

Research Paper

Effects of a nitrogen-based supplement on intake, live weight and body energy reserves in breeding *Bos indicus* cross cows

Efecto de una suplementación basada en nitrógeno en el consumo de forraje, la ganancia de peso vivo y las reservas energéticas de vacas Bos indicus × B. taurus

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Abstract

Breeding cows grazing seasonally dry rangelands usually lose substantial live weight (LW) during the dry season, when in late pregnancy. An experiment investigated the effects of feeding a N-based supplement to cows in late pregnancy on voluntary intake, total live weight (T-LW), body condition score (CS) and estimated body net energy content (Body-NE), as well as carry-over effects during lactation. In Phase A for 139 days from mid-pregnancy, mature *Bos indicus* cross breeders [initially 438 kg T-LW and 5.7 CS units (9-point scale)] were fed in pens on low quality tropical grass hay alone (Control) or with a N supplement (Supplemented). Most (17/22) of the cows calved during this interval. Voluntary hay intake averaged 6.74 g DM/kg T-LW/d in Control cows, and was increased by 35% ($P < 0.001$) when supplement was fed. As a result, feeding supplement reduced loss in conceptus-free live weight (CF-LW) by 30% (from 1.11 kg/d to 0.78 kg/d; $P < 0.001$) and in Body-NE by 20% (from 26.6 to 21.2 MJ NE/d; $P = 0.007$). Control cows mobilized 24% of maternal LW and 32% of body energy when fed low quality hay during late pregnancy, and these losses were substantially reduced when a N-based supplement was fed. During Phase B, when the lactating cows with their calves grazed a high quality rainy season grass-*Stylosanthes* pasture, the previously supplemented cows produced more milk ($P = 0.065$) and their calves grew faster ($P = 0.077$) in early lactation than Control cows. In addition, during early lactation Control cows exhibited compensatory LW gain relative to the Supplemented cows (0.80 vs. 0.43 kg/d, respectively; $P < 0.001$) and there was no discernable weight difference between the groups by 205 days of lactation. In conclusion the losses in LW and body energy reserves by late pregnant cows fed low quality tropical grass hay were substantially reduced by a N supplement, but the differences were not maintained when the cows subsequently grazed high quality pasture.

Keywords: Growth rates, reproduction, supplementation, tropical rangelands.

Resumen

En pastizales nativos estacionalmente secos, las vacas de cría generalmente pierden peso en forma sustancial durante la estación seca cuando se encuentran al final de la gestación. En un experimento realizado en el norte de Australia se estudiaron los efectos de un suplemento basado en nitrógeno en el consumo voluntario, el cambio de peso vivo (PV) total, la condición corporal de los animales y el contenido energético corporal al final de la gestación de las vacas, así como los efectos posteriores durante la lactancia. En la Fase A del experimento se alimentaron vacas *Bos indicus* × *B. taurus* adultas durante 139 días a partir de la mitad de la gestación [438 kg de PV inicial y 5.7 unidades de condición corporal en una escala de 9 puntos] en confinamiento con solo heno de baja calidad (testigo) de una gramínea nativa (*Heteropogon contortus*) o heno más un

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suplemento nitrogenado. Diecisiete de 22 vacas parieron durante este intervalo. El consumo voluntario de heno fue de 6.74 g MS/kg PV por día en las vacas testigo e incrementó en 35% ($P < 0.001$) cuando se suministró el suplemento. Como resultado, el suplemento redujo las pérdidas de PV sin el concepto ('conceptus-free live weight') en 30% (de 1.11 para 0.78 kg/día; $P < 0.001$) y las del contenido energético corporal en 20% (de 26.6 para 21.2 MJ/día; $P = 0.007$). Las vacas testigo movilizaron 24% del PV materno y 32% de la energía corporal cuando fueron alimentadas con heno de baja calidad durante la última etapa de la gestación; estas pérdidas se redujeron sustancialmente cuando fueron suplementadas. Durante la Fase B, cuando en la temporada de lluvias las vacas lactantes estuvieron con sus crías en una pastura de alta calidad (gramínea nativa en activo crecimiento asociada con la leguminosa *Stylosanthes*), las vacas anteriormente suplementadas produjeron más leche ($P = 0.065$) y sus terneros crecieron más rápido ($P = 0.077$) en la lactancia temprana que las vacas testigo. Las vacas testigo presentaron una ganancia de peso compensatorio superior al de las vacas suplementadas (0.80 vs. 0.43 kg/d; $P < 0.001$); a los 205 días de lactancia no se registró diferencia de PV significativa entre los grupos de animales. En conclusión, las pérdidas de PV y reservas de energía corporal de vacas en gestación avanzada y alimentadas con heno de baja calidad, se redujeron sustancialmente cuando se les suministró un suplemento nitrogenado. Sin embargo, las diferencias no fueron iguales cuando posteriormente las vacas tuvieron acceso a una pastura de alta calidad.

Palabras clave: Gramíneas tropicales, reproducción, suplementación, tasa de crecimiento.

