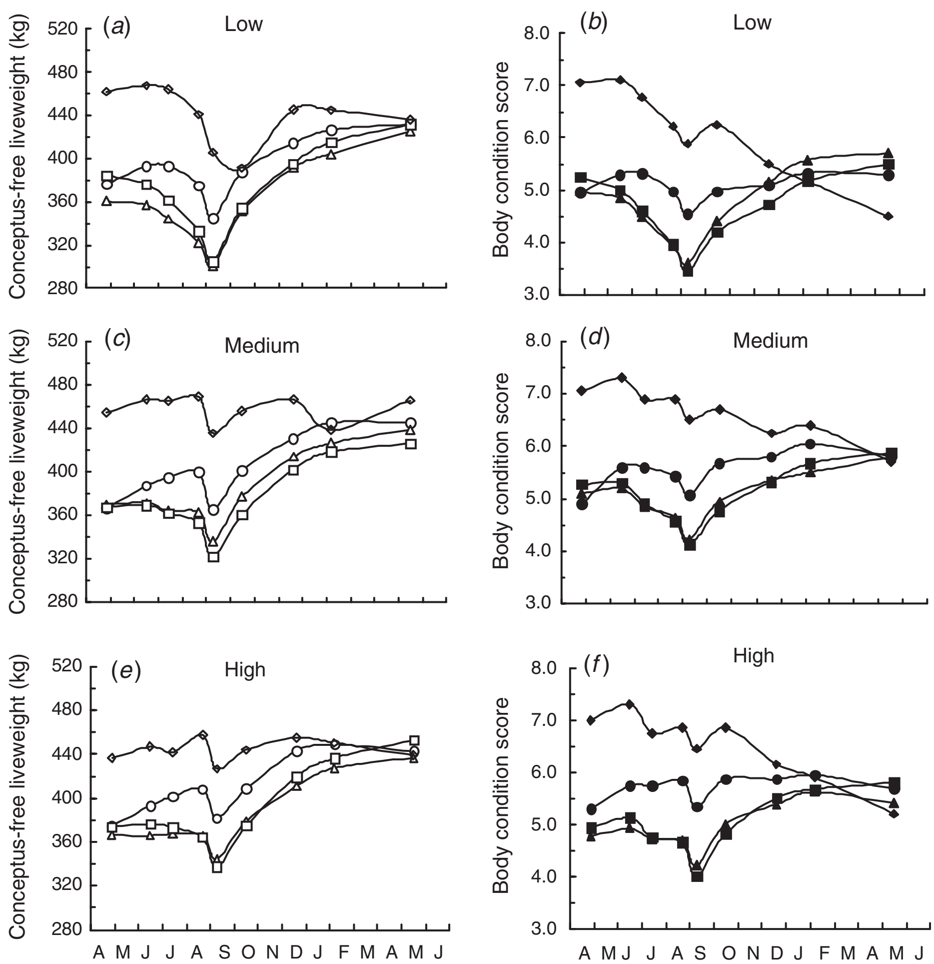

Fig. 3. The conceptus-free liveweight and body condition score of cows given (*a* and *b*) LOW, (*c* and *d*) MEDIUM, or (*e* and *f*) HIGH nutritional regimes from 28 April 1998 until 3 February 1999; cows then grazed as a single herd until 17 May 1999. Treatments within the nutritional regimes were weaned on 28 April 1998 (W1; ○, ●), weaned on 13 July 1998 (W2; △, ▲), weaned on 8 September 1998 (W3; □, ■), or not lactating at the commencement of the experiment (NOCALF; ◇, ◆). Values are means of cows lactating or non-lactating during the 1998–99 wet season; 76% of NOCALF cows, and 46–59% of W1, W2 and W3 cows were lactating through this interval. The seasonal break occurred on 30 August 1998.

1999 than the NOCALF treatment cows. CF.LW in February 1999 was 23 kg lower ($P < 0.05$) in the LOW treatment lactating cows than in the MEDIUM treatment lactating cows, but the difference was only 11 kg ($P < 0.10$) in non-lactating cows. This was in accord with lower diet quality and voluntary DM intake, as estimated by F.NIRS, in the LOW nutritional regime.

