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lalina.muir@publish.csiro.au

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Prepartum supplementation effects on growth and fertility in *Bos indicus*-cross cows

G. Fordyce[A], *L. A. Fitzpatrick*[B], *T. J. Mullins*[C], *N. J. Cooper*[A], *D. J. Reid*[D] *and K. W. Entwistle*[E]

[A] Queensland Department of Primary Industries, Swan's Lagoon Beef Cattle Research Station, Millaroo, Qld 4807, Australia.
[B] Department of Biomedical and Tropical Veterinary Sciences, James Cook University of North Queensland, Townsville, Qld 4811, Australia.
[C] Queensland Department of Primary Industries, PO Box 538, Bowen, Qld 4805, Australia.
[D] Queensland Department of Primary Industries, PO Box 1054, Mareeba, Qld 4880, Australia.
[E] Faculty of Science, University of New England, Armidale, NSW 2350, Australia.

Summary. Three experiments were conducted in the dry tropics of north Australia using *Bos indicus*-cross cows. Cows in mid–late pregnancy were either unsupplemented during the late dry season or offered *ad libitum* (2 kg/day) molasses with 7.4% urea (w/w) (M8U) or cottonseed meal (1 kg/day) for up to 54 days commencing 2 months before the start of the calving season. Supplementation reduced weight loss in experiments 1 and 2 ($P<0.05$), but had no significant effect on weight or body condition in experiment 3. Supplementation had no effect on subsequent calf growth or cow lactation yields.

Following early wet season rains in experiment 1, 9 and 49% of cows were ovulating 40 and 80 days post-partum, respectively, with no effect of supplementation. In experiment 2, 10 and 100% of cows had ovulated by 60 and 200 days post-partum, respectively. At any time between 80 and 180 days post-partum, supplemented cows were more likely to be cycling ($P<0.05$), independent of supplementation effects on weight or body condition. The average post-partum interval to oestrus was 30 days less in cows supplemented for 42 days ($P = 0.08$).

In experiment 3, pregnancy rates in 1/2 and 3/4 Brahmans supplemented with M8U for 54 days (MU54) or whose calves were weaned at 2–3 months of age (WEAN) were 14% higher in the latter 2 months of mating than in cows supplemented for less than 40 days. Good seasonal conditions resulted in high pregnancy rates in all mature 5/8 Brahmans; when not weaned early, their average calving to conception interval (CCI) was 54 days (s.e. = 8.5 days). Pregnancy rates of first-lactation 5/8 Brahmans (average CCI of 125 days) supplemented for 39 days or less and weaned when calves averaged 6 months of age were 14–32% lower between 2 and 9 months post-partum than in contemporaries in the MU54 or WEAN treatment groups.

It was concluded that dry-season supplementation of mid- to late-pregnant *Bos indicus*-cross cows with an energy concentrate for 42–54 days ('spike' feeding) may reduce post-partum anoestrus intervals via a mechanism which is not dependent on the effects on weight or body condition.

Introduction

Beef production systems on extensive grazing properties in north Australia are low cost and generally involve minimal cattle handling and continuous mating. Production is characterised by high cow mortality rates and low weaning rates with post-partum anoestrus being the major factor limiting cow fertility (Entwistle 1983). From the average weaning rate for the region of 63% (O'Rourke *et al*. 1990), and considering levels of embryonic mortality (Holroyd *et al*. 1993), level and timing of foetal and calf losses (Holroyd 1987), and other data including mortalities and herd structure as collated by Holroyd and O'Rourke (1987) and O'Rourke *et al*. (1990), we estimate that post-partum anoestrus extends for an average of 7 months. This is well beyond the 2–3-month interval which allows cows to raise a calf to weaning annually.

Premating body condition or weight and the time since calving are the most important variables affecting the probability of conception in cows which are mated for a limited period each year (Rudder *et al*. 1985; Anderson *et al*. 1988). In most analyses of cow fertility, the variable 'year' also has a significant influence and may be responsible for up to 25% of the variation (Anderson 1990). The year effect is not fully explained by weight and weight change effects, and therefore is difficult to resolve. Rudder *et al*. (1985) suggested some of the year variation was due to rainfall over a 6-month

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period up to the start of mating, presumably related to feed quality during the normal dry season. These conclusions have subsequently been confirmed by Anderson (1990) who reported that fertility was significantly related to the amount of rainfall received, and months of pasture growth, in the dry season immediately before calving.

This indicated that improving prepartum diet quality had the potential to reduce the post-partum anoestrus interval. This paper reports 3 experiments investigating this possibility through short-term feeding of an energy-rich supplement to *Bos indicus*-cross cows in late pregnancy.