Introduction

In breeding beef cows grazing rangelands in the seasonally dry tropics the intake of nutrients typically varies widely between seasons during the annual cycle. The metabolizable energy (ME) and protein concentrations and voluntary intakes of pastures, and therefore liveweight (LW) gains, are typically high during the early to mid-rainy season but decrease markedly with declining pasture quality in the late rainy season and the dry season ([Winks 1984](#); [Entwistle and McCool 1991](#); [Dixon et al. 2011a](#); [Holroyd and McGowan 2014](#)). Breeding herds that are 'control mated' are usually managed to calve during the late dry season or early rainy season, when high quality rainy season pastures are expected to be available to meet the high nutritional demands for lactation and calf growth. Year-round-mated herds tend to have a similar calving pattern due to most conceptions occurring during the rainy season. The importance of managing the nutrition, mating and weaning of breeding herds so that cows have at least moderate body reserves at parturition is well recognized. Numerous studies have reported general relationships between cow LW or body condition score (CS) and reconception of lactating cows and cow mortality in seasonally dry tropical environments, especially in southern Africa ([Richardson et al. 1975](#); [Buck et al. 1976](#)) and northern Australia ([Goddard et al. 1980](#); [Doogan et al. 1991](#); [Holroyd and Fordyce 2001](#); [Mayer et al. 2012](#); [Holroyd and McGowan 2014](#)). However, maintaining LW and CS in cows grazing low quality senesced tropical pastures is often difficult in environments with infertile soils and short pasture growing seasons, and especially during years when the seasonal rainfall break is late and dry season conditions are prolonged. In such environments and seasonal conditions, breeding cows often do not obtain sufficient intakes of nutrients to meet their requirements for pregnancy

and lactation and also to maintain body reserves of live weight and condition.

During the mid- to late dry season senesced tropical grass pastures are usually deficient in N for grazing cattle. Numerous pen experiments have reported that supplementation of growing cattle fed low quality hays with non-protein N (NPN), usually provided as urea, substantially increased voluntary intake and reduced LW loss but had little effect on dry matter (DM) digestibility ([Ernst et al. 1975](#); [Lindsay et al. 1984](#); [Hunter and Siebert 1985](#); [Hennessy and Williamson 1990](#); [Kennedy et al. 1992](#)). Experiments with growing cattle grazing tropical grass pastures during extended dry seasons have often reported benefits from NPN supplementation with reduced live-weight loss and occasionally increased liveweight gain ([Winks et al. 1979](#); [Foster and Blight 1984](#); [Coates and Dixon 2008](#); [Dixon and Coates 2010](#)). In addition NPN supplements can substantially reduce LW loss of late-pregnant cows fed low quality C4 grass hay in pens ([Lindsay et al. 1982](#)). However, experiments with breeding cows grazing native speargrass pastures in northern Australia have reported large variation between years in the responses to NPN supplements. The responses of breeding cows to NPN supplements expressed as changes in LW and CS have ranged from no effect in years with benign dry season conditions (e.g. when there were early seasonal breaks and some winter rainfall) through to reductions in liveweight up to 35 kg and losses in CS (on a 9-point scale) of c. 1 unit during harsh dry seasons ([Holroyd et al. 1977, 1983, 1988](#); [Dixon 1998](#); [Dixon et al. 2011a](#)). Commensurate with higher LW and CS at the end of the dry season, reconception rates of cows have been increased by up to 15 percentage units during the following rainy season ([Holroyd et al. 1979, 1988](#); [Dixon 1998](#); [Dixon et al. 2011a](#)). In these and other experiments ([Ford 1976](#); [Taylor et al. 1982](#)), cow mortality,

or the proportion of cows considered at risk of dying, has been reduced by NPN supplements.

In the low-input management systems typical of extensive beef cattle production in seasonally dry tropical rangelands, including in northern Australia, NPN supplementation is widely practiced as it provides one of the few economically viable management options to improve nutrient intake during the dry season and to reduce losses of LW and CS and mortality of breeding cows. An essential aspect of applying quantitative cattle nutrition for management of breeding cows in seasonally dry environments is to improve quantitative understanding of nutrient intakes during the annual cycle, maintenance requirements, the utilization of nutrients for tissue growth (e.g. as conceptus growth, milk production and cow body reserves) and the mobilization of body tissues when intakes of nutrients are insufficient (Hogan 1996; Dixon et al. 2007). The nutritional requirements of breeding cows are generally well established (e.g. CSIRO 2007) and the intakes of nutrients of grazing cattle, including in herds on-farm, can be estimated with a variety of diagnostic tools such as on-ground and remote-sensing pasture evaluation, and fecal near infrared spectroscopy. However, there is limited information on the circumstances and extent to which *Bos indicus* cross breeding cows mobilize body energy reserves of fat and muscle, and the extent to which such mobilization can be reduced by provision of NPN supplements in the dry season, when cows are usually also pregnant (Hogan 1996). Improved understanding of the latter aspects of cow nutrition is essential for better application of quantitative nutrition in these production systems.

