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Nutrition of beef breeder cows in the dry tropics. 1. Effects of nitrogen supplementation and weaning on breeder performance

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Abstract. The effects of two dry season management strategies consisting of timing of weaning and/or nitrogen (N) supplementation on the body reserves, nutritional status and reproductive performance were, commencing in the early dry season, examined in *Bos indicus* × *Bos taurus* breeder cows ($n = 122$) grazing native pasture in the seasonally dry tropics. Cows were early-weaned in April in the early dry season or late-weaned in September in the late dry season. The supplement consisted of loose mineral mix which provided on average 14 g N/day, principally as non-protein N. In the early dry season in April 1997 all of the cows had been lactating for 3–5 months, averaged 363 kg (s.d. = 28) conceptus-free liveweight (CF.LW) and 4.7 (s.d. = 0.6) body condition score (9-point scale), and 53% were pregnant. In addition, from April to June 1997 10/26 non-pregnant lactating cows, and 24/31 non-pregnant non-lactating (i.e. early-weaned) cows became pregnant so that 81% of cows were pregnant by June. Predictions of diet from near-infrared spectroscopy of faeces indicated that the forage diet selected during the dry season (April–November) by the cows contained on average 9% (s.d. = 2) non-grass dicotyledonous plants and 4.4% (s.d. = 0.38) crude protein (CP), while DM digestibility was 51.1% (s.d. = 1.3). The diet CP concentration, the ratio of CP to metabolisable energy (ME) in the diet (mean 5.7, s.d. = 0.53, g CP/MJ ME) and faecal N concentration (mean 1.05, s.d. = 0.097, % N) all indicated that unsupplemented cows were deficient in dietary N during the dry season. Microbial CP synthesis in unsupplemented non-lactating cows decreased from 360 to 107 g microbial CP/day, or from 6.5 to 2.4 g microbial CP/MJ ME intake, as the dry season progressed from May to September 1997. Net endogenous N transfer to the rumen of up to 2 g CP/MJ ME apparently occurred from May to August. Microbial CP synthesis was 25% higher ($P < 0.001$) in lactating than in non-lactating cows. From April to September cow CF.LW was improved by 0.35 kg/day ($P < 0.001$) by early weaning, and by 0.11 kg/day ($P < 0.10$) by N supplementation, but there was no interaction ($P > 0.10$) between these treatments. From April to June 1997 calf LW gain averaged 0.79 kg/day, but from June to September was only 0.10 kg/day in unsupplemented paddocks and 0.13 kg/day in N-supplemented paddocks. Pregnant cows calved from November 1997 to March 1998. During subsequent mating 96% of non-lactating cows, but only 17% of lactating cows became pregnant. During the 1997–98 wet season there was compensatory LW gain of lower CF.LW non-lactating cows but not of lactating cows. In conclusion, weaning early in the dry season had a much greater effect than a non-protein N-based supplement to conserve breeder cow body reserves, and the effects of the two management strategies were additive.

Additional keywords: cow liveweight, cow body condition score, non-protein N supplement, faecal near infrared spectroscopy, microbial crude protein.

Introduction

In the seasonally dry tropics undernutrition constitutes a major constraint to cattle productivity since the nutritional quality of pastures is generally high for only a brief interval during the rainy season, and during the dry season the intake of nutrients from pasture may be insufficient even for maintenance (Winks 1984). Cattle typically gain liveweight (LW) slowly or lose LW during the dry season, and gain substantial LW only during the wet and wet–dry transitional seasons. In breeder cows in late pregnancy or lactation the dry season losses in body reserves are exacerbated by the high nutritional demands for these physiological functions. Breeder herd production systems in such environments usually alleviate the consequences of dry season undernutrition by calving in the late dry or early wet season so that higher-quality wet season pasture is available to the lactating cow and the growing calf, and calves can be readily weaned at the commencement of the following dry season. However, for a variety of reasons such as limitations in control of cattle on

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commercial cattle properties in the extensive rangelands, a proportion of breeder cows are often lactating during the dry season (Winks 1984).

It is clear that cow body reserves and nutrition, particularly near parturition, have important effects on milk output, weaning weight, reconception, and mortality from dry season undernutrition in the seasonally dry tropics (Lamond 1970; Topps 1977; Entwistle and McCool 1991). Thus in such an environment 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. Terminating milk synthesis by 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). In addition, because dry season pastures in the seasonally dry tropics are usually deficient in nitrogen (N), supplements containing protein meal or non-protein N often alleviate dry season LW losses (Winks 1984; Dixon and Doyle 1996). In low-input grazing systems typical of extensive rangelands, earlier weaning and N supplementation often comprise the only economically viable management strategies to reduce breeder LW loss through the dry season.

Nutritional management of the breeder herd clearly requires quantitative estimation of the nutrient intake of the cow, and an understanding of the consequences of management manipulations on 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 management 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 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 improved information for their nutritional management, including in the context of management for weaning, manipulation of body reserves and reproductive performance.

The following experiment was undertaken to improve understanding of the consequences of weaning and non-protein N supplements fed during the dry season on the diet selected, intake of nutrients, body reserves and performance of breeder cows and their calves through an annual cycle in a seasonally dry tropical environment. Concurrent estimates of diet quality and nutrient intake from F.NIRS, of metabolites, and of microbial CP synthesis were made to allow nutrient supply to be estimated in relation to the ME demands and thus enhance understanding of nutrient supply in relation to the performance of grazing breeder cows.

Materials and methods

Pastures and cattle

The experiment was conducted at the Swan's Lagoon Research Station (20°4′S, 147°15′E) situated 100 km south-southeast of Townsville in the seasonally dry tropics of northern Australia. At this site the soils are generally low-fertility duplex soils. Rainfall is summer-dominant with ~80% of the annual average of 871 mm occurring from October to March. The pastures grazed in the experiment comprised tropical grasses native or naturalised to the open eucalypt woodlands of the speargrass region of coastal north-eastern Australia. Major grass species were black speargrass (*Heteropogon contortus*) with other tropical tall grasses and medium grasses including particularly *Chrysopogon fallax* and *Bothriochloa pertusa*. These soils and pastures, and the consequences for cattle production, have been described by Winks (1984).

The cows (n = 122) used were ~5/8 *Bos indicus* × 3/8 *Bos taurus* (>F_2) crossbreds initially 4.0–4.5 years old from the research station herd. All of these cows had calved for the second time during the early to mid wet season preceding the experiment. These calves, designated as cohort A, were on average 142 kg (s.d. = 17) when the experiment commenced.

Experimental procedures

On 9 April 1997 the cows were mustered, weighed, body condition score (BCS) estimated and pregnancy status and fetal age measured by rectal palpation. The mean LW and BCS (1–9 scale, 1 = emaciated, 9 = overfat; NRC 1996) of the cows were 363 kg (s.d. = 28) and 4.7 (s.d. = 0.57), respectively. The cows (n = 12 per paddock except for two paddocks with n = 13) were allocated to 10 paddock groups by stratified randomisation, the strata being: (i) pregnancy status and fetal age among cows >6 weeks pregnant; (ii) elevated plasma progesterone concentrations measured 2–3 weeks previously indicating ovarian activity or pregnancy; and (iii) BCS of the cow. These, and subsequent pregnancy diagnoses, indicated that 65/122 (53%) of the cows were pregnant in April 1997. The cows had been mated as a herd for 10 weeks before the experiment commenced, and mating was continued with two bulls per paddock until 6 June 1997. The cows grazed in the 10 trial paddocks until 21 January 1998, when they were moved and grazed as a single herd in a 600-ha native pasture paddock until 27 April 1998. The cows were mated with six bulls from 27 January 1998. The 10 trial paddocks (30 or 40 ha) were considered, on the basis of soil and vegetation as five paddock blocks each of two paddocks and were located in two adjacent long-term trial site areas, six in site 1 and four in site 2. The sites had comparable soil, woody vegetation and pasture, but grazing and fire regimes had differed and there was much more native browse (*Acacia*, *Melaleuca* and *Eucalypt* spp.) present in the site 2 paddocks.