Materials and methods

Environment

The experiments were conducted at Swan's Lagoon Beef Cattle Research Station (20°05'S, 147°14'E) located in North Queensland's dry tropics. The climate is characterised by a hot, wet summer period (wet season) and a warm, dry winter period followed by a hot, dry period (dry season). Mean maximum and minimum temperatures for January (mid summer) are 31 and 23°C, and for July (mid winter) are 26 and 9°C, respectively. Distribution and amount of annual rainfall is highly variable. On average, 72% of the 862 mm of average annual rainfall occurs between December and March inclusive.

The vegetation is open woodland (primarily *Eucalyptus* spp.) with a native unimproved pasture which is predominantly black spear grass (*Heteropogon contortus*) with tropical tall grasses and other medium grasses. The experimental area is flat and soils are generally of low fertility. A more detailed description of the site is given by Fordyce *et al.* (1996).

Animals, treatments and measurements

Experiment 1. The animals used were F_n 1/2 and 3/4 *Bos indicus* crosses (primarily with Beef Shorthorn) described in Table 1. Before allocation, these cattle had grazed as 1 herd except for the annual 3-month mating period between mid–late January and mid April.

Animals were allocated using stratified randomisation on stage of pregnancy within body condition score, genotype, and age to 3 treatments at the start of the treatment period in early September 1986. Weight and previous lactation status were randomised across treatments. Each treatment group was divided into 2 subgroups of 25 cows and stocked at 1 cow per 4 ha.

CONT animals received no energy supplement. The MU38 treatment group received *ad libitum* (1.9 kg/day) molasses with 7.4% (w/w) urea (M8U), while cows in the CM38 treatment group were fed 1 kg of cottonseed meal/day (CP 44%); this was fed twice weekly and was usually consumed within 2 h. Twice-weekly feeding with cottonseed meal has the same efficacy as daily feeding when fed at the same average daily intake (Hennessey *et al.* 1981). Supplements were fed from 9 September 1986 for 38 days. Average intakes of supplements in the MU38 and CM38 groups had similar nitrogen (70 and 64 g/day, respectively) and energy (13 and 11 MJ of metabolisable energy/day, respectively) levels. Mineral blocks [38% molasses; approximate mineral composition (g/kg): P 64, Ca 101, Na 111, Mg 45, Cl 121, Zn 0.6, Cu 0.07, Mn 0.09, I 0.001, Co 0.001, Mo 0.0002] were

Table 1. Cows used in each experiment

Cow age shown is their age at calving during the experiments

Fractions refer to *Bos indicus* content

The number of cows which raised a calf to weaning during the experimental period is shown in parentheses

Treatment	Cows rearing first calf (3 years)					Mature cows (4–9 years)					Aged cows (9–11 years)		Total no. of cows
	Brahman cross			Sahiwal cross		Brahman cross			Sahiwal cross		Brahman cross		
	1/2	5/8	3/4	1/2	3/4	1/2	5/8	3/4	1/2	3/4	1/2	3/4	
						Experiment 1							
CONT	5 (4)		7 (7)	10 (10)	4 (4)				20 (19)	4 (3)			50 (47)
CM38	5 (4)		7 (6)	9 (9)	5 (4)				20 (17)	4 (3)			50 (43)
MU38	5 (5)		7 (7)	9 (6)	5 (5)				20 (19)	4 (4)			50 (46)
						Experiment 2							
CONT											14 (11)	11 (9)	25 (20)
CM42											14 (13)	11 (11)	25 (24)
						Experiment 3							
CONT	10 (9)	23 (23)	13 (13)			16 (13)	15 (14)	15 (15)					92 (87)
MU26	10 (10)	24 (21)	13 (10)			14 (11)	13 (12)	14 (13)					88 (77)
MU39	10 (9)	24 (24)	13 (12)			16 (14)	13 (13)	15 (13)					91 (85)
MU54	10 (8)	23 (22)	13 (13)			15 (14)	14 (14)	16 (14)					91 (85)
WEAN	10 (9)	24 (22)	13 (12)			15 (14)	13 (11)	15 (15)					90 (83)

available to all cows over the period of supplementation; intake was 4–23 g/day.

Available paddock feed during the period of supplementation was typical poor-quality, dry season pasture (i.e. 35–40% digestibility, 0.6–0.8% nitrogen). Total rainfall of 12 mm in 3 falls over the period of supplementation did not result in substantial pasture growth. The first wet season rainfall occurred immediately after supplementation, i.e. late October around the start of the calving season.

At the cessation of supplementation, cows were reallocated to paddocks across treatments to minimise paddock effects and to facilitate management.

Calving dates were estimated from paddock inspections 3 times weekly over the calving period between late October 1986 and mid January 1987. All cows and calves were weighed (early morning before drinking) and scored for condition (9-point scale: Holroyd 1978) every 4–6 weeks over the duration of the experiment or until ovariectomy of the cow. Calves were not weaned before 80 days post-partum.