The changes in cow BCS tended to follow the same pattern as the changes in CF.LW and were also statistically significant (Fig. 3). BCS of W1 cows increased through May and June, and then decreased before the seasonal break. The NOCALF and lactating cows lost BCS from April to September. By September the LOW W2 and W3 cows had declined to BCS 3.5, but BCS was 4.0 or higher in all the weaning treatment groups when the MEDIUM and HIGH nutritional regimes were provided.

Metabolic measurements in the cow

Microbial CP synthesis was 21 and 29% higher ($P < 0.05$) in lactating cows than in non-lactating cows during August and September 1998, and did not differ ($P > 0.05$) among the nutritional regimes (Table 3). The efficiency of microbial CP synthesis in the non-lactating W1 cows grazing the LOW and MEDIUM nutritional regimes was on average 2.6 (range 2.1–3.6) g microbial CP/MJ ME intake.

PUN concentration during the dry season was higher in the MEDIUM than in the LOW nutritional regime, and was further increased ($P < 0.001$) by supplement in the HIGH nutritional regime (Table 4). In addition, in the LOW treatment the concentration of PUN was lower, or tended to be lower ($P < 0.10$ to $P < 0.01$), in W3 lactating cows than W1 weaned cows. Urinary urea excretion was higher ($P < 0.05$ or $P < 0.10$) in the MEDIUM than for the LOW nutritional regime, and was increased by the supplement in the HIGH nutritional regime ($P < 0.05$ or $P < 0.01$) (Table 3). Concentrations of PIP were similar in the LOW and MEDIUM treatments, but in August 1998 were lower ($P < 0.05$) in the cows given the HIGH treatment (Table 4). The concentration of PIP was consistently

Table 3. Microbial crude protein (CP) synthesis (g CP/day) and urea excretion (g N/day) in August and September 1998 of cows given three nutritional regimes (LOW, MEDIUM and HIGH) and weaned in April (W1) or September (W3)

The W1 cows were not lactating, and the W3 cows were lactating, when the measurements were taken. Since the HIGH nutritional regime cows consumed negligible molasses-urea supplement after 30 August 1998 the MEDIUM and HIGH nutritional regimes were nominally the same on 8 September 1998. Means each represent five paddock groups. W, weaning; N, nutritional regime. The W × N interactions were not significant ($P > 0.10$). n.s., not significant; (–), $P < 0.10$; *, $P < 0.05$; ***, $P < 0.001$

Measurement	Microbial CP			Urinary urea excretion		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
20 August 1998						
Sig.						
W1	95	101	116	1.3	7.6	26.6
W3	109	128	141	1.8	6.6	28.9
s.e.d.	12.9	13.5		0.26	2.77	
W	n.s.	*		(–)	n.s.	
N	–	n.s.		–	***	
8 September 1998						
Sig.						
W1	150	120	126	7.8	14.5	24.8
W3	183	158	171	9.7	13.7	24.5
s.e.d.	26.7	24.8		1.41	3.29	
W	n.s.	*		n.s.	n.s.	
N	–	n.s.		–	*	

lower ($P < 0.01$ or $P < 0.01$) in W3 lactating than W1 weaned cows within each nutritional regime.

Growth of cohort B calves

From April to July 1998 the LW gains for MEDIUM and HIGH nutrition calves were similar (0.69 and 0.72 kg/day, respectively, $P > 0.05$), while the LW gain for the LOW nutrition calves (0.63 kg/day) was lower ($P < 0.05$) than for the HIGH calves (Table 5). From July to September 1998 LW gain for the MEDIUM calves was lower ($P < 0.05$) than for the HIGH nutrition calves (0.08 and 0.22 kg/day, respectively), while the LOW nutrition calves lost LW at 0.03 kg/day. Overall, the HIGH nutrition calves were heavier than the LOW nutrition calves by 8 kg in July and by 23 kg in September, while the LW of the MEDIUM nutrition calves was similar to the HIGH calves in July and intermediate between the LOW and HIGH in September.