The present experiment investigated the responses in voluntary intake, LW and estimated mobilization of maternal body energy reserves to a N-based supplement in late-pregnant *Bos indicus* cross cows fed a diet of low quality tropical grass hay in pens. It also investigated the carry-over effects of providing this N supplement on cow and calf growth during lactation. While studies on supplementation of breeding cows under grazing conditions have been conducted previously, this study under closely controlled conditions allowed us to examine in detail and partition the severe losses in LW and body energy reserves that occur in pregnant cows in seasonally dry tropical environments during harsh dry seasons, and the recovery when high quality pasture is available.

Materials and Methods

General

A group of 25 *Bos indicus* × *Bos taurus* (Droughtmaster type with c. 5/8 *Bos indicus* - 3/8 *Bos taurus*) cows, 5–6 years of age and initially 3–6 months pregnant, were used in a study

conducted at the Swans Lagoon Research Station (20°4' S, 147°15' E) situated about 100 km south-southeast of Townsville in northern Queensland, Australia. Mean T-LW (including weight of conceptus) on 5 July 1996 was $438 \pm$ (SD) 36 kg (range 391–513 kg) and CS was 5.7 ± 0.53 (range 4.5–6.5). All experimental procedures were carried out according to the Code of Practice for the Care and Use of Animals for Scientific Purposes and with the approval of the relevant Animal Ethics Committee of the Queensland Department of Primary Industries operating when the experiment was conducted.

Phase A – cows held in pens

On 5 July 1996 the cows were placed in individual pens and fed hay alone for 11 days to allow adaptation to pens and to identify any animals with unsatisfactory behavior. On 16 July cows were allocated by stratified randomization based on stage of pregnancy and CS to 4 groups, which were allocated at random to 1 of 2 dietary treatments. These treatments comprised a low quality tropical native grass hay fed alone (Control), and hay plus a N-based supplement (Supplemented). Both the hay and supplements were offered ad libitum for 139 days (16 July–3 December 1996). The hay consisted of native pasture grasses, predominantly black speargrass (*Heteropogon contortus*), harvested from mature pasture during the mid-dry season. The supplement comprised a loose mix containing (g/kg) 267 cottonseed meal, 225 urea, 167 dried molasses, 150 salt, 117 monocalcium phosphate and 75 ammonium sulfate.

For 99 days of the 139 days of Phase A, the 4 groups of cows were group-fed in 4 pens, but for 2 interim periods (M1, 2–26 August; M2, 2–18 October) were fed in individual pens. During group-feeding, hay was fed as large round bales in hay feeders and the groups were moved at weekly intervals through the 4 pens to counteract any differences individual pens might have on cow intake or performance. During individual-feeding, chopped hay was offered in feed troughs 3 times each week at a level 10–30% above previous average intake and refusals were collected. DM intake was measured during the last 7 days of each individual-feeding period (M1 and M2). The supplement was offered in separate troughs and adequate trough space was provided in group pens for all cows to access the supplement. Feces were collected for analysis from fresh dung pats as well as per rectum during the last 7 days of periods M1 and M2. The calving period extended from 17 October 1996 to 8 January 1997 with a mean calving date of 13 November. While most (17/22) cows calved during Phase A when the cows were in the pens, some (5/22) calved during Phase B when cows grazed pasture, as described below. Unfasted LW and CS of cows estimated on a 9-point scale (NRC 1996) were recorded at 1–3 week intervals.

Phase B – cows and calves grazing grass-legume pasture

The seasonal rainfall break occurred on 23 November 1996 (54 mm rain) and subsequent falls of rain maintained pasture growth (December 31 mm, January 117 mm, February 306 mm, March 247 mm, April 0 mm, May 66 mm, June 32 mm and July 0 mm). On 3 December 1996 at the commencement of Phase B, all cows and calves were removed from the pens to graze rainy season native grass-*Stylosanthes* spp. pastures on a rotational basis as a single herd through a series of 6 similar 40 ha paddocks. The herd was moved every 1–2 weeks to a new paddock until 27 July 1997, when the study terminated. Every 1–3 weeks cows and calves were weighed without fasting, and CS of cows was assessed. On 7 occasions milk production by cows was measured using a weigh-suckle-weigh procedure (Neville 1962) with calves removed from cows for 8 hours before weighings commenced.

Laboratory analyses, calculations and statistical analyses

DM concentration of hay and supplement offered and refused, and of feces, was determined by oven drying (70 °C). Concentrations of organic matter, total N and minerals in the hay and supplement were analyzed as described by Dixon et al. (2011a). Digestibility of the hay was estimated from near infrared reflectance spectroscopy of feces (F.NIRS) and application of calibration equations appropriate to the pasture system (Dixon and Coates 2009; Coates and Dixon 2011). Conceptus-free live weight (CF-LW) of cows was calculated from the measured cow LW and the day of pregnancy calculated from the actual calving date (O'Rourke et al. 1991). To distinguish between total LW (including conceptus) and the CF-LW the former is abbreviated as T-LW for measurements during pregnancy, while LW is used post-partum when there was no conceptus to be considered. Body net energy content of the cows (Body-NE) was calculated from LW and CS (CSIRO 2007), assuming a standard reference weight of 550 kg. The rates of change in cow T-LW and CF-LW from 5 July 1996 until parturition, and cow and calf LW gains from parturition to Day 90 and from Day 90 to 205 of lactation of individual cows, were calculated by linear regression of LW with time. Milk production was calculated for the same intervals.