At the commencement of the experiment, all Sahiwal-cross animals were allocated using stratified randomisation on stage of pregnancy within supplement treatment and age group to ovariectomy at either 40, 60 or 80 days (± 5 days) post-partum as part of accompanying studies (Fitzpatrick *et al*. 1988; Fordyce *et al*. 1988).

From calving to either ovariectomy or the end of the experiment (110 days after the average day of calving), cows were bled on days 1 and 11 of each month for determination of plasma progesterone concentrations. Post-partum ovulation was defined as progesterone levels >1 ng/mL and/or by evidence of recent ovulation from examination of ovaries at ovariectomy.

Experiment 2. The 50 animals used (Table 1) were pregnant F_n 1/2 and 3/4 Brahman x Beef Shorthorn-cross cows aged from 9 to 11 years. All animals grazed unfertilised native pasture at 1 cow per 3.8 ha.

Pre-experimental management and methods of allocation (in June 1987) to groups were the same as in experiment 1. There were 2 unreplicated treatments, CONT and CM42, with CM42 cows being fed cottonseed meal as in experiment 1 for 42 days from 8 September 1987. As in experiment 1, the 3- and 4-day rations of cottonseed meal were consumed within 2 h of feeding. In both treatments, cattle had *ad libitum* access to mineral blocks (as for experiment 1) during the supplementation period; intake averaged 41 g/day.

The 1987 dry season was particularly severe due to low preceding wet season rainfall (54% of average), with pastures being of poor quality and deteriorating between May and November. In mid November, soon after commencement of calving, and 1 month after supplementation ceased, wet season rains commenced.

Six weeks after supplementation ceased, all lactating cows (half) were allocated to 1 paddock, and the balance to the second paddock; both treatments were then equally represented in each paddock.

All cattle were weighed and condition scored every 6 weeks from allocation through to early December and thereafter at 3-weekly intervals. Calving extended from early November 1987 to mid January 1988; calving dates were estimated as described for experiment 1. Average calving date (± s.d.) was 1 and 4 December 1987 (± 21 days) for CONT and CM42 treatments, respectively.

Lactation yield was estimated once using the weigh–suckle–weigh technique (Neville 1962) in mid January when calves were between 8 and 67 days of age; this measurement excluded cows whose calves had died (*n* = 5) and whose calves were unborn (*n* = 1). Calves were weighed before and after 20 min of suckling at 17 and 24 h after an initial 20-min sucking-out period. Between suckling periods, cows had access to pasture and water in an area adjacent to the holding yards where the calves were held and fasted. Though the cattle had not previously experienced this technique, there were no apparent behavioural problems.

Half the cows which did not experience a foetal or calf loss (*n* = 22) were allocated to regular bleeding. Allocation was by stratified randomisation on day of calving within treatment, age and genotype. For each cow, blood samples were obtained by jugular venipuncture at 9–11-day intervals commencing 20 days post-partum for subsequent determination of plasma progesterone concentrations. Post-partum ovulation was considered to have occurred when plasma progesterone levels exceeded 1 ng/mL (Hansel and Convey 1983). The balance of the cows were ovariectomised 80 days post-partum as part of an accompanying study (Fitzpatrick *et al*. 1994).

Calves were weaned in late June at an average age of 6 months, irrespective of whether their dams had ovulated or not. Two cows had not cycled by 30 June 1988 (weaning) but did so immediately after.

Experiment 3. The 452 animals used (Table 1) were pregnant F_n 1/2, 5/8 and 3/4 Brahman x Beef Shorthorn-cross cows aged 3–6 years. Pre-experimental management for the 1/2 and 3/4 Brahmans was as described for experiment 1. The 5/8 Brahmans were selected from a separate continuously-mated herd.

Cows were allocated to groups using the same method as in experiment 1. The treatments were: no supplementation with weaning when average calf age was 6 months (CONT) or weaning when calves were about 2–3 months of age (WEAN); and *ad libitum* M8U fed for 26 (MU26), 39 (MU39) or 54 (MU54) days commencing on 5 September 1988. Each treatment group, except the WEAN group, was divided into 3 replicates of about 30 cows which grazed unfertilised native pasture (1 cow per 3.3 ha); 3 blocks of 4 paddocks were used, with a replicate of each treatment randomly allocated to each block. The WEAN treatment was grazed in 1 paddock at the same stocking rate.

Intakes of M8U averaged 2.0–2.1 kg/day (variation of 1.5–2.5 kg/day). Estimated average daily intakes from the supplement were about 70 g of nitrogen and 13–14 MJ of metabolisable energy.

Seasonal conditions were better than average during this experiment. Winter rainfall (80 mm) sustained good pasture conditions through to early September, from when pasture quality deteriorated rapidly. Wet season rains commenced on 21 November.