Two treatments were imposed in a 2 × 2 factorial design. One paddock in each paddock block was allocated at random to be offered N supplement during the dry season, while no supplement was fed in the other paddock. In addition, half of

the cows in each paddock were randomly allocated to one of two weaning treatments; these were to be early-weaned at 3–5 months of age in the early dry season at the commencement of the experiment (9 April 1997) or late-weaned at 8–10 months of age in the late dry season (15 September 1997). The cohort A calves that were not weaned were allocated with their dams to their designated paddocks. The timing of these and other experimental procedures are summarised in Table 1. Due to the prevailing seasonal conditions and their BCS status, seven cows that had lactated through the dry season (six not supplemented and one supplemented) were removed from the experiment on 20 November 1997.

The N supplement consisted of loose mineral mix offered *ad libitum* from 15 April 1997 until 26 November 1997 (i.e. for 7 months). Until 11 August 1997 the supplement consisted of (g/kg) 330 cottonseed meal, 300 salt, 210 calcium phosphate, 150 urea and 10 elemental sulfur, and thereafter of 350 cottonseed meal, 300 urea, 100 salt, 150 calcium phosphate and 100 ammonium sulfate. The two supplements contained 91 and 183 g N/kg DM, respectively, and 76 and 87%, respectively, of the N was in the non-protein N form. In addition, because of the prevailing pasture conditions and BCS of the cows, a molasses-urea supplement (72 g urea/kg) was offered *ad libitum* to all paddock groups from 26 November 1997 until the seasonal break on 15 December 1997.

The cows calved from 1 November 1997 through to 22 March 1998, and these were designated as cohort B calves. Frequent inspections identified calving dates and dams of individual calves through until 21 January 1998 when the cows were moved to the large paddock. Since these inspections were not possible in the latter situation the calving date of the 27 cows that calved subsequently was estimated from the LW of the calf at the next muster and by assuming that the calf birthweight was 25 kg and that the calves gained LW at 0.8 kg/day; this was the mean growth rate of the calves for which calving dates were available. Seven cows diagnosed pregnant aborted or lost their calves neonatally. All the cattle were vaccinated against botulism, all of the females against leptospirosis, and all the cohort A calves against clostridial diseases and tick fever (*Babesia* spp. and *Anaplasma centrale*).

Measurements

The cows and calves were mustered each 4–6 weeks and on each occasion were weighed and BCS of cows was estimated. As well as the initial diagnosis, pregnancy status was determined during May, June and August 1997 to identify later conceptions. To determine pregnancies from the January to April 1998 mating, pregnancy status was determined on 27 April 1998 and 17 June 1998.

Two cows from each weaning treatment in each paddock were selected at random at the commencement of the experiment for blood sampling. Blood and urine samples were obtained at each muster from May to October 1997. The former were obtained by jugular puncture using vacutainers containing lithium heparin as an anticoagulant, and were immediately placed in iced water. Plasma was separated by centrifugation ($3000g \times 10$ min), and stored frozen pending analysis. Manual stimulation of the vulva was used to initiate urination, and urine was successfully sampled on 64% of occasions. Urine samples were immediately acidified (pH <3 using 10 M HCl) and chilled in iced water. The urine samples derived from each weaning treatment within each paddock were pooled and then stored frozen pending analysis. Faecal samples were obtained per rectum from all cows in May and June 1997 and from designated sampler cows until thereafter. Samples were successfully obtained on 82% of occasions and were dried (70°C) immediately. The faecal samples obtained from May and June were scanned individually to obtain NIR spectra, whereas the samples obtained at subsequent musters were pooled within each weaning treatment and within paddocks in August and September 1997, and thereafter within paddocks. Faecal samples from paddocks not fed N supplement at each sampling date were pooled within weaning treatment and within paddock for subsequent analysis of total N and total phosphorus (P).

Table 1. Brief description of the treatments, activities and measurements during the experiment
B, blood; BCS, body condition score; F, faeces; LW, liveweight; U, urine

Month (1997 or 1998)	Cattle, treatments and measurements
April	Experiment commenced with cows and calves in 10 small trial paddocks. Cows had been mated for 10 weeks. 'Early-wean' treatment cows weaned. Measurement of LW and BCS
May	Measurement of LW and BCS. Sampling of B, U and F
June	Measurement of LW and BCS. Sampling of B, U and F. Mating terminated
July	–
August	Measurement of LW and BCS. Sampling of B, U and F
September	'Late-wean' treatment cows weaned. Measurement of LW and BCS. Sampling of B, U and F
October	Measurement of LW and BCS. Sampling of B, U and F
November	Measurement of LW and BCS. Sampling of F. Loose mineral mix supplement terminated. Molasses supplement fed to all cattle for 3 weeks from late November. Cows commenced calving with cohort B calves
December	Measurement of LW and BCS. Seasonal break. Sampling of F
January	All cows and calves moved from small trial paddocks to a single large paddock. Measurement of LW and BCS. Sampling of F. Mating commenced
February	–
March	Measurement of LW and BCS
April	Measurement of LW and BCS. End of experiment. Sampling of F. Mating terminated

Laboratory analyses

Plasma urea N (PUN) and plasma inorganic P (PIP) were analysed following Tiffany *et al*. (1972) and Wang *et al*. (1983). Purine derivatives (allantoin and uric acid) and creatinine in urine were measured by high-performance liquid chromatography (Resines *et al*. 1992). Urinary excretion was calculated from the creatinine concentration, assuming a daily creatinine excretion of 0.558 mmol/kg $W^{0.75}$; this value had been determined in similar cattle fed similar forages and with analysis in the same laboratory (P. W. Kennedy, unpubl. data). Microbial CP synthesis was calculated from the excretion of purine derivatives (Chen and Gomes 1992), assuming an endogenous purine derivative excretion of 0.190 mmol/kg $W^{0.75}$.day (Bowen *et al*. 2006). Total N content of faeces was determined following Sweeney (1989), and total P content colorimetrically (AOAC 1975).

Dried faecal samples were ground (1-mm screen, Model 1093 Cyclotec mill, Foss Tecator AB, Hoganas, Sweden). For NIRS analysis samples were redried (65°C), cooled in a dessicator, and scanned (400–2500-nm range) using a monochromator fitted with a spinning cup module (Foss 6500, NIRSystems, Inc., Silver Spring, MD, USA). Chemometric analysis used ISI software (Infrasoft International, Port Matilda, PA, USA). The Coates (2004) and Coates and Dixon (2008*a*) F.NIRS calibration equations were used to predict the CP concentration and DM digestibility (DMD) of the diet, DM intake, and the $\delta^{13}C$ content and total N content of the faeces. Diet non-grass was calculated from the $\delta^{13}C$ of faeces.

Calculations and statistical analyses

The intake of N supplement per cow was calculated from the supplement DM offered and refused, and the assumption (Eggington *et al*. 1990; Dixon 1998) that calves consumed negligible supplement. Conceptus-free LW (CF.LW) of the cows was calculated from the cow LW less the weight of the conceptus; conceptus weight was calculated as described by O'Rourke *et al*. (1991) where the age of the conceptus was estimated from the calving date. ME intake was calculated from the F.NIRS estimates of voluntary DM intake and the DMD, with the assumption that digestible DM contained 15.5 MJ ME/kg DM (CSIRO 2007). Since the Coates (2004) calibrations for voluntary intake cannot be applied to cattle where N supplements are fed to correct a deficiency, or to lactating cows (Dixon *et al*. 2007), estimates of intakes of DM and ME were made only in unsupplemented non-lactating treatment cows.

Statistical analysis was completed using GENSTAT release 11.1 (VSN International Ltd., Hemel Hempstead, UK). Because cow LW pathways through the annual cycle were complex due to interactions with the reproductive status of individual cows, treatment effects for LW and BCS were evaluated for individual measurement dates using residual maximum likelihood with an error structure that had cows within weaning treatment, within paddocks and within paddock block, respectively. The effects of time and treatments on the concentrations of metabolites during the 1997 dry season were evaluated using residual maximum likelihood in a repeated-measures analysis with an unstructured covariance. Linear regression was used to investigate relationships between F.NIRS predictions of diet attributes, and between these diet attributes and time. A proportional hazards model (Cox 1972) was used to analyse reconception of cows during both the 1997 and the 1998 mating intervals, although for the latter the effects of lactation were also included in the model.