From April to July 1998 the LW gain of the cohort B calves in the LOW nutrition (Y, kg/day) was inversely related to the LW change of the cows (X, kg/day) as follows:

$$Y = 0.55 - 0.315X\,(n = 40,\ R^2 = 0.17,\ P < 0.01)$$

There was a similar relationship between calf LW gain and change in cow BCS ($R^2 = 0.19$, $P < 0.01$). However, there were no comparable relationships between cow body reserves and calf growth in the MEDIUM or HIGH nutritional regime. From July to September 1998 the LW gain of the calves in the HIGH nutritional regime (Y, kg/day) tended to be inversely related to the LW change of the cows (X, kg/day) as follows:

$$Y = -0.00793 - 0.425X\,(n = 19,\ R^2 = 0.14,\ P = 0.06)$$

Table 4. Concentration of plasma urea nitrogen and plasma inorganic phosphorus of cows given three nutritional regimes (LOW, MEDIUM and HIGH) and weaned in the early (W1) or late (W3) dry season

The W1 cows were not lactating, and the W3 cows were lactating, when the measurements were taken. Means each represent five paddock groups. W, weaning; N, nutritional regime. n.s., not significant; (–), $P < 0.10$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

Measurement	Plasma urea (mM)			Plasma inorganic phosphorus (mM)		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
15 June 1998						
Sig.						
W1	2.16	4.52	5.76	1.87	1.61	1.50
W3	1.74	4.10	5.68	1.63	1.38	1.28
s.e.d.	0.235	0.287		0.151	0.113	
W	(–)	n.s.		n.s.	**	
N	–	***		–	n.s.	
W × N	–	n.s.		–	n.s.	
13 July 1998						
Sig.						
W1	1.54	2.82	4.62	1.71	1.56	1.35
W3	1.26	2.84	4.72	1.34	1.31	1.07
s.e.d.	0.086	0.318		0.127	0.183	
W	**	n.s.		**	**	
N	–	***		–	n.s.	
W × N	–	n.s.		–	n.s.	
20 August 1998						
Sig.						
W1	1.80	3.08	6.06	1.86	1.73	1.40
W3	1.38	3.22	6.80	1.47	1.30	1.14
s.e.d.	0.201	0.297		0.107	0.103	
W	*	**		**	***	
N	–	***		–	*	
W × N	–	*		–	n.s.	

Table 5. Liveweight (LW, kg) of cohort B calves on 28 April 1998 and their LW change (kg/day) from the commencement of the experiment until weaning in the mid dry season (W2) after 76 days (n = 40 per treatment), and from the mid to the late dry season weaning (W2–W3) after an additional 57 days

Means each represent five paddock groups. n.s., not significant; *, $P < 0.05$. The mean cow body condition score (BCS) during the intervals is also given (n = 18–20 per treatment)

Measurement	Nutritional regime		
	LOW	MEDIUM	HIGH
Initial calf LW at W1 (n = 40)	144	141	144
LW at W2 weaning (n = 40)	191	193	199
LW change from W1 to W2	0.63	0.69	0.72
s.e.d.	–	0.035	
Significance	–	n.s.	
Mean cow BCS (April–July)	5.0	5.2	4.9
LW at W3 weaning (n = 20)	189	197	212
LW change from W2 to W3	–0.03	0.08	0.22
s.e.d.	–	0.062	
Significance	–	*	
Mean cow BCS (July–September)	4.0	4.5	4.5

However, there were no comparable relationships for the cows and calves in the LOW or MEDIUM nutritional regimes.

Carryover effects of the treatments on cow body reserves, growth of cohort C calves, and reconception of cows during the 1998–99 wet season

LW gain of cohort C calves (Y, kg) from February to May 1999 was related to the LW of the cow in February 1999 (X, kg) as follows:

$$Y = 38.3 + 0.085X\,(n = 109,\ \text{r.s.d.} = 9.63,\ R^2 = 0.12,\ P < 0.001)$$

Thus each additional 25 kg of cow LW in February increased calf LW by only 2 kg in May at weaning.

The pregnancy rate of non-lactating cows mated from February to May 1999 averaged 95%, and was not related to the LW or BCS of the cows. The overall pregnancy rate of lactating cows was 68%, and was curvilinearly related to cow BCS and LW at the start of mating. The reconception rates of lactating cows of BCS <4, 4.0–4.5 and ≥5 on 3 February 1999 were 50, 76 and 88%, respectively.