At the end of supplementation in the MU39 group, cows in the CONT, MU26 and MU39 treatments were reallocated across 7 paddocks (2 per block plus the paddock which had held the WEAN treatment) with each treatment equally represented in each paddock. At the same time, the WEAN cows were reallocated across 3 paddocks, 1 in each block, to facilitate subsequent weaning. Two weeks later at the end of supplementation, cows in the MU54 treatment were reallocated across the 3 paddocks, 1 in each block, in which they had been supplemented because calving had commenced and reallocation of cows in other treatments would have caused significant mismothering.

Calving occurred between late October 1988 and early February 1989. Calving dates were estimated as described for experiment 1.

In the WEAN treatment, calves >79 kg were weaned on 23 January 1989 (n = 39) and 28 days later (n = 44), with the 3 remaining calves weaned a further 38 days later; estimated calf age (± s.d.) at weaning was 69 ± 15 days. All calves from the other treatments were weaned on 5 June 1989 at an average estimated age of 6 months (182 ± 22 days).

The 5/8 Brahmans (41% of cows) were continuously mated from the start of calving in late October. The remaining cows (1/2 and 3/4 Brahmans) were mated between 23 January and 20 April 1989.

Weighing and scoring of body condition of cattle were carried out at the previous weaning muster in April 1988, at the beginning of supplementation (5 September 1988), when supplementation ceased in the MU39 group, and at the start and end of the controlled mating period.

Rectal palpation to estimate foetal age, thus time of conception, was carried out on 20 April 1989 and 7 weeks later. This was repeated in continuously-mated cows in July 1989 and May 1990.

Progesterone analyses

Progesterone concentrations were estimated by radioimmunoassay in unextracted plasma samples using a modification of the Danazol (R-004-RK; Sterling-Winthrop Research Institute, New York) method of McGinley and Casey (1979) as described by Jolly (1992). The sensitivity of the assay (90% zero-binding) was 0.10 ng/mL, while the intra- and inter-assay coefficients of variation were 4.7 and 9.0%, respectively.

Statistical analyses

Only data from cows which reared a calf to the end of the data collection period for each experiment were included in the analyses. Following ovariectomy at 40 and 60 days post-partum in experiment 1, 25 and 47% of cows were excluded from the analyses of percentage ovulating 60 and 80 days post-partum, respectively.

Weights of pregnant cows were initially corrected by subtracting the estimated weight of the uterus and its contents; the latter was calculated using the method of Silvey and Haydock (1978) assuming a calf birth weight of 27 kg (Fordyce *et al*. 1993). Weight, daily weight changes, body condition, body condition changes, and calving to conception intervals (CCIs) were analysed by standard analysis of variance with unequal subclass numbers using LSMLMW (Harvey 1975). The proportions ovulating and pregnant post-partum (where day 0 is the day of calving for individual cows) were analysed using GLIM (Baker and Nelder 1985) with logistic models and binomial errors. Treatment effects on proportion ovulating between 40 and 200 days post-partum in experiment 2 were analysed by GLIM (Baker and Nelder 1985) using a survival data analysis method (Cox 1972; Bartlett 1978).

Management requirements in experiment 3 necessitated a design which allowed confounding of paddock with genotype, but minimised confounding of treatment with both paddock and genotype. The resulting partial confounding between treatments required a separate analyses for the WEAN treatment. Similarly, MU54 treatment data collected subsequent to the end of supplementation in the MU39 group, also required separate analyses. The experimental design required that paddock within breed replace replicate in most analyses.

In all analyses, treatment and breed/cow age (as shown in Table 1) were included as factors, and day of calving was a covariate. Other covariates also included were: weight/condition score at the start of the period in growth analyses; cow weight at the end of supplementation in fertility analyses; and cow weight at the end of calving in milk yield analyses. Calf sex was only included as a factor in calf growth rate analyses.

Non-significant interactions and covariates were successively eliminated to determine the final models. LSMLMW was then used to estimate least squares means and standard errors.

Results

Experiment 1

All cows lost weight steadily between early June and the end of supplementation (Fig. 1*a* and *b*). Supplementation significantly (P<0.01) reduced weight