Results

Seasonal conditions, cow conceptions during the 1997 and 1998 wet season, and supplement intakes

Rainfall during the 1996–97 wet season preceding the experiment was comparable with the long-term average for the site (Table 2) and pasture quality and availability at the commencement of the experiment were within the expected range for the region. Rainfall in May and June 1997 in the early dry season (106 mm) was almost twice the long-term average for these months and was sufficient to cause active pasture growth. However, there was no further effective rain during the dry season until the seasonal break on 15 December 1997.

The pregnancy diagnoses indicated that 65/122 (53%) of the cows were pregnant on 9 April 1997 at the commencement of the experiment (Table 3). In addition, from April to June 1997 10/61 (16%) lactating (i.e. late-weaned) cows and 24/61 (39%) non-lactating (early-weaned) cows became pregnant, and was higher ($P < 0.05$) in the latter group. Thus, in total, 81% of the cows were pregnant following the 1997 mating, and 25, 43, 9, 17 and 6% subsequently calved (cohort B calves) in the months November 1997 through to March 1998, respectively. During the 1998 mating, a lower proportion ($P < 0.001$) of lactating cows

Table 2. Monthly rainfall (mm) at the trial site preceding (July 1996–March 1997) and during the experiment (April 1997–April 1998), and the 34-year average

Month	1996–97	1997–98	34-year average
July	114	113	15
August	0	18	19
September	29	0	9
October	22	21	30
November	51	0	67
December	22	270	123
January	43	151	195
February	259	93	187
March	221	21	114
April	0	47	44
May	69	103	40
June	37	8	18
Total	767	745	871
Seasonal break	24 November 1996[A]	15 December 1997[B]	17 December[C]

[A]Forty-six mm on 24 November 1996, followed by scattered falls of ≤23 mm providing an additional 65 mm up to 2 February 1997, and then 51 mm on 3 February 1997.

[B]Preceded by 21 mm on 1 October 1997; there was 53 mm from 15 to 16 December 1997.

[C]Estimated as the median date for ≥50 mm in 3 days.

Table 3. Percentages and numbers of cows that were pregnant in April and June in each treatment during the 1997 dry season, or that later became pregnant during the 1998 wet season as a consequence of mating from 27 January to 27 April 1998

L, lactation; S, supplement; n.s., not significant; *, $P < 0.05$

Cow group	Treatments during the 1997 dry season							
	Not lactating		Lactating			Probability		
	No supplement	Plus supplement	No supplement	Plus supplement	Total	L	S	L × S
1997 dry season (9 April 1997–6 June 1997)								
Pregnant on 9 April 1997	48 (15/31)	50 (15/30)	48 (15/31)	67 (20/30)	53 (65/122)	n.s.	n.s.	n.s.
Pregnant on 6 June 1997	87 (27/31)	90 (27/30)	71 (22/31)	77 (23/30)	81 (99/122)	*	n.s.	n.s.
1997–98 wet season (27 January 1998–27 April 1998)[A]								
Reconceiving while lactating	25 (6/24)	23 (6/26)	0 (0/20)	18 (4/22)	17 (16/92)	n.s.	n.s.	*
Reconceiving while not lactating	100 (7/7)	75 (3/4)	100 (10/10)	100 (7/7)	96 (27/28)			

[A]During the 1997–98 wet season there was a main effect of lactation ($P < 0.001$). The cows calved from November 1997 through to March 1998, the distribution of calving being 25, 43, 9, 17 and 6% in the respective months. Because the data were analysed using a proportional hazards model no s.e.d. values are presented.

(17%) than non-lactating (96%) cows became pregnant. Furthermore pregnancy rate of the lactating cows during this mating was influenced by the interaction between the previously imposed treatments of lactation and supplementation during the 1997 dry season; cows that had lactated during the 1997 dry season and were not fed supplements had lower ($P < 0.05$) pregnancies (0%) than cows given the other three treatments (18–25%).

Average intake of the N supplement (Fig. 1) through the dry season ranged among paddocks from 73–137 g DM/cow.day, and averaged 103 g DM/cow.day. The coefficient of variation between weeks within paddocks averaged 34%. Average voluntary intake of supplementary N from April to November 1997 ranged among paddocks from 9 to 19 g N/cow.day, averaged 14 g N/cow.day across paddocks, and increased as the dry season progressed ($P < 0.01$). Intake of supplementary P averaged 4.6 g P/day. During the 3 weeks preceding the seasonal break on 15 December 1997 intake of molasses-urea supplement averaged 1.5 kg as-fed/cow.day, and provided ~12 MJ ME/day as well as non-protein N.

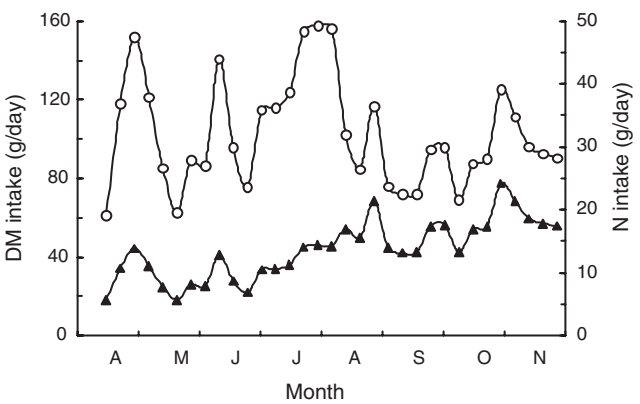

Fig. 1. Average voluntary intake of the loose mineral mix supplement DM (○) and N (▲) by the five paddock groups of cows from 15 April to 26 November 1997. The supplement mixture was changed on 11 August 1997. The relationship between N intake (Y, g N/day) and time (X, months) was as follows: $Y = 1.67X + 1.63$ ($n = 33$, $R^2 = 0.65$, $P < 0.01$, r.s.d. = 2.82).

F.NIRS estimates of diet quality and intakes of DM and ME

In May and June 1997, when faecal samples were obtained from individual cows, the diet non-grass was influenced by the treatments. In May the diet non-grass was higher ($P < 0.05$) in unsupplemented cows, regardless of whether they were lactating or non-lactating (both 10.1%), than in lactating supplemented cows (6.7%), which was higher ($P < 0.05$) than in non-lactating supplemented cows (3.1%). Also, in June the proportion of diet non-grass was higher ($P < 0.05$) in unsupplemented lactating cows (6.3%) than in N-supplemented lactating cows (3.6%). The F.NIRS estimates of diet CP, diet DMD or DM intake, or of faecal N concentration, were not affected ($P > 0.05$) by either the provision of N supplement or lactation status.

Diet non-grass averaged 9% (s.d. = 2) from May to October 1997, and then increased to 13% in November and 15% in December 1997 (Fig. 2*a*). From May to November 1997 the diet CP and diet DMD were on average 4.4% (s.d. = 0.38) and 51.1% (s.d. = 1.3), respectively. During the same interval the concentration of CP/MJ ME in the diet averaged 5.7 g CP/MJ ME (s.d. = 0.53), and faecal N concentration 1.05% (s.d. = 0.097) N (Fig. 2*b*). Regression analysis indicated that the diet CP, diet DMD, diet CP/MJ ME and faecal N concentration each declined slowly ($P < 0.05$ or $P < 0.01$) during the dry season. Diet quality was higher during the subsequent wet season (diet CP and DMD were 9.6 and 61.8%, respectively, in January 1998), but had decreased substantially by April 1998 in the late wet season. Voluntary intake of pasture of unsupplemented non-lactating cows early in the dry season (May and June 1997) was estimated to be 19 g DM/kg LW and 158 kJ ME/kg LW.day (58 MJ ME/cow.day), declined linearly ($P < 0.05$) through the dry season, and then increased after the seasonal break (Fig. 2*c*).