Discussion

Reliability and limitations of the F.NIRS predictions of diet attributes and intake

The application of F.NIRS to estimate quality and the intake of the diet selected by cattle grazing pastures comparable with the present study has been discussed by Coates (2004), Dixon and Coates (2010) and Dixon *et al*. (2011). The F.NIRS calibrations for diet quality attributes which were applied were likely particularly appropriate since the majority of the data used to develop the calibrations were obtained in the same region, including some at the same site. Furthermore, the Mahalanobis distance values (i.e. global H values in the ISI software used for the chemometrics) calculated during predictions were (mean ± s.d.) 0.8 (±0.28) for CP, and 1.2 (±0.47) for DMD and DM intake, and thus were much lower than the maximum desirable value of 3.0 suggested by Shenk and Westerhaus (1993). However, a limitation was that the F.NIRS predictions of DM intake cannot accommodate changes in voluntary forage intake such as those due to compensatory LW gain or lactation (Dixon and Coates 2009). Thus voluntary intake could not be estimated in the lactating cows in the present study. Furthermore since cows in all of the treatments were likely in compensatory LW gain following the seasonal break, the voluntary intakes of DM and ME during this interval were likely underestimated by F.NIRS. This is supported by results from a previous experiment at the same site where F.NIRS apparently underestimated voluntary intake of lactating breeders during the early to mid wet season (Dixon *et al*. 2007).

The Coates (2004) calibrations were developed for cattle ingesting forage diets, and where supplements also contributed a small proportion of the diet the predicted diet composition attributes are for the forage component of the diet. Intake of more than ~2.4 g DM/kg LW.day of molasses with a forage diet may introduce error into F.NIRS predictions of diet CP concentration (Dixon and Coates 2005). Since the intakes of molasses supplement shortly before the occasions when faecal samples were obtained for F.NIRS were <1.5 g DM/kg LW.day, the estimates of the nutritional quality of the forage component of the HIGH diet should not have been affected. However, the N in the molasses-urea supplement ingested during the dry season in the HIGH nutritional regime would have resulted in a diet higher in CP than that estimated by F.NIRS. Calculations from the likely intakes and composition of the forage and supplement suggested that the actual CP concentration of the HIGH diet during the dry season would have been ~3.2% units greater than that predicted by F.NIRS.

Seasonal conditions and nutritional status of the cows and calves through the experiment

The higher non-grass in the diet selected by cattle in the MEDIUM treatment than those in the LOW treatment was presumably due principally to selection of the stylos present in the former pasture. Nevertheless this non-grass was only a minority component of the diet selected by the MEDIUM and HIGH nutrition cows, averaging 16% from June 1998 to February 1999. That the highest proportion of stylo (22%) occurred in June 1998 was consistent with reports that stylos are likely to make their maximum contribution to the diet of cattle grazing tropical grass-stylo pastures in the late wet season and early dry season (Gardener 1980; McLean *et al*. 1981; Coates 1996). The contribution of stylo to the diet was low compared with many previous studies, but likely reflected the proportion of the stylo in the pasture. Nevertheless the stylo that was ingested likely made a substantial contribution to the higher dietary CP and DMD, and higher intakes of DM and ME, in the MEDIUM and HIGH nutritional regimes.

The rainfall distribution and dry season conditions through the experiment were unusual for the region in that the seasonal break on 30 August 1998 was ~3.5 months earlier than the long-term average. Also there was sufficient rain following the seasonal break to allow active wet season pasture growth for 7 months instead of 3–4 months as usually occurs in this region. In most years at the site breeder cows would be losing LW through a dry season characterised by progressively deteriorating nutrition until a seasonal break in December, and to have a relatively short interval to recover body reserves before the next dry season. Interpretation of the results of the present study in relation to management of breeder cows in the seasonally dry tropics requires cognizance of these unusual seasonal conditions.

The F.NIRS estimates that on average during the dry season the diet contained 4.2% CP and 5.4 g CP/MJ ME, and faecal N concentration was 0.9% N, indicated that the cows in the LOW nutritional regime were deficient in rumen degradable protein during this interval (Winks *et al*. 1979; Minson 1990; Dixon and Doyle 1996; Dixon and Coates 2005). The diet CP concentration and DMD of the MEDIUM nutrition cows were substantially higher through both the dry and wet seasons than for the LOW nutrition cows, and was to be expected for pastures augmented with stylo. The similarity of the F.NIRS predictions of diet quality for the MEDIUM and HIGH nutrition indicated that selection of pasture was not modified by the provision of the supplement. Also, since F.NIRS predictions of diet quality are not affected by lactation (Dixon *et al*. 2007), the similarity of the predicted diet quality of the W1 and W3 cows indicated that lactational status had little if any effect on the diet selected.