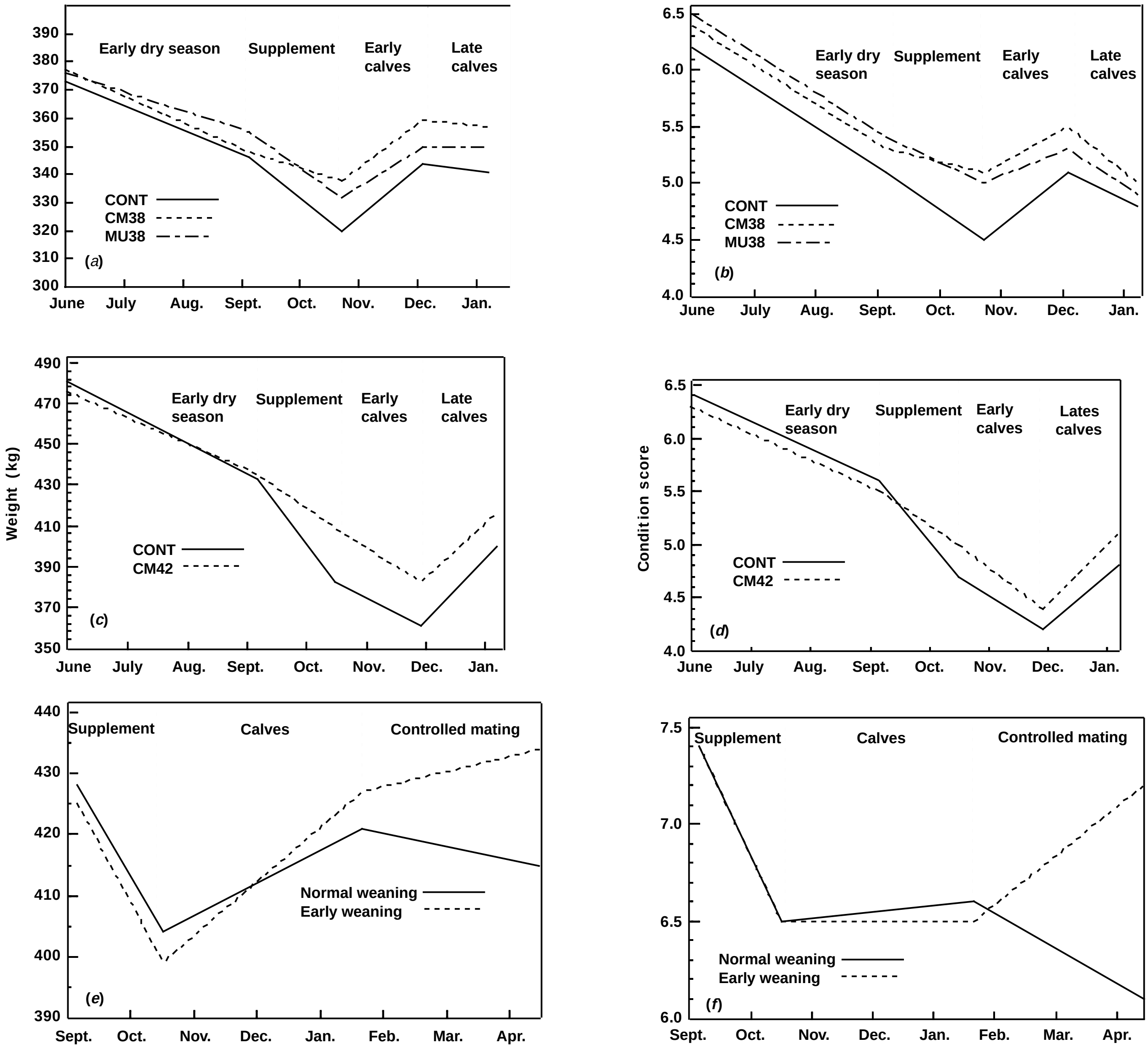

Figure 1. Prepartum supplementation effects on weight (adjusted for stage of pregnancy) (*a*, *c* and *e*) and body condition score (*b*, *d* and *f*) of *Bos indicus*-cross cows in experiments 1 (*a*, *b*), 2 (*c*, *d*) and 3 (*e*, *f*). See text for explanation of treatments.

loss with no difference between CM38 and MU38 treatments (CONT = –0.54 kg/day *v*. CM38 = –0.35 kg/day and MU38 = –0.34 kg/day; s.e.m. = 0.02 kg/day). Differences in weight between different supplement treatments were not significant at the end of supplementation (320, 338 and 332 kg for CONT, CM38 and MU38, respectively; s.e.m. = 3.7 kg). Early in the calving season, cow growth rates were high but levelled off with drying pasture conditions later in the calving season (s.e.m. = 0.03–0.04 kg/day).

Treatment had no effect on calf growth rate which averaged 0.89 ± 0.014 kg/day from the end of the calving period to weaning.

There were no differences between treatment groups in proportions of cows ovulating (Fig. 2*a*) with 9, 29 and 49% (s.e.m. = 3–6%) showing evidence of cyclic ovarian activity by 40, 60 and 80 days post-partum, respectively. Date of calving, breed-age group and weight following supplementation had no effect on proportions ovulating at these times.