LW and BCS changes in the cows

Since pregnancy during the 1997 dry season had no discernable effect on the CF.LW of the cows, the CF.LW of cows non-lactating or lactating during the 1997–98 wet season are shown separately only from November 1997 (Fig. 3). The following description of the responses to treatments focuses on the cows which were pregnant during the 1997 dry season and then

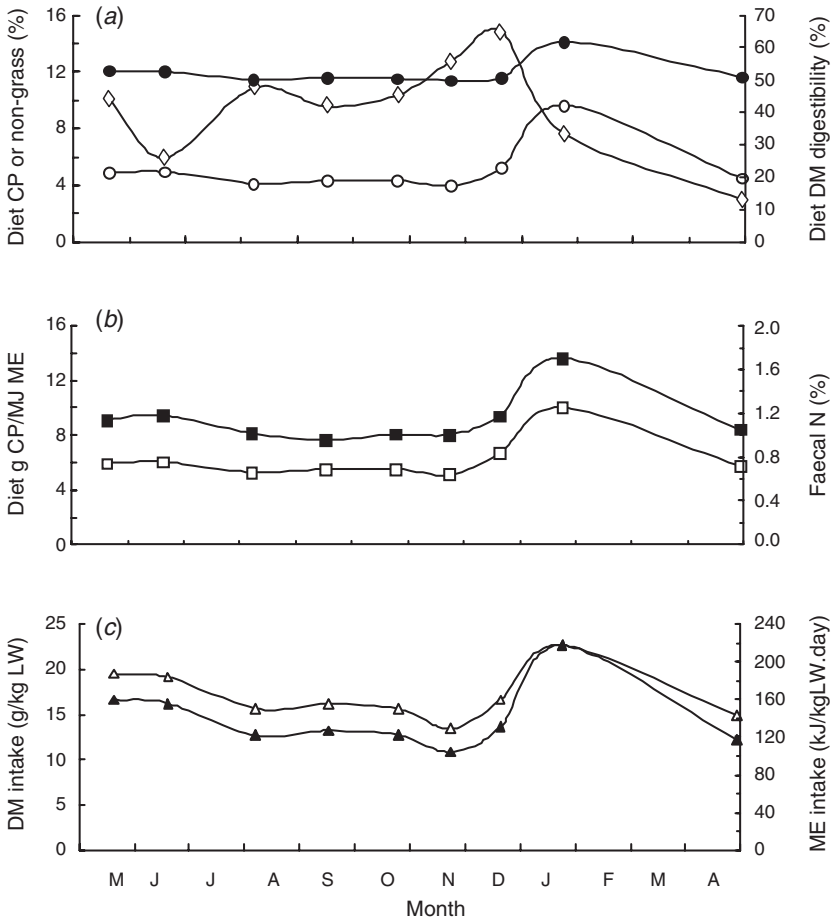

Fig. 2. F.NIRS estimates of the non-grass proportion (◇), crude protein concentration (○) and DM digestibility (●) of the diet (*a*), the CP/MJ ME of the diet (□) and the concentration of N in the faeces (■) (*b*) in non-lactating and lactating cows not given supplements. Also the F.NIRS estimates of DM intake (Δ) (g DM/kg LW) and ME intake (▲) (MJ ME/day) calculated from DM intake and predicted DMD in non-lactating cows not given supplements are shown in (*c*).

lactated through the 1997–98 wet season except where otherwise stated. Also since there was no discernable interaction ($P > 0.05$) between the main effects of weaning and N supplementation, the results are described primarily in the context of these main effects.

The unsupplemented late-weaned (and thus lactating) cows progressively lost CF.LW and BCS during the dry season. The average loss was 52 kg CF.LW and 1.3 BCS units from April until weaning in September, and then a further loss of 19 kg CF.LW after weaning through to December 1997 by which some of the cows had calved (i.e. these cows lost 71 kg CF.LW from April to December 1997) (Fig. 3). On average, the benefit of the N supplementation was 17 kg CF.LW (0.10 kg/day) over the dry season from April to September 1997 ($P < 0.10$) and 11 kg CF.LW (0.04 kg/day) over the entire dry season from April to December 1997 ($P < 0.10$). In comparison, the benefit of weaning on CF.LW was 57 kg in September (0.36 kg/day) ($P < 0.001$), and 46 kg in December (0.18 kg/day) ($P < 0.001$). Relative to weaning in September, weaning in April increased ($P < 0.001$) cow CF.LW. Also relative to unsupplemented cows the N supplementation tended ($P < 0.10$) to increase cow CF.LW, at each measurement from May 1997 through to April 1998 at the end of the annual cycle. In December 1997 the benefits on CF.LW of cows that were pregnant during the 1997 dry season and calved in the 1997–98 wet season were 35 kg ($P < 0.001$) and 12 kg ($P < 0.10$) for early weaning and N supplements, respectively. Also in December 1997 the cows that were non-pregnant during the 1997 dry season were on average 15 kg CF.LW heavier than the cows that were pregnant, while the effects of weaning and N supplementation were comparable.

In addition to the effects of imposed treatments, the LW change of individual cows during the 1997 dry season was negatively related to their CF.LW at the commencement of the dry season. Within a treatment, heavier cows mobilised more body tissue during the dry season; for each additional kg CF.LW in April, cows lost an additional 0.25 kg CF.LW between April and September, or an additional 0.35 kg CF.LW between April and December 1997.

CF.LW of cows that were pregnant during the 1997 dry season and lactated during the 1997–98 wet season tended ($P < 0.10$) to be lower in December 1997, and was significantly ($P < 0.001$) lower in January and April 1998,

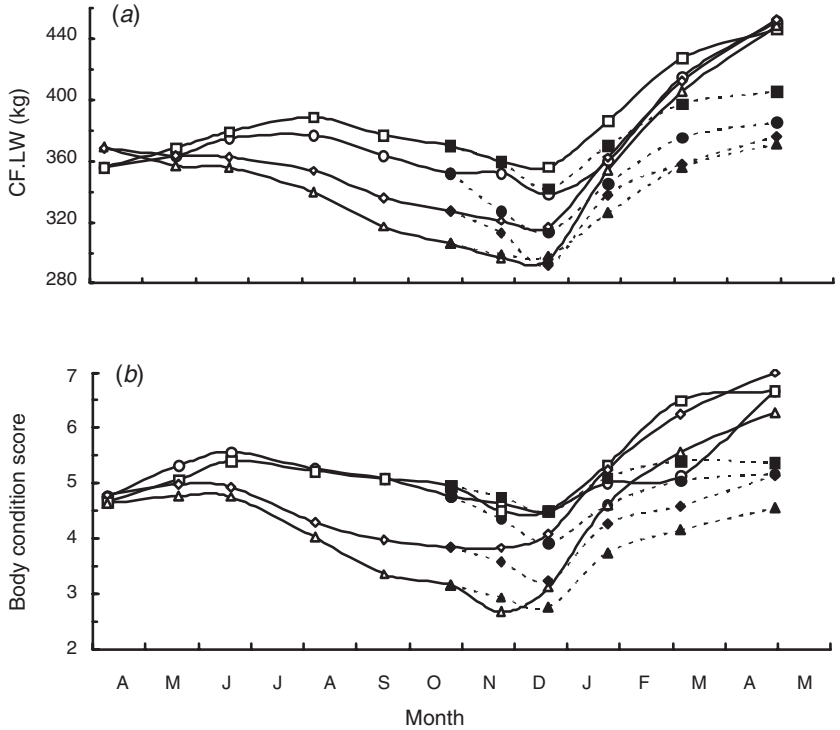

Fig. 3. The CF.LW (*a*) and body condition score (*b*) of early-weaned cows not lactating through the 1997 dry season and not supplemented (○) or supplemented (□), respectively, late-weaned cows lactating through the 1997 dry season and not supplemented (Δ) or supplemented, respectively (◇), and also not lactating through the 1997–98 wet season. Cows given the same respective treatments through the 1997 dry season but lactating through the 1997–98 wet season are shown as ●, ■, ▲ and ♦, respectively. Molasses-urea supplements were fed for 3 weeks from late November until the seasonal break on 15 December, but no supplements were fed thereafter.

than of cows that were non-pregnant and non-lactating during this interval. Cow CF.LW was reduced in December, January, March and April by 14, 23, 47 and 69 kg CF.LW, respectively, while cow BCS was reduced from 7.1 to 4.8 in April 1998. The extent to which cows in low CF.LW at the end of the 1997 dry season exhibited compensatory LW gain during the 1997–98 wet season appeared to depend on whether they were lactating. Low LW non-lactating cows recovered LW, relative to the higher LW cows that were early-weaned and fed N supplements, so that from being 18–60 kg lower in CF.LW in December 1997 they were similar in CF.LW (<6 kg difference among treatments and $P > 0.10$) by April 1998 (Fig. 3). Low-LW lactating cows recovered less LW; CF.LW of cows in April 1998 was 33 kg lower ($P < 0.001$) if cows had lactated during the 1997 dry season, and 22 kg lower ($P < 0.10$) if the cows had not been fed N supplements during the 1997 dry season. Thus in these lactating cows some of the CF.LW benefit due to the treatments during the dry season was retained through the subsequent wet season.