Intake of pasture by cows when grazing was estimated as described by CSIRO (2007) using the QuikIntake V5 spreadsheet (S.R. McLennan and D.P. Poppi, unpublished software) along with measurements of mean cow LW, LW gain and milk production plus calf live weight and liveweight gain during the interval. The diet was estimated to contain 8.8 MJ metabolizable energy (ME)/kg DM; this

was the 4-year average ME concentration measured in subsequent years with F.NIRS during the 3 months after the seasonal break with grass-*Stylosanthes* pastures in the same trial area (Dixon 2005).

Statistical analyses were conducted separately for the pregnancy phase (5 July in mid-pregnancy to parturition) and the lactation phase (Days 1–90 and Days 91–205 post-partum) by ANOVA using GENSTAT (release 16.1 9VSN International Ltd, Hemel Hemstead, UK). Individual cows were considered as experimental units. The coefficients of the linear regressions of cow LW, CF-LW and calf LW with time for Days 1–90 and 91–205 of lactation were adopted as the best estimates of LW change during these intervals, while the LWs predicted from these regressions were adopted as the best estimates of LW at Days 90 and 205 after parturition. Initial LW, CF-LW and CS of cows on 5 July 1996, calculated day of conception and gender of the calf were examined as potential covariates in the analyses of response variables, and were included when there was >0.9 probability that the covariate did affect the response.

Results

Phase A – cows held in pens

One cow in the Control group aborted and 2 cows in the Supplemented group were withdrawn from the experiment due to low body condition so that during pregnancy data from 22 cows (12 Controls and 10 Supplemented) were analyzed. In addition, during the individual feeding period M2 in October, 1 cow had extremely low intakes of hay and data for this cow for this period were excluded. Measurements for 2 cows, whose calves died neonatally, were included in the data set during pregnancy but not during lactation. Most (17/22) of the cows calved during Phase A (Table 1).

Table 1. The number of cows calving in fortnightly intervals during the final 8 weeks of Phase A to 3 December 1996, and during the first 6 weeks of Phase B.

Phase	Time relative to end of Phase A	Treatment	
		Control	Supplemented
A	6–8 weeks before	1	0
A	4–6 weeks before	3	5 ¹
A	2–4 weeks before	3	3
A	0–2 weeks before	2	0
B	0–2 weeks after	2	1 ¹
B	2–4 weeks after	1	0
B	4–6 weeks after	0	1
Total		12	10

¹One calf in each of these subgroups died neonatally, so data were available for 10 cows and 8 cow-calf pairs in the Supplemented treatment during pregnancy and lactation, respectively.

The hay offered contained 6.9 g total N/kg DM, 0.6 g phosphorus/kg DM and 2.8 g calcium/kg DM. In vivo DM digestibility and metabolizable energy (ME) concentration of the diets measured by near infrared reflectance spectroscopy of feces were 528 g/kg DM and 7.4 MJ ME/kg DM, respectively. The hay thus contained c. 5.8 g crude protein/MJ ME. The supplement contained 130 g total N/kg DM, 87% of which was non-protein N. Fecal N concentration averaged 14 g N/kg DM.

Supplemented cows consumed 0.38 and 0.24 kg supplement DM/day (0.95 and 0.59 g supplement DM/kg T-LW/d) during periods M1 and M2, respectively, which

provided 49 and 31 g N/d, respectively. These compare with mean intake of supplement during the 139 days of Phase A of 0.21 ± 0.066 kg/d or 0.53 ± 0.16 g DM/kg T-LW/d, which provided 27 g N/d. Intakes of supplement during M1 and M2 were 81 and 14% greater, respectively, than average intake when the cows were fed as groups. Mean voluntary intakes of hay by the Control group were similar during periods M1 and M2 (6.36 and 7.13 g DM/kg T-LW/d, respectively) (Table 2). During periods M1 and M2 the supplement increased hay intakes in Supplemented cows to 9.15 and 9.03 g DM/kg T-LW/d, i.e. by 44 and 27%, respectively ($P < 0.001$ and $P = 0.022$). Total intakes of the diets were

Table 2. Changes in total live weight (T-LW), conceptus-free live weight (CF-LW), condition score (CS) and body net energy content (Body-NE) of cows from mid-pregnancy through to 3–5 days after calving plus hay and supplement intakes. Cows were held in pens and fed either hay alone or hay with a urea-based supplement (Control and Supplemented, respectively). Intakes of hay and supplement were measured during periods M1 and M2 when cows were fed in individual pens. Means were adjusted for the covariates where these were significant at $P < 0.10$.