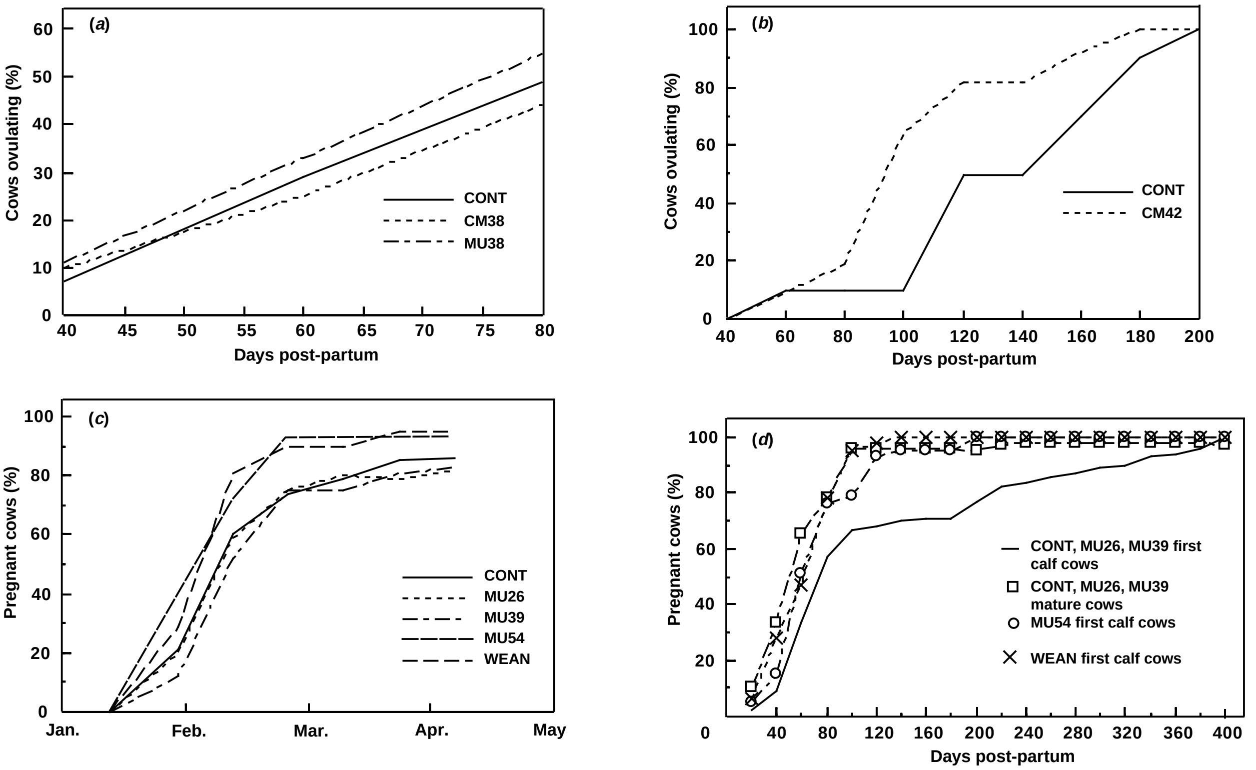

Figure 2. Prepartum supplementation effects on post-partum fertility of *Bos indicus*-cross cows. (*a*) Experiment 1; (*b*) experiment 2; (*c*) experiment 3, 1/2 and 3/4 Brahmans; and (*d*) experiment 3, 5/8 Brahmans. See text for explanation of treatments.

Experiment 2

Weight loss (± s.e.m.) between early June and early September was high (–0.45 ± 0.025 kg/day) and became very high in unsupplemented cows during the subsequent supplementation period (Fig. 1*c*: CONT = –1.25 kg/day, CM42 = –0.63 kg/day; s.e.m. = 0.055 kg/day; *P*<0.01). As in experiment 1, supplemented cows were not significantly heavier than CONT cows at the end of supplementation (409 *v*. 382 kg, respectively; s.e.m. = 8.6 kg). CONT and CM42 cows lost 0.9 and 0.5 condition score units (s.e. = 0.08 units; *P*<0.01), respectively, during the supplementation period (Fig. 1*d*). Weight loss (s.e.m. = 0.05–0.06 kg/day) continued early in the calving season with a recovery in the latter half after pasture regrowth.

There was no effect of supplementation on either lactation yield (6.4 ± 0.25 kg/day) or calf growth rate (0.96 ± 0.018 kg/day).

Supplementation advanced ovulation following calving by 30 days (101 *v*. 131 days for CM42 and CONT cows, respectively; s.e.m. = 8 days; *P* = 0.08). Between 80 and 180 days after calving, the proportion of cows with cyclic ovarian activity tended to be higher for CM42 cows (Fig. 2*b*; s.e. = 6.9–11.7%), although this difference was only significant at 100 days post-partum (64 and 10% for CM42 and CONT cows, respectively; s.e.m. = 9.5%; *P*<0.05). The survival analysis confirmed this effect, showing that from 80 to 180 days post-partum, supplemented cows were more likely to be cycling than unsupplemented cows (hazard ratio = 2.7; approximate 95% confidence interval of 1.0–7.3).