Consideration of the cow LW differences between the MEDIUM and HIGH treatment cows and the amount of molasses ingested in the latter treatment suggested that the small increase in cow CF.LW could be attributed entirely to the ME provided by the supplement. Over the entire supplementation interval the supplement provided ~960 MJ ME per cow, while the additional LW of the supplemented cows corresponded to ~220 MJ net energy (CSIRO 2007). The additional calf LW of 15 kg in the HIGH nutritional regime would have required an additional 93 kg milk (Drewry *et al*. 1959; Lampkin and Lampkin 1960) and 340 MJ net energy (CSIRO 2007). Thus the benefits of the supplement on the cow and calf LW could be explained as due to use of the molasses ME with an efficiency of 0.58 to conserve cow body reserves and synthesise milk. This hypothesis is consistent with the observation that microbial CP synthesis in the HIGH treatment was increased by 8% in August and that supplement ME was equivalent to ~12% of the ME intake from pasture in the same nutritional regime estimated by F.NIRS. These observations support the hypothesis that the excess urea in the supplement did not increase intake of this grass-stylo pasture.

The F.NIRS estimates of the intakes by the W1 cows indicated that both DM and ME intakes declined as the dry season progressed, but increased markedly from September 1998 with the seasonal break and the availability of wet season pasture. Such changes in DM intake through the seasonal cycle would be expected from the changes in pasture quality. In addition, lactation would be expected to increase intake of low to medium quality forages by 20–30% (Penzhorn and Meintjes 1972; Hunter and Siebert 1986), but as discussed above would not be observed in F.NIRS predictions of pasture intake (Dixon and Coates 2009; Dixon *et al*. 2011). The observation that microbial CP synthesis was on average 25% greater in the lactating than in the non-lactating cows (Table 5), and the expectation from both principles of rumen fermentation and experiments that microbial CP synthesis is proportional to ME intake (Cetinkaya *et al*. 2006; CSIRO 2007), suggested that pasture intake was increased in this proportion by lactation.

Treatment effects on cow body reserves and calf growth

In the present study each increase in level of nutrition and each change to earlier weaning was associated with improvement in the body reserves of the cow through the dry season. These observations are consistent with previous experiments reporting a reduced rate of loss of breeder cow LW and body condition with improved nutrition and earlier weaning (Burns 1964; Moore and da Rocha 1983; Holroyd *et al*. 1988; Schlink *et al*. 1994).

An important observation of the present study was the absence of any discernable interaction effects between time of weaning and the nutritional regime on the rates of loss of body reserves of the cow. Thus management decisions to achieve specific targets for cow body condition or LW at future dates such as the expected time of calving or the seasonal break (Herd and Sprott 1986; Dixon 1998) should be able to apply, in a simple additive manner, estimates of the existing body reserves of the cow, rate of LW change from current and expected nutrition, and an allowance for the ME costs of lactation. For management convenience these may be expressed as LW equivalents of the cow, such as from the present study expecting LW loss of 0.42 kg/day of continuing lactation during the early to mid dry season and 0.18 kg/day in the mid to late dry season. The estimates in the present study and that of Dixon *et al*. (2011) are comparable with previous estimates of lactation reducing cow LW in the early to mid dry season by 0.26–0.60 kg/day (Fordyce *et al*. 1988; Holroyd *et al*. 1988; Dixon *et al*. 2007), and reducing cow LW in the mid to late dry season by 0.13–0.17 kg/day (Burns 1964; Sullivan *et al*. 1992). The nutrient balance of the cow and cow LW loss will be expected to depend on lactational output. In comparable environments and with cattle of similar genotype in mid to late lactation grazing dry season pasture, milk production has been reported to be in the range 2–4 kg/day (Lampkin and Lampkin 1960; Allan *et al*. 1972; Dixon 1998). Presumably the expected cow LW loss will have to be adjusted for specific circumstances with consideration of the lactational potential of the genotype, stage of lactation, cow body condition and current nutrient intake.