Differences among the five paddock blocks

There were differences among the paddock blocks in the CF.LW change of unsupplemented cows during the dry season from April to September 1997. The change ranged from –19 to +27 kg CF.LW in early-weaned (non-lactating) cows, and –70 to –40 kg CF.LW in late-weaned (lactating) cows. On average the cows in site 2 paddocks lost 13 kg more CF.LW than those in site 1 paddocks. From April to September 1997 the CF.LW changes in non-lactating and lactating cows were correlated ($P < 0.05$ or $P < 0.01$) with both the average diet CP ($R^2 = 0.81$ and 0.96, respectively), and diet DMD ($R^2 = 0.87$ and 0.92, respectively), of the individual paddocks, even though the diet CP ranged from only 4.5 to 4.8%, and the diet DMD from only 50.9 to 52.4%. However, diet CP and DMD were also correlated ($R^2 = 0.95$; $P < 0.01$).

The mean voluntary intake of the N supplement from April to November 1997 ranged among paddock blocks from 9 to 19 g N/day, and was negatively correlated ($P < 0.05$) with the diet CP ($R^2 = 0.70$) and DMD ($R^2 = 0.73$). Voluntary intake of supplementary N was negatively related to the average CF.LW change of the cows, both lactating and non-lactating, in the paired unsupplemented paddock within each block (Fig. 4). Because only the average supplement intake was measured in each paddock it was not possible to examine the relationships for the lactating and non-lactating groups separately. The benefit in CF.LW of cows due to the N supplement from April to September 1997 was inversely related ($P < 0.05$) to the CP and to the CP/MJ ME (Fig. 5*a*, *b*) of the forage component of the diet. This benefit of N supplements on CF.LW was also related to the CF.LW change of the unsupplemented cows in the paired paddocks during the same interval, and there were separate relationships for the lactating and non-lactating cows (Fig. 5*c*). These relationships suggested that, regardless

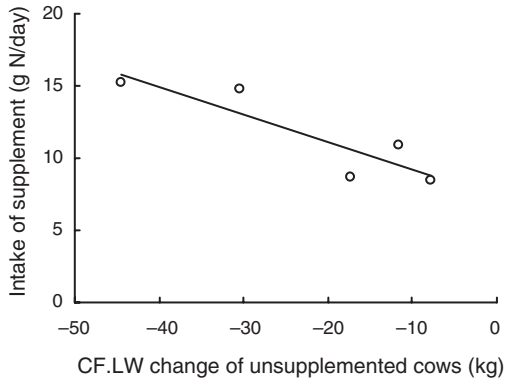

Fig. 4. The relationship between the average CF.LW change (kg) of non-lactating (early-weaned) and lactating (late-weaned) cows in each unsupplemented paddock and the average voluntary intake of supplementary N in the paired supplemented paddock through the dry season from April to September 1997. The regression equation was: $Y = –0.19X + 7.3$ ($n = 5$, $R^2 = 0.78$, $P < 0.05$, r.s.d. = 1.75).

of lactation status, there was no response to the N supplement when diet CP was >4.8%, or when the CP/MJ ME was >5.9.

Microbial CP synthesis and concentrations and excretion of metabolites

Rumen microbial synthesis (Fig. 6*a*) in unsupplemented non-lactating cows was 380 g microbial CP/day in May 1997, and decreased ($P < 0.001$) as the dry season progressed to average 107 g microbial CP/day in October 1997. Microbial CP was on average 25% higher ($P < 0.001$ or $P < 0.01$) in lactating cows than in non-lactating cows at each sampling date, including in October 1997 a month after weaning of the lactating cows. There was no discernable effect ($P > 0.05$) of the N supplement on microbial CP synthesis. In non-lactating non-supplemented cows, microbial CP synthesis (Y, g microbial CP/day) was related to ME intake (X, MJ ME/day) as follows:

$$Y = 17.4X - 648 \ (n = 5,\ R^2 = 0.92,\ P < 0.01,\ \text{r.s.d.} = 34.4)$$

In addition, for this same group of cows, the efficiency of microbial CP synthesis per MJ ME intake decreased as the dry season progressed, from 6.5 g microbial CP/MJ ME in May 1997 to 2.4 g microbial CP/MJ ME in October 1997, and averaged 4.6 g microbial CP/MJ ME (Fig. 6*b*). This efficiency was also correlated with ME intake, diet CP% and the CP/MJ ME in the diet.

PUN concentration was influenced by interaction effects between lactation status and time ($P < 0.05$) (Fig. 7*a*); PUN increased from May to September 1997 in lactating cows ($P < 0.05$), but not in non-lactating cows. On average, provision of the N supplement increased ($P < 0.01$) PUN from 1.59 to 1.85 mmol/L. Urinary urea excretion (Y, mmol/day) was related to PUN (X, mmol/L) as follows:

$$Y = 87.1X - 41.9 \ (n = 20,\ R^2 = 0.40,\ P < 0.01,\ \text{r.s.d.} = 37.8)$$

In supplemented cows and non-lactating non-supplemented cows the concentration of PIP (Fig. 7*b*) increased ($P < 0.05$) from May to August 1997, then decreased ($P < 0.05$) through to

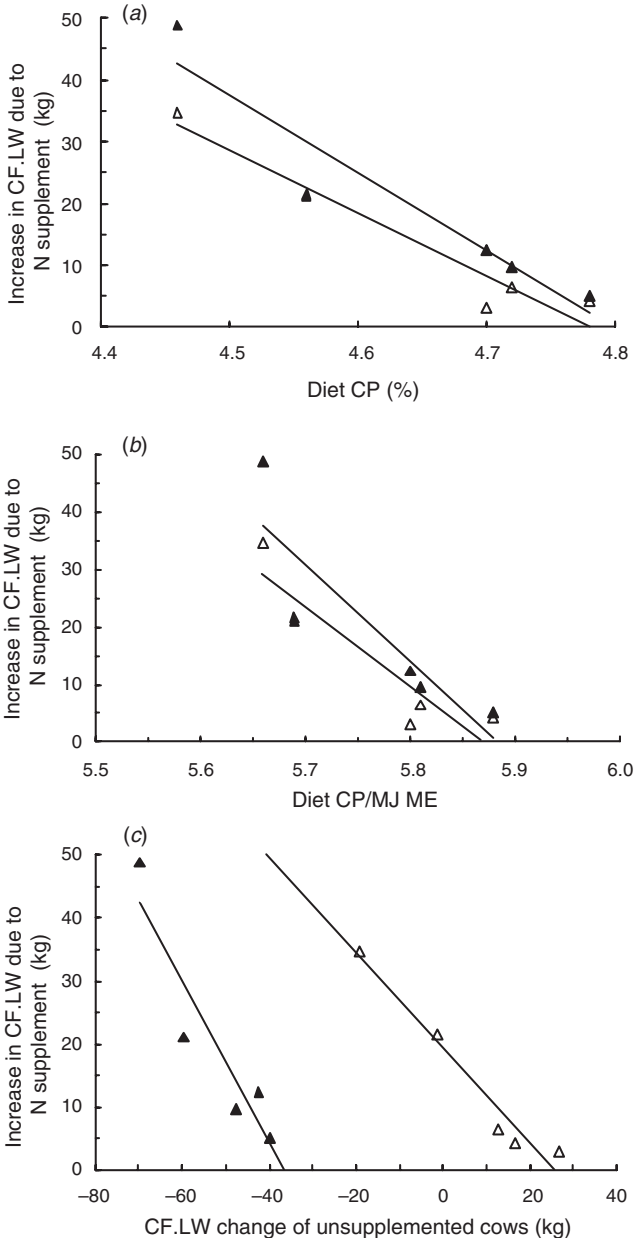

Fig. 5. The relationships for non-lactating (Δ) and lactating (▲) cows between the average diet forage CP% (X_1) (*a*), average diet forage CP/MJ ME intake (X_2) (*b*), and the average CF.LW change (kg) (X_3) (*c*) and the increase in CF.LW due to provision of loose mineral mix supplement containing urea (kg) through the dry season from April to September 1997 in five blocks of paired paddocks and where one paddock in each block was supplemented. The regression equations were:

(*a*) Non-lactating cows $Y = 486 – 101\ X_1$ ($n = 5$, $R^2 = 0.94$, $P < 0.01$, r.s.d. = 4.1).
Lactating cows $Y = 607 – 127\ X_1$ ($n = 5$, $R^2 = 0.90$, $P < 0.01$, r.s.d. = 6.5).

(*b*) Non-lactating cows $Y = 813 – 139\ X_2$ ($n = 5$, $R^2 = 0.84$, $P < 0.01$, r.s.d. = 6.4).
Lactating cows $Y = 987 – 168\ X_2$ ($n = 5$, $R^2 = 0.76$, $P < 0.05$, r.s.d. = 9.8).

(*c*) Non-lactating cows $Y = –0.75\ X_3 + 19.4$ ($n = 5$, $R^2 = 0.95$, $P < 0.01$, r.s.d. = 3.38).
Lactating cows $Y = –1.29\ X_3 – 47.6$ ($n = 5$, $R^2 = 0.87$, $P < 0.01$, r.s.d. = 7.26).

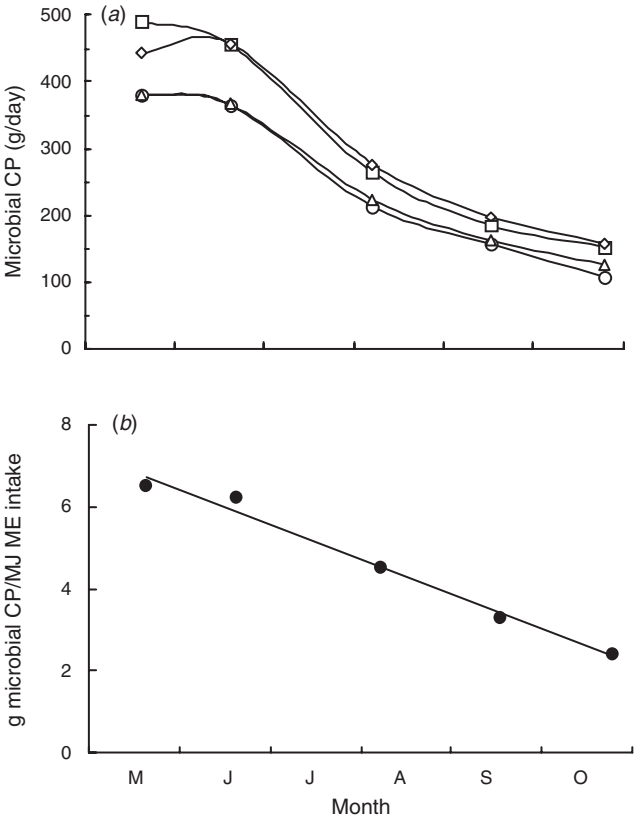

Fig. 6. (*a*) The microbial crude protein (CP) synthesis estimated from urinary excretion of purine derivatives in (○) non-lactating, non-supplemented cows, (□) lactating, non-supplemented cows, (Δ) non-lactating, supplemented cows, (◇) lactating, supplemented cows through the dry season from May to October 1997 is shown. The lactating cows were weaned in September. In (*b*) the efficiency of microbial CP synthesis per MJ ME intake (Y, g/MJ ME) in non-lactating, non-supplemented cows (●) declined linearly as the dry season progressed and was related to the month of the year as follows: Y = 10.7 – 0.85X (n = 5, R^2 = 0.99, P < 0.001, r.s.d. = 0.227).

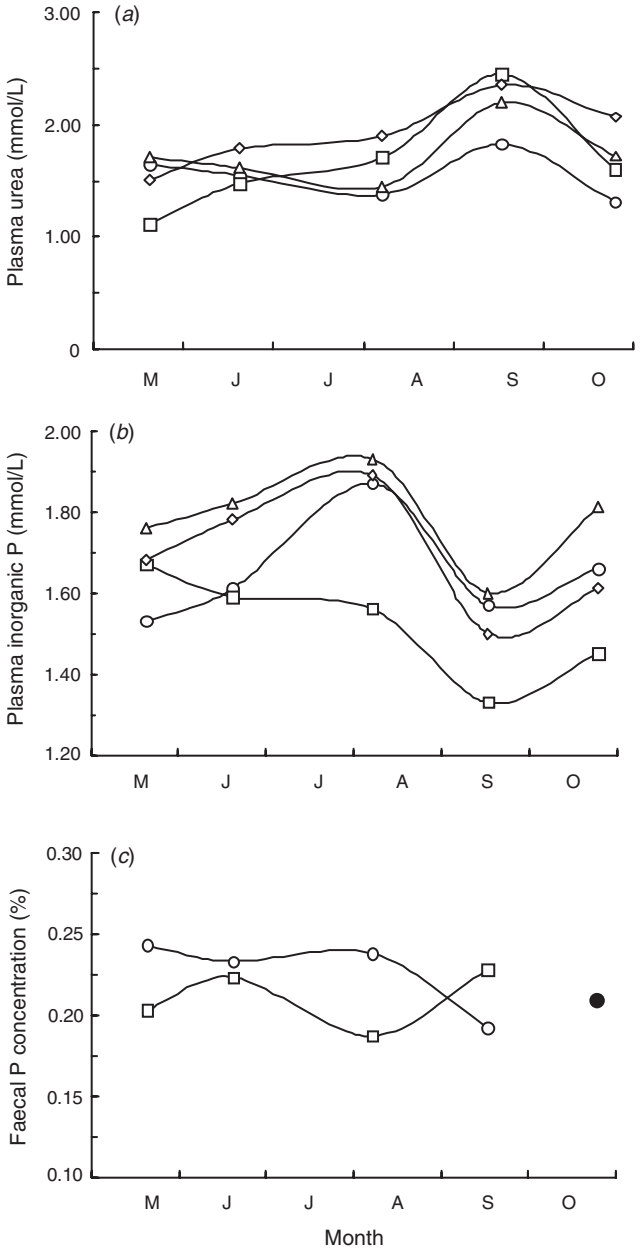

Fig. 7. Concentration of plasma urea (*a*), concentration of inorganic phosphorus in plasma (*b*), and concentrations of total phosphorus in faeces of non-lactating and lactating cows in paddocks not fed supplements, or of cows post-weaning (●) (*c*). The symbols represent (○) non-lactating, non-supplemented cows, (□) lactating, non-supplemented cows, (Δ) non-lactating, supplemented cows, (◇) lactating, supplemented cows. The lactating cows were weaned in September.

September, and then increased in October 1997. Unsupplemented lactating cows had PIP concentrations of 1.67 mmol/L in May, but then declined during the dry season to 1.33 mmol/L in September. The concentration of total P in faecal DM (Fig. 7*c*) of cows not offered supplement averaged 0.22% (s.d. = 0.023) P, and there did not appear to be any change in this concentration through the dry season, or any differences between lactating and non-lactating cows (P > 0.05).