Weight following supplementation had no effect on the proportion of cows cycling. Day of calving also had no effect except in early May (5 months after the average day of calving) when fewer late-calving cows were cycling (b: –0.009 ± 0.0043% units/day; *P*<0.05).

Experiment 3

Due to the good seasonal conditions, weight and body condition of cows remained high throughout the experiment (Fig. 1*e* and *f*). Treatment had no effect on weight and body condition losses (± s.e.m. derived from analyses excluding the WEAN treatment) during the supplementation period (–0.56 ± 0.01 kg/day and –0.9 ± 0.03 units, respectively). Cows gained weight marginally during the calving season (0.20 ± 0.01 kg/day and 0.2 ± 0.03 condition score units) with no effect of treatment.

During the controlled mating period, lactating cows lost weight (–0.06 ± 0.016 kg/day) and body condition (–0.4 ± 0.04 units) while cows in the WEAN treatment gained weight and body condition, and were heavier at the end of mating than cows in the other treatments (weight: 434 ± 4.3 *v.* 415 ± 2.8 kg; body condition: 7.2 ± 0.07 *v.* 6.1 ± 0.05; s.e.m. for lactating cows derived from analyses excluding MU54 cows).

Mature cows (4–9 years) were consistently about 8% heavier than young cows (3 years). There was no age effect on body condition in the supplementation period. However, mature cows gained body condition (+0.40 units) in the calving season, while young cows only maintained condition (0.03 units; $P<0.01$). This gave mature cows an advantage of 0.4–0.5 units of condition score during the controlled mating season ($P<0.01$). These results were for the CONT, MU26 and MU39 treatments; however, they were closely matched in the MU54 and WEAN treatments.

In lactating cows within the CONT, MU26 and MU39 treatments, body condition of 1/2 and 3/4 Brahmans was 0.20–0.25 units higher than in 5/8 Brahmans over the supplementation period. The 5/8 Brahmans lost body condition during calving (–0.16 units), in contrast to the 1/2 and 3/4 Brahmans which gained condition (0.50 and 0.23 units in 1/2 and 3/4 crosses, respectively), resulting in the 5/8 Brahmans being 0.7–0.8 condition score units poorer by the end of mating (5.6 *v.* 6.4 units, respectively; $P<0.01$). The experimental design caused genotype effects to be confounded with the effects of mating management and paddock.

Precalving supplementation for up to 39 days did not influence pregnancy rates. Day of calving and weight at the end of supplementation also had no significant effects on pregnancy rates.

Within 1/2 and 3/4 Brahmans, pregnancy rates in the MU54 cows were an average of 14% higher from 1 month after the start of mating than in CONT cows and those fed M8U for shorter periods (MU26, MU39). Cumulative pregnancy rates in the WEAN group closely matched those in the MU54 group (Fig. 2*c*). Standard errors of least squares means (range: 3.1–6.8) indicated that the advantage of WEAN and MU54 groups over the other treatment groups was significant. There was no effect of age on cumulative pregnancy rates.

Within first-calf, 5/8 Brahmans, cumulative pregnancy rates between 2 and 9 months post-partum were 14–32% higher in the MU54 group than in either CONT cows or those previously fed for 39 days or less (Fig. 2*d*); peak differences occurred at 4–7 months post-partum. Cumulative pregnancy rates in the WEAN cows were similar to those of the MU54 cows. The standard errors of the means (range: 2.7–9.9) indicate that the advantages of MU54 and WEAN cows were significant between 3 and 11 months post-partum.

In 5/8 Brahmans within the CONT, MU26 and MU39 groups, mature cows had higher pregnancy rates than young cows between 20 and 260 days post-partum (s.e.m. = 2.0–4.6; $P<0.05$; Fig. 2*d*) with peak differences occurring at 3–6 months post-partum. This was reflected in the much longer CCIs of young cows (125 *v.* 54 days; s.e.m. = 8.5 days; $P<0.05$). There was no evidence of an age effect on cumulative pregnancy rates in the continuously-mated 5/8 Brahmans in either the MU54 and WEAN groups.

Calving to conception intervals (± s.e.m.) in continuously-mated 5/8 Brahmans in the CONT, MU26 and MU39 treatments averaged 90 ± 9.0 days. The CCI was significantly reduced (as indicated by s.e.m.) to 70 ± 6.8 and 60 ± 4.5 days in the MU54 and WEAN treatments, respectively.

Discussion

Our results indicate that 42–54 days of dry-season supplementation of late-pregnant *Bos indicus*-cross cows grazing poor-quality, native pasture can, in some years, significantly improve subsequent fertility, particularly in cows rearing their first calf. Following this supplementation strategy in experiments 2 and 3, all classes of cows, except for the mature 5/8 Brahmans, had a more rapid return to oestrus after calving. We have called this form of supplementation ‘spike’ feeding (short-term spike in the feed quality curve).