Parameter	Supplementation treatment		s.e.	Covariate ¹	Probability
	Control	Supplemented			
Number of cows	12	10			
Mean date of parturition	15 Nov	11 Nov	-	-	-
T-LW					
Initial (kg)	446	438	-	-	-
Final (kg)	331	356	5.9	2,5	0.008
Change (kg/d) ²	-0.87	-0.68	0.051	5	0.014
CF-LW					
Initial (kg)	436	427	-	-	-
Final ³ (kg)	331	356	5.9	2,5	0.008
Change (kg/d) ²	-1.11	-0.78	0.044	5	<0.001
CS					
Initial	5.6	5.8	-	-	-
Final	3.4	4.2	0.11	3,5	0.011
Change	-2.3	-1.6	0.20	5	0.015
Body-NE					
Initial (GJ)	10.88	10.77	-	-	-
Final (GJ)	7.38	8.22	0.17	2,5	0.002
Change (GJ)	-3.50	-2.55	0.172	2,5	0.005
Change (MJ/d)	-26.6	-21.2	1.33	2,5	0.007
Voluntary feed intake – Period M1					
n	12	10	-	-	-
Hay (kg DM/d)	2.53	3.78	0.165	2	<0.001
Supplement (kg DM/d)	0	0.38	-	-	-
Total (kg DM/d)	2.53	4.16	0.171	2	<0.001
Hay (g DM/kg T-LW/d)	6.36	9.15	0.397	-	<0.001
Supplement (g DM/kg LW/d)	0	0.95	-	-	-
Total (g DM/kg T-LW/d)	6.36	10.10	0.409	-	<0.001
Voluntary feed intake – Period M2					
n	11	10	-	-	-
Hay (kg DM/d) ⁴	2.66	3.49	0.245	2	0.021
Supplement (kg DM/d)	0	0.24	-	-	-
Total (kg DM/d)	2.66	3.73	0.252	2	0.002
Hay (g DM/kg T-LW/d) ⁴	7.13	9.03	0.557	2,5	0.022
Supplement (g DM/kg LW/d)	0	0.59	-	-	-
Total (g DM/kg T-LW/d)	7.13	9.62	0.609	2	0.004

¹Covariates: 1, initial LW; 2, initial CF-LW; 3, initial CS; 4, initial Body-NE; 5, day of conception.

²Changes in T-LW and CF-LW were calculated by regression.

³T-LW and CF-LW after parturition were identical.

⁴Results for intakes by one cow during M2 were not included.

increased to 10.10 and 9.62 g DM/kg T-LW/d, i.e. by 59 and 35% in periods M1 and M2, respectively. When intakes of hay and total DM during M1 and M2 were examined in a repeated measures analysis across time, it was revealed that the supplement increased ($P<0.001$) intakes of both hay and total DM but neither the main effect of time nor the time \times supplement interaction was significant ($P>0.10$). Initial CF-LW of cows on 5 July and day of pregnancy were significant ($P<0.001$) covariates affecting intakes of hay and total DM.

From 5 July 1996, when the cows were in mid-pregnancy, until shortly after parturition Supplemented

cows lost less ($P<0.05$ to $P<0.001$) T-LW (-0.68 vs. -0.87 kg/d), CF-LW (-0.78 vs. -1.11 kg/d), CS (-1.6 vs. -2.3 units) and Body-NE (-21.2 vs. -26.6 MJ ME/d) than Control cows (Table 2). Losses for Control and Supplemented cows represented 26 and 19% of T-LW, 24 and 17% of CF-LW and 32 and 24% of Body-NE, respectively.

Phase B – cows and calves grazing grass-legume pasture

Data from 2 cows in the Supplemented treatment with neonatal deaths of calves were excluded, so data during

Table 3. Changes in live weight (LW), condition score (CS) and body net energy content (Body-NE) of cows and LW of calves post-parturition. LW gains of the cows and calves were calculated by regression of LW with time, while changes in CS and Body-NE were calculated by difference. Means were adjusted for the covariates where these were significant at $P<0.10$.