Growth of calves

LW gain of the cohort A calves averaged 0.79 kg/day from April until June 1997 and was not affected by N supplements (Fig. 8). Calf LW gain decreased later in the dry season from June to September 1997 and was increased by supplementation; LW gain of calves in the supplemented paddocks (0.13 kg/day) was higher (P < 0.05) than in the unsupplemented paddocks (0.10 kg/day), although there was no difference (P > 0.10) in the final calf LW.

LW gain of the cohort B calves during the 6 weeks from 4 March to 27 April 1998 averaged 0.82 (s.d. = 0.13) kg/day (n = 78), and the calf LW at the end of the experiment on 27 April 1998 averaged 119 kg (s.d. = 28).

Discussion

Reliability and limitations of estimation of diet attributes, voluntary intake and microbial CP synthesis

Several studies have demonstrated that in ruminants consuming forage diets F.NIRS can reliably estimate attributes of the diet

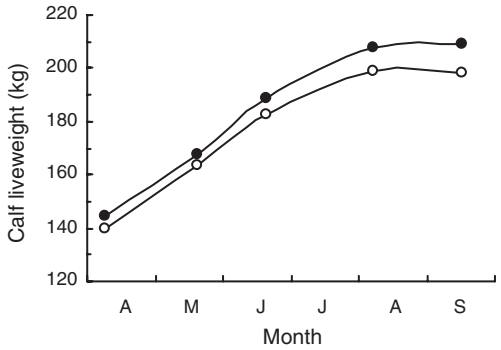

Fig. 8. Growth of suckling cohort A calves in paddock groups not fed supplement (○) ($n = 31$) or fed N supplements (●) ($n = 30$) during the 1997 dry season.

(Lyons and Stuth 1992; Coates 2004; Dixon and Coates 2009). The Coates (2004) calibrations for diet CP and DMD used in the present study were developed from a tropical forages dataset which included native pasture diets from the site of the present study. The bias (i.e. actual – predicted) in estimation of diet CP within the Coates (2004) calibration was small, being on average –0.22 (s.d. 0.73) percentage units for the native pasture diets ≤5% CP ($n = 142$), and –0.02 (s.d. 0.87) percentage units for all the native pasture diets ($n = 282$). The bias in estimation of diet DMD within the Coates (2004) calibration averaged –0.9 (s.d. 2.8) percentage units for the native pasture diets ($n = 88$). Low Mahalanobis distance values of prediction, expressed as a global H in the ISI software used for the chemometric analysis, provided further evidence that the calibrations used were appropriate. The global H (mean ± s.d.) for diet non-grass, CP, DMD, DM intake and faecal N attributes were 0.6 (±0.19), 0.8 (±0.32), 1.5 (±0.72), 1.5 (±0.72) and 0.7 (±0.24), respectively. Thus global H was rarely >3.0 considered a desirable maximum for prediction (Shenk and Westerhaus 1993). Comparable low global H values have also been observed when the Coates (2004) calibrations were applied in other studies with cattle grazing pastures in the northern speargrass pasture region (Dixon *et al*. 2007; Dixon and Coates 2010).

When forages are supplemented with loose mineral mixes such as used in the present study the Coates (2004) calibrations predict the forage component of the diet (Dixon and Coates 2005). Thus the CP concentration of the entire diet of the supplemented cows was calculated from the estimated intakes and CP concentrations of the forage and supplement components of the diet. Since non-protein N supplements generally do not change DMD in cattle fed tropical forage diets (Romero *et al*. 1976; Kennedy *et al*. 1992), no similar adjustment of the F.NIRS estimate of DMD was considered necessary. However, the F.NIRS predictions of voluntary intake using the Coates (2004) calibrations are specific for young growing cattle fed forages, and cannot be applied if voluntary intakes are modified by supplements or by physiological state (e.g. lactation or compensatory growth) (Dixon 2008; Dixon and Coates 2008, 2009). Despite these limitations the LW change, and therefore by implication voluntary intake, of young non-pregnant non-lactating breeders grazing northern speargrass pastures has been predicted satisfactorily (Dixon *et al*. 2007). Thus in the present study the F.NIRS predictions of DM intake and ME intake were expected to apply only to the non-lactating unsupplemented treatment cows during the dry season, and likely underestimated voluntary intake of lactating cows during the dry season and of all cows during the wet season when substantial compensatory LW gain was occurring. These constraints with use of F.NIRS are comparable with those associated with use of diet digestibility to predict voluntary intake of ruminants as described by ARC (1980) and CSIRO (2007).

Estimation of microbial CP synthesis in the rumen from the concentrations of purine derivatives and creatinine in 'spot' samples of urine is well established (Chen *et al*. 1995; Tas and Susenbeth 2007), but depends on an assumed value for endogenous creatinine excretion. Because in the present study the estimate for each treatment at each sampling date was derived from on average 19 cows the errors from variability among animals in creatinine excretion should have been small. However, bias error would have occurred if the actual creatinine excretion differed from the assumed value of 0.558 mmol/kg $W^{0.75}$. This latter value was adopted as that measured in total collection experiments in cattle of similar genotype, fed low-quality tropical forage diets, and with analysis in the same laboratory (P. W. Kennedy, unpubl. data). It is comparable with that reported by Nsahlai *et al*. (2000) and Ojeda *et al*. (2005) with *B. indicus* cross cattle.

Diet selected and ME intake of the cows in the various treatments

The amount and distribution of rainfall during the study was comparable with the long-term average for the site and is representative of many regions of the seasonally dry tropics. The observation that in the early dry season the proportion of non-grass in the diet was reduced by the provision of the N supplement, and among supplemented cows was further reduced by weaning, is consistent with observations of a similar change in diet selection due to N supplementation of cattle grazing buffel grass pasture in the same region of northern Australia (Dixon and Coates 2010). It is consistent with a lower requirement for dietary N in non-lactating than lactating cows, and with reports that cattle may modify dietary selection to alleviate specific nutritional deficiencies (Provenza 1996; Coates and Le Feuvre 1998; Kyriazakis *et al*. 1999). Since non-grass herbage is usually higher in CP than grasses (Ash *et al*. 1995; Coates and Dixon 2007), a higher dietary non-grass should have alleviated the effects of low CP concentration of the grass.

The F.NIRS predictions of diet quality indicated, as expected, a low diet quality and a progressive decline in diet quality, as the dry season progressed. The F.NIRS estimates of diet non-grass, CP and DMD were similar to those previously observed for cows grazing similar pastures during comparable dry season conditions (Dixon *et al*. 2007). The diet CP concentration, CP/MJ ME and faecal N concentration all indicated that the diet would be deficient in N (Winks *et al*. 1979; Minson 1990; Dixon and Coates 2005). The concentrations of total P in faeces

and of PIP in the unsupplemented non-lactating cows indicated that their P status was likely adequate and the primary nutritional limitation was rumen degradable protein. However, the low PIP in unsupplemented lactating cows, and the decline as the dry season progressed, suggested that the diet of these cows was deficient in P (Wadsworth *et al*. 1990; McCosker and Winks 1994).

The relationships across the paddock blocks (Fig. 5*a*, *b*) indicating that there was no LW response to the urea supplement when the diet was ≥5% CP, or when the diet contained ≥6 g CP/MJ ME. These appear to be threshold values below which the cattle in the present study would have responded to the N supplement. These may be also generally applicable as threshold values indicating when responses to non-protein N supplements are likely to occur in cattle grazing tropical dry season native pastures. These values are appreciably lower than the value of 6.2% diet CP proposed by Minson (1990), or a diet CP : ME ratio in the range 9–11 g CP/MJ ME, which can be calculated from the diet N to digestibility values suggested by Hogan (1982) and Moore *et al*. (1999). The greater ability of *B. indicus* than *B. taurus* cattle to conserve N and maintain rumen ammonia concentrations on low-N forage diets (Hunter and Siebert 1985), and their lesser response to N supplements (Hunter and Siebert 1987; Hennessy *et al*. 2000) may at least partially explain the differences between the present study and those referred to above.