The specific mechanism by which the supplementation regime described here may enhance fertility is not clear. Jolly *et al.* (1994), in their review, indicated that nutritional stress may act directly and (or) indirectly on both the hypothalamo-pituitary axis and the ovary to suppress fertility. The effects of spike feeding on folliculogenesis could be due to changes in gonadotrophin secretion, effects of metabolites of the supplements, or hormones produced in response to these metabolites acting directly at one or more levels of the hypothalamo-pituitary-ovarian axis (Fitzpatrick 1994). Accompanying ovarian studies in experiment 2 demonstrated that precalving supplementation was associated with enhanced folliculogenesis 80 days after calving (Fitzpatrick *et al.* 1994). In supplemented cows, follicle numbers tended to be higher (82 *v.* 54), there were more granulosa cells per follicle (80×10^6 *v.* 52×10^6), concentrations of oestradiol were higher in follicular fluid of large follicles (1.4 *v.* 0.5 ng/mL), concentrations of progesterone in follicular fluid were lower in small follicles (4.7 *v.* 7.8 ng/mL), and granulosa cell aromatase activity was higher (0.34 *v.* 0.25 ng oestradiol/mL of culture medium); this suggests increased functional dominance of large follicles in supplemented cows. In their review, Spicer and

Echternkamp (1986) concluded that such an increase in functional dominance is associated with the approach of the first post-partum oestrus.

Above-average base nutrition could explain why spike feeding did not improve fertility in some circumstances. As a result of above-average seasonal conditions in experiment 3, mature 5/8 Brahmans were in better condition than equivalent first-lactation cows, presumably because of the required diversion of energy to growth in the latter. It appears that folliculogenesis in these cows was not sufficiently impaired by dry-season nutrition for spike feeding to be of benefit. This resulted in a short average CCI (54 days) in unsupplemented, mature cows with no response to supplementation or weaning.

The early commencement of the wet season in experiment 1 (reflected in high cow growth rates early in the calving season) resulted in unsupplemented cows returning to oestrus relatively quickly after calving and appeared to negate any potential fertility advantages gained by supplementation. However, data collected in accompanying studies of subgroups of first-lactation cows indicated that some advantage to supplementation had occurred, even if it was not expressed in overall percentage ovulating. In ovaries removed 80 days post-partum, there was a trend for increasing numbers of small follicles as a result of supplementation (20, 29 and 39 for CONT, CM38 and MU38, respectively; Fitzpatrick *et al.* 1988); there were also significantly more medium-sized follicles in the MU38 treatment (16 for MU38 *v.* 8 and 10 for CONT and CM38, respectively). As well, when ovariectomised at either 40, 60 or 80 days post-partum, there was a trend for more supplemented cows to have commenced cycling (25, 33 and 37% for CONT, CM38 and MU38, respectively; Fordyce *et al.* 1988).

The reproductive responses to precalving supplementation were achieved even when there were no significant direct effects on weight or body condition as occurred in experiment 3. Marston *et al.* (1995) also reported a similar effect in beef cows (pregnancy rate: +11%), even though their feeding period was about double that used in our experiments. The effect of precalving supplementation with an energy and protein concentrate appears to be due primarily to differences in the quality of nutrients available. Teleni *et al.* (1984) reported that, in a study of ovulation rates in ewes, responses were a consequence of the energy-yielding substrates. Several research groups have also shown the significant benefit to fertility of increased precalving energy levels, though reported feeding regimes are usually much longer and the effects are partially related to changes in precalving condition and condition at calving (Wiltbank *et al.* 1962; Dunn *et al.* 1969; Selk *et al.* 1988). This contrasts to reported studies using low levels of urea-based supplements for considerably longer periods in the dry season (e.g. Holroyd *et al.* 1977), where increases in fertility are not achieved without improved weight and body condition.

The lack of supplement effects on weight and body condition of cows in our experiments was also reflected in the absence of effects on both lactation yields and calf growth.

Our results may partially explain the large 'year' effects which have been described for weight–fertility relationships in lactating cows in harsh environments (Rudder *et al.* 1985; Anderson *et al.* 1988). Predicted probabilities of conception based on precalving or premating weights typically vary by up to 25% between years in many analyses (Anderson 1990). Our results also concur with anecdotes from North Queensland that supplementing pregnant cows with *ad libitum* M8U during drought conditions dramatically improves fertility in the following year even when cows remain in backward condition (score <5 on a 9-point scale), and that early storms are followed by good fertility in the subsequent mating season independently of effects on weight. This latter suggestion is supported by Anderson (1990) who showed that both early rain and a high Southern Oscillation Index (difference in barometric pressure between Darwin and Tahiti) were related to higher subsequent fertility.

As a result of this research, spike feeding of heifers in their first pregnancy is now being adopted by beef producers in north Australia. Fordyce and Entwistle (1992) estimated that astute use of spike feeding would, on average, return double the investment.

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