Although in the present study the nutritional and weaning treatments clearly improved body reserves of the cows as the season progressed, the changes in cow LW may not have accurately reflected the changes in body energy reserves. First, in grazing cattle in the seasonally dry tropics digesta load as a proportion of animal LW can change substantially through the annual cycle. Calculations from studies in northern Australia (McLean *et al*. 1983) and Sahelian Africa (Lechner-Doll *et al*. 1990; Schlecht *et al*. 2003) indicate that in the present study digesta load may have increased by up to 20 kg through the dry season. Therefore, in the present study the rates of body energy loss during the April–August interval were likely higher than indicated by the decreases in CF.LW. It is also clear that there is an abrupt decrease in digesta load at the seasonal break when the diet changes from poor quality senesced forage to high quality new growth forage of sparse availability (Norman 1967; McLean *et al*. 1983; Lechner-Doll *et al*. 1990; Schlecht *et al*. 2003). In the present study the average 26-kg decrease in LW from the August to September 1998 measurements was likely due principally to such a decrease in digesta load, and this change would have been equivalent to a gradual loss in body tissues of ~0.2 kg/day in April until August 1998 in the present study. In addition, because the contents of fat and net energy in body tissues decrease as an animal loses LW the losses in body energy reserves will be greater than indicated by the changes in CF.LW. It was clear that in the present study both the weaning and nutritional treatments had large effects on the body reserves of the cows, but because of the errors discussed above it is difficult to express the changes in units of ME or net energy.

Several physiological mechanisms may have contributed to the lower CF.LW gain, or greater CF.LW loss, in the NOCALF cows than in the W1 April-weaned cows in the early to mid dry season between April and July. First, the BCS and the CF.LW indicated that the body fat contents of the NOCALF and the W1 cows would have been ~26 and 19%, respectively, a difference sufficient to substantially modify voluntary intake of forage diets per unit of LW (Bines *et al*. 1969; Djajanegara and Doyle 1989).

Second, because the NOCALF cows were heavier they would have had higher maintenance energy requirements. Third, the increased voluntary intake associated with lactation is often maintained for some weeks after weaning (Foot and Russel 1979). Only 75% of the higher body reserves of the NOCALF cow at the commencement of the dry season were retained through to the seasonal break in late August. This is in agreement with previous observations that breeder cow LW loss during the dry season may be inversely related to LW at the start of the dry season (Fordyce *et al*. 1988; Dixon *et al*. 2011).

In the early to mid dry season from April to July when treatment means of cow BCS ranged from 4.9–5.2 among the three nutritional regimes, there was only a small effect of the nutritional regimes on calf growth (Table 5). Since calf growth is closely related to milk output (Lampkin and Lampkin 1960; Arthur *et al*. 1997) it appears that cows in the LOW nutritional regime were able to mobilise sufficient additional body reserves to maintain lactation at levels comparable with the MEDIUM and HIGH nutrition cows. This hypothesis is supported by the relationship between cow LW loss and calf growth during this interval. However, in the mid to late dry season (July–September) there were differences in calf growth between the nutritional regimes of up to 0.25 kg/day in calf growth. At this time the BCS of the cows in the LOW nutritional regime averaged only 4.0, less than that of the MEDIUM and HIGH regimes (BCS 4.5). It therefore appears that in cows in BCS 4.0 in late lactation the milk production was reduced by the sub-maintenance nutrient intake of the LOW nutritional regime. These observations are in accord with other studies where even small increases in nutrient intake from urea-based supplements (Allan *et al*. 1972; Holroyd *et al*. 1979; Dixon 1998) or small amounts of protein meals (Little *et al*. 1994; Osuji *et al*. 1995) have substantially increased milk output of comparable *Bos indicus* cow genotypes during the dry season. Calf growth will often be a consideration in the management decision on when to wean, since when calf growth is low there will be lesser advantage for the calf to delay weaning.

Conclusions

The present study demonstrated that the benefits of weaning and of improved nutrition to conserve body reserves of *Bos indicus* cross breeder cows through the dry season were additive over the range of nutritional intakes and weaning times commonly used in the extensive grazing industry. Thus nutritional management of the breeder cow to achieve specified target cow body reserves through the dry season can consider the benefits of weaning and of improved nutrition as separate factors. The study also demonstrated the use of F.NIRS to provide estimates of diet quality, and in non-lactating cows of DM and ME intake, which can be used to improve application of quantitative nutrition to the management of the grazing breeder cow in the seasonally dry tropics.

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