Although voluntary intake of supplement N averaged ~14 g N/head.day over the entire dry season, because intake increased as the dry season progressed it was higher (17 g N/head.day) from August to November in the late dry season when pasture CP concentration was lower. Thus the supplementary N intake in the present study was lower than the 20–30 g non-protein N/head.day usually recommended for breeder cows in the seasonally dry tropics (Winks 1984; Dixon and Doyle 1996). However, in the present study the diet CP and the diet CP/MJ ME were higher than often observed under dry season conditions in northern Australian pastures (Dixon and Doyle 1996; Coates and Dixon 2008*b*; Dixon and Coates 2010). This was most likely associated with the substantial rain in the early dry season, and is in accord with the observations of Dixon *et al*. (2007) at the same site. Since lactating cows have been reported to consume substantially more of a low palatability supplement offered free choice than non-lactating cows (Eggington *et al*. 1990), it is likely that in the present study the lactating cows ingested more N supplement than the non-lactating cows in the same paddock. Calculations from the F.NIRS estimates of DM intake by non-supplemented non-lactating cows, and the amounts of supplementary N ingested, suggested that the supplement would have increased the CP content of the diet by ~1.7% CP units. Thus the average CP content of the entire diet ingested by the N-supplemented cows during the late dry season (August–November 1997) would have been ~5.9% CP. Experiments which have examined the effects of increasing amounts of supplementary urea in cattle fed low-quality tropical forages (Hennessy and Williamson 1990; Kennedy *et al*. 1992) suggest that the supplemented cows in the present study ingested sufficient supplementary urea for the majority of the potential response in higher forage intake to occur.

The large differences between the paddock blocks in LW change of unsupplemented cows was unexpected. However, because there were no similar relationships ($P > 0.05$) between diet CP or DMD and the change in CF.LW across the paddocks where the N supplement was fed, it appears that the differences among paddocks were primarily associated with differences in diet rumen degradable N supply rather than diet DMD. The correlation between the voluntary intake of N supplement and the LW change during the dry season in the various paddock groups of cows (Fig. 4) is consistent with observations that voluntary intake of supplements such as loose mineral mixes is inversely related to forage quality and forage intake (Riggs *et al*. 1953). The differences in voluntary intake of low palatability supplements may simply be a consequence of greater energy deficit and hunger of the animals in some paddocks as indicated by the respective LW losses of unsupplemented cows during the dry season.

Protein supply to the cows

The 25% increase in microbial CP synthesis due to lactation in the present study was consistent with increases in voluntary DM and ME intake of similar magnitude of low- to medium-quality forages during mid lactation, including in *B. indicus* cross cows (Penzhorn and Meintjes 1972; Hunter and Siebert 1986). The estimated efficiency of microbial CP synthesis of 6.5 g microbial CP/MJ ME in the early dry season was not markedly less than an expected efficiency of ~8 g microbial CP/MJ ME intake for tropical forages where rumen substrates are adequate (CSIRO 2007). The decrease in efficiency of microbial CP synthesis as the dry season progressed, to 2.4 g microbial CP/MJ ME in October 1997 in the late dry season, is consistent with the low microbial CP efficiencies reported in several other studies with cattle fed tropical forages (e.g. 2–6 g microbial CP/MJ ME; Kennedy 1982; Shem *et al*. 1999; Bowen 2004). The present study appears to be the first to observe a progressive decline in efficiency of microbial CP synthesis as pasture quality declined through the dry season. Such low microbial CP efficiencies may be related to an inadequate rumen degradable protein supply (Poppi *et al*. 1997), as likely occurred in the present study.

The dietary CP ingested and the microbial CP synthesis in the unsupplemented non-lactating cows (Figs 2*b*, 6) indicated that there was net gain of CP across the forestomachs in May and June 1997 with the flow of CP from the rumen being 1.3 of diet CP intake. This declined as the dry season progressed such that by October 1997 net flow of CP from the rumen was only 0.6 of estimated diet CP intake and was equivalent to a net loss of 91 g CP/day across the forestomachs. Net gains of CP across the forestomachs early in the dry season are in agreement with previous reports for low-N forage diets (Hogan 1982; Minson 1990), and with net transfer of endogenous urea N to the rumen (Kennedy and Milligan 1980; Hettiarachchi *et al*. 1999). The consistency of the present study with previous studies of rumen N metabolism in confined cattle fed tropical forages provides evidence that the F.NIRS and purine derivative procedures used did estimate with acceptable accuracy the nutrient intake and digestion in the grazing cattle in the present study.

LW and BCS of the cows

Earlier weaning in April and N supplementation through the dry season both improved the cow LW status and the body condition relative to late-weaned and unsupplemented cows (Fig. 2). Importantly there was apparently no interaction between time of weaning and N supplementation on the changes in CF.LW of the breeder cow through the dry season, although as discussed above the lactating cows likely consumed more N supplement than the non-lactating cows. Clearly weaning the cow, which on average reduced CF.LW loss by 0.35 kg/day, had a much greater effect than the non-protein N supplement, which reduced CF.LW loss by 0.11 kg/day.

This effect of weaning was comparable to previous studies in similar environments where cow LW loss in the early to mid dry season was reduced by 0.26–0.60 kg/day (Fordyce *et al*. 1988; Holroyd *et al*. 1988; Schlink *et al*. 1994; Dixon *et al*. 2007), and in the mid to late dry season by 0.13–0.17 kg/day (Burns 1964; Sullivan *et al*. 1992). The magnitude of this LW benefit is presumably proportional to the lactational output of the cows. For *B. indicus* cows in mid to late lactation in a seasonally dry environment ~6 kg of milk are required per kg calf LW gain (Lampkin and Lampkin 1960). This suggests that in the present study the milk production from April to September 1997 averaged 2.3 kg/day; this amount of milk would contain ~7 MJ net energy and require ~8 MJ ME if it were synthesised entirely from mobilised body tissues (CSIRO 2007). This estimate is consistent with measurements of milk production with similar cattle genotypes in mid to late lactation grazing dry season pasture in comparable environments (Teleni *et al.* 1977; Holroyd *et al*. 1979; Dixon 1998). In the cows in the present study the difference in mobilised LW of 0.36 kg/day due to weaning would correspond to ~7 MJ ME/day, which is remarkably similar to the estimate of ME required for milk synthesis.

Non-protein N supplements have reduced breeder cow LW loss by up to 35 kg, or 0.23 kg/day, during severe dry seasons in the seasonally dry tropics (Winks 1984; Dixon and Doyle 1996; Dixon 1998). Non-protein N supplementation of growing cattle has given similar benefits on animal LW (Dixon and Doyle 1996; Coates and Dixon 2008*b*; Dixon and Coates 2010). Thus the benefit of the urea supplement in the present study was on average across paddocks only about half that which has been observed under severe dry season conditions. This may have been associated with the rain in the early dry season and with diet quality not decreasing to the extent often observed in seasonally dry environments in the tropics.

Although the monthly measurements of animal LW indicated that the non-lactating cows gained LW from April through to early August (21 and 33 kg CF.LW in the unsupplemented and supplemented cows, respectively), some of this LW gain was likely not associated with an increase in body tissues or body energy. The digesta load of cattle in seasonally dry tropical environments has been observed to be greater during the dry season than the wet season by 8–22 kg (McLean *et al*. 1983; Lechner-Doll *et al*. 1990; Schlecht *et al*. 2003). Thus in the present study the decreases in the body energy reserves of the cows through the dry season were likely greater than the changes in cow CF.LW would indicate, leading to errors in the calculation of utilisation of ME for maintenance and milk synthesis.

Conclusions

The study indicated that the beneficial effects of weaning or of provision of N supplements on breeder cow body reserves during the dry season in a tropical seasonally dry environment were additive. Improved cow body reserves during the dry season can also be achieved by management for high body reserves at the commencement of the dry season, but such increased body reserves were only partly retained through to the late dry season. Since the magnitude of each of these management strategies to achieve high breeder cow body reserves can be estimated for individual herd and pasture circumstances, improved management to achieve specific target cow body reserves for calving and for the commencement of the subsequent wet season can be achieved. Current F.NIRS estimates of diet quality and intake derived from F.NIRS, and of microbial CP synthesis, indicated that animal LW responses to the N supplement occurred when diet contained less than ~5% CP, or 6 g CP/MJ ME.

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