Parameter	Treatment during late pregnancy		s.e.	Covariate ¹	Probability
	Control	Supplemented			
Cows					
Number of cows	12	8 ²	-	-	-
Cow LW					
Post-calving (kg)	326	358	6.2	2,5	<0.001
Day 90 – lactation (kg)	387	391	7.0	2,5	0.703
Change (Days 1–90) (kg/d)	0.80	0.43	0.062	5	<0.001
Day 205 – lactation (kg)	450	422	12.4	-	0.108
Change (Days 90–205) (kg/d)	0.33	0.27	0.031	5	0.184
Change (Days 1–205) (kg/d)	0.55	0.42	0.035	5,6	0.005
Cow CS					
Post-calving	3.3	4.2	0.17	5,3	<0.001
Day 90 – lactation	4.4	4.8	0.15	5,3	0.125
Change (Days 1–90)	1.1	0.5	0.15	-	0.014
Day 205 – lactation	4.8	5.1	0.19	3	0.217
Change (Days 90–205)	0.4	0.4	0.15	5	0.898
Change (Days 1–205)	1.5	0.9	0.19	5	0.045
Cow Body-NE					
Post-calving (GJ)	7.24	8.32	0.152	2,5	<0.001
Day 90 – lactation (GJ)	9.01	9.26	0.177	2,5	0.310
Change (Days 1–90) (MJ/d)	19.2	10.9	1.86	-	0.004
Day 205 – lactation (GJ)	10.52	10.24	0.310	2	0.513
Change (Days 90–205) (MJ/d)	12.6	9.3	2.45	5	0.324
Change (Days 1–205) (MJ/d)	15.6	9.9	1.74	5	0.027
Milk production (Days 1–90) (kg/d)	4.5	5.4	0.32	5	0.065
Milk production (Days 90–205) (kg/d)	4.6	4.8	0.21	-	0.525
Calves					
Number of calves	12	8	-	-	-
Mean date of birth	15 Nov	11 Nov	-	-	-
Birth weight (kg)	24.3	23.9	1.28	-	0.824
Calf LW (kg)					
Day 90	90.9	99.8	3.47	5	0.077
Day 205	190	194	5.6	-	0.545
Calf LW gain (kg/d)					
Days 1–90	0.77	0.85	0.036	5	0.111
Days 90–205	0.81	0.80	0.027	-	0.852

¹Covariates: 1, initial LW; 2, initial conceptus-free live weight; 3, initial CS; 4, initial body energy content; 5, day of conception; 6, gender of calf.

²Twenty-two cows calved but 2 calves in the Supplemented treatment died neonatally so observations were made on only 8 cows & calves.

lactation were available for 12 and 8 cow-calf pairs in the Control and Supplemented treatments, respectively (Table 1). Shortly after calving Supplemented cows were 10% heavier (358 vs. 326 kg) and had 15% higher Body-NE (8.32 vs. 7.24 GJ) (both $P < 0.001$) than Control cows (Table 3). During the first 90 days post-partum, when high quality rainy season pasture was available for most of the time for most cows, Control cows exhibited compensatory growth relative to previously Supplemented cows, gaining LW (0.80 vs. 0.43 kg/d, $P < 0.001$) and Body-NE (19.2 vs. 10.9 MJ/d, $P < 0.004$) more rapidly than Supplemented cows. By Day 90 post-partum there were no discernable differences ($P > 0.05$) in LW or Body-NE between the 2 groups of cows. From Day 90 to Day 205 post-partum, Control cows continued to gain LW (0.33 kg/d) and Body NE (12.6 MJ/d), but these rates of change were not significantly affected ($P > 0.05$) by supplementation during late pregnancy. Birth weight of calves (mean 24.1 kg) was similar for Control and Supplemented groups (Table 3). Cows supplemented during pregnancy tended ($P = 0.065$) to produce more milk during the first 90 days of lactation than Control cows and their calves tended ($P = 0.077$) to be heavier (8.9 kg) at 90 days post-partum (Table 3).

Discussion

The present experiment demonstrated that N supplementation of late-pregnant mature *Bos indicus* cross cows fed low quality tropical grass hay in pens for about 4½ months substantially reduced LW loss during this period. Ingestion of on average 27 g supplementary N/d, most as urea, would have increased crude protein (CP) concentration in the total diet to 10–11% and the dietary CP:ME ratio from c. 6 g CP/MJ ME to c. 13–16 g CP/MJ ME. Thus the rumen-degradable N available for microbial growth would have been deficient in the Control diet and adequate in the Supplemented diet (Hogan 1996; CSIRO 2007). If rumen ammonia concentrations in ruminants fed C4 grasses are lower than for temperate C3 grasses as reported by Hogan et al. (1989), the availability of rumen degradable N in the Control cows may have been much lower than indicated by the 6 g CP/MJ ME and there may have been a severe deficiency of N as a substrate for rumen microbial growth. For the Supplemented cows, although the average amount of supplementary rumen-degradable N ingested by the cows during the entire 139 days of Phase A (27 g N/day) was lower than during the M1 or M2 periods, this lower intake of supplementary N would still have provided a high dietary CP:ME ratio. Thus it is unlikely that the supply of rumen-degradable N as ammonia would have limited voluntary intake of hay in the Supplemented cows.

The very low voluntary intakes of hay by Control cows in the present experiment, and the large increases in hay intake (44 and 27% during periods M1 and M2, respectively) in the cows fed the N supplement, were comparable with the intakes and increases in intakes by late-pregnant cows also fed mature native pasture hay reported by Lindsay et al. (1982) and in other experiments summarized by Hogan (1996). In addition, the large increases in hay intake by Supplemented cows were in accord with increases reported in growing cattle fed comparable low quality tropical grass hays in pens and fed NPN supplements (Ernst et al. 1975; Lindsay et al. 1984; Hennessy and Williamson 1990; Kennedy et al. 1992; Hogan 1996), and hence were not unexpected. The reduced T-LW and CF-LW losses in the pregnant cows in the present experiment were also consistent with similar reduced losses in pregnant cows grazing dry season speargrass native pasture and ingesting a diet with c. 6 g CP/MJ ME reported by Dixon et al. (2011a), and with the effects of NPN supplements on cow LW discussed below.

Numerous grazing experiments have measured the changes in LWs of herds of breeding cows through annual cycles in seasonally dry tropical environments and calving over 3–4 months, including with and without NPN supplementation. However unfortunately the reports of such experiments have not included the data needed to calculate rates of loss of CF-LW during late pregnancy. Usually reports have provided the overall mean LWs of treatment groups at infrequent intervals (e.g. June and October in the dry season and the following April in the late rainy season), but not changes in LW or maternal LW of sub-groups of cows within treatment groups that calved at various times, including before and after the seasonal rainfall break. Firstly, these measurements underestimate the losses in maternal LW (CF-LW) since the true losses are masked by the increasing weight of the conceptus that typically weighs c. 54–66 kg in *Bos indicus* cows at parturition (O'Rourke et al. 1991). Since it is the cow's own tissues that provide the body reserves that impact on survival and subsequent fertility, both the T-LW and CF-LW in late pregnancy are important for quantitative nutrition. Secondly, reported LW changes of treatment groups are usually confounded with the time of the seasonal rainfall break. This is important because cows are generally losing LW before the seasonal break and gaining LW after the break. An example of the consequences of these difficulties can be observed in the data from a 3-year experiment reported by Holroyd et al. (1988) in cows grazing native pasture. During 2 harsh dry seasons cows were reported to have lost 20 and 27 kg LW during July–October, but cows were mated in the previous January and the conceptus would have grown by

about 20 kg during July–October. Thus the actual loss in maternal tissues of the cows (CF-LW) would have been c. 40–47 kg. Furthermore, the graphical representation of the results indicated that from July to the following December–January cows lost c. 80–95 kg LW during 2 harsh dry seasons, LW losses comparable with those observed from July to parturition in the present experiment. More generally, where the calving season extends over several months as generally occurs, it is usually not possible from the data reported in the literature to calculate the changes in maternal body weight of the sub-groups of cows calving during intervals before and after the seasonal break. This knowledge is essential for understanding nutrient balances and applying quantitative nutrition. Estimates of changes in maternal body weight (e.g. estimated as CF-LW in the present experiment) are needed to estimate changes in body energy of cows. If a substantial proportion of cows calve before the seasonal break when cows are losing LW, and the remainder after the seasonal break when cows are gaining LW, the mean LW of the herd at any time provides a poor estimate of the true losses in maternal LW during the late dry season, and will seriously underestimate weight loss in cows calving earlier. It is often these sub-groups of cows in the herd that are most at risk from undernutrition. It is not possible to calculate changes in body energy reserves of various sub-groups of cows in published reports of breeding herds to compare with the results of the present experiment.

A number of studies (e.g. [Lamberth 1969](#); [Forbes 1970, 1996](#); [Penzhorn and Meintjies 1972](#)) have reported that voluntary intake of lower quality forage diets by cattle generally decreases during the last 6–8 weeks of pregnancy and suggested that this was due to the physical limitations of abdominal capacity and possibly also hormonal changes ([Forbes 1984](#)). However, there was no such decline in intake in the present experiment. This observation was in accord with reports of Hunter and Siebert ([1986](#)), who also observed no change in intake of a forage diet in *Bos indicus* cross heifers during late pregnancy. The absence of any decrease in intake in the present experiment may have been associated with the very low intakes of hay (<10 g DM/kg LW/d) and, based on low calf birth weights, a low volume of the conceptus. Both factors would presumably have reduced any effects of lower abdominal capacity in late pregnancy on intake. Most importantly the increase in intake of low quality hay and the reduction in liveweight loss (0.2–0.3 kg/d) due to N supplementation in these late-pregnant cows were comparable with responses previously reported in growing cattle ([Winks 1984](#); [Dixon 2011](#)) and in similar genotype cows in pens ([Lindsay et al. 1982](#)) or grazing

senesced tropical dry season pastures ([Holroyd et al. 1988](#); [Dixon 1998](#); [Dixon et al. 2011a](#)).

In the present experiment, although supplementation had substantial effects on cow live weight and body reserves immediately after parturition, the effects on calf growth were small. Calf birth weight was not affected by N supplementation, although birth weight (mean 24 kg) was considerably lower than the 30–34 kg reported in a series of experiments with cows of very similar genotype and grazing native pastures ([Holroyd et al. 1979](#); [1983](#); [1988](#)). Although milk production and calf growth tended to be higher during the first 3 months of lactation in Supplemented cows, there were no discernible differences in calf weights at 205 days of age, representative of weaning weight. Milk production and calf growth rates, and the small response to provision of N-based supplements during the dry season, are in accord with previous experiments with cows of similar genotype at the same experimental site ([Holroyd et al. 1979](#); [1983](#); [1988](#)). The observation that Control cows provided sufficient milk for calves to grow at 0.77 kg/d, while gaining 0.80 kg/d themselves, during the first 90 days post-partum indicated that the cows must have achieved very high nutrient intakes when grazing the grass-*Stylosanthes* pasture during Phase B. Our calculations suggested that Control cows were ingesting 42 g DM/kg LW/d and 133 MJ ME/d, while the previously Supplemented treatment cows consumed 35 g DM/kg LW/d and 116 MJ ME/d. In the other experiment used to estimate dietary ME concentration the pastures were continuously grazed, while in the present study the pastures were rotationally grazed and at a low stocking rate. Hence the ME concentration in the diet of cows when grazing in the present experiment may well have been underestimated, and feed intake overestimated, by the calculations. Regardless, by 90 days post-partum the Control cows had recovered 88% of the LW difference between the 2 treatment groups immediately after parturition.

The magnitude of this compensatory growth of Control cows during early lactation appears unusual for breeding cows in the seasonally dry tropics and was likely associated with the high quality of the grass-*Stylosanthes* pasture available to the cows. The adequate and well-distributed rainfall combined with temperatures and light excellent for growth of such pastures, and the regular movement to paddocks of fresh pasture, would have provided unusually high quality pasture compared with that usually available to cows in early lactation. The high compensatory growth observed in the present experiment was in accord with the large and rapid compensatory growth of *Bos taurus* beef cows during lactation following feed restriction during pregnancy in temperate pasture production systems,

presumably of high nutritional quality (Nicol and Kitessa 1997). In more typical tropical rangeland circumstances, where cows are grazing native grass pastures containing little or no legume, diet quality and voluntary intake during the rainy season are likely to be appreciably lower than in the present experiment. As a result lesser compensatory growth in cows with low live weight and body condition at the seasonal break would be expected. This hypothesis is supported by observations in other experiments at Swans Lagoon Research Station (North Queensland), where the extent of compensatory growth in similar cows during the rainy season and the first 3 months post-partum, relative to heavier cows in better condition was only c. 50% (Dixon et al. 2011a; 2011b) and much lower than the 88% compensation observed in the present study. The rapid LW gain of Control cows in the present experiment suggests that in general the primary limitation to the recovery of live weight by low CS mature cows in early lactation is from their inability to ingest sufficient nutrients from available pasture rather than from any carryover effects of severe undernutrition when pregnant during the dry season.

In general, benefits from dry season N supplementation are associated with higher LW and body reserves of breeding cows in the late dry season and near parturition. This provides the cow with a buffer of energy reserves to alleviate the consequences of a delayed seasonal break and/or a failed rainy season, as cows calve in higher body condition and the risk of cow mortalities is reduced. It is generally neither possible nor acceptable to handle or transport cows in late pregnancy or early lactation and the usual alternative management option for reducing cow mortalities is high-cost supplementation with molasses-urea mixtures or other concentrate supplements. The present study demonstrated the importance of cow body reserves in the dry season to sustain cows through annual cycles in harsh seasonally dry tropical environments with extended dry seasons. From the mid-dry season in July through to immediately after calving in the late dry season (December), Control cows mobilized 105 kg (24%) of their conceptus-free live weight and an estimated 3.5 GJ (32%) of their net energy in body reserves. The latter mobilization of body net energy was equivalent to 26.6 MJ/day. Despite these high losses over 4½ months of poor nutrition and during the equivalent of harsh dry season conditions, the cows survived until rains came, and good rainy season pasture enabled them to lactate satisfactorily and produce weaners of 190 kg at 205 days of age. The reasonable weights and body condition (446 kg and 5.6 CS) of the cows in the mid-dry season in July were no doubt important to allow such extensive tissue mobilization. Nevertheless comparable nutritional conditions are likely to apply in some regions of the seasonally dry tropics where herd weaning rates are

regularly <55% and many cows conceive, calve and lactate only every second year as a consequence of lactation stress combined with inadequate nutrition, resulting in extended anestrus periods after calving. In such environments cow survival and production are possible only because many cows replenish body reserves during alternate rainy seasons when not pregnant or lactating.

Conclusions

This study provided detailed information on the effects of N supplementation on performance of late-pregnant cows ingesting low quality N-deficient forage. It demonstrated in a closely controlled situation the potential of N-based supplements to substantially reduce loss of live weight and body reserves and thus delay the adverse effects of severe undernutrition in reproducing cows. In commercial herds and circumstances this liveweight advantage due to supplementation of cows in the late dry season would be expected to result in fewer mortalities in breeding cows. When high quality pasture was available in early lactation, which allowed rapid recovery of cow body reserves as well as calf growth, there were negligible carry-over benefits of supplementation on cow live weight by weaning. However, the carry-over benefits of supplementation are likely to be greater in environments where lower pasture quality and availability prevent a rapid recovery of cow live weight as was observed in the present experiment.

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