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Follicular growth and ovulation in postpartum beef cows following calf removal and GnRH treatment

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Abstract

This study investigated the effects of calf removal (CR) and gonadotrophin releasing hormone (GnRH) administration on the duration of the postpartum anoestrous period in suckled beef cows. Experiment 1 involved 20 multiparous suckled cows that were assigned to each of two treatments on Day 61 postpartum: (i) unlimited access to their calves (C; $n = 10$) and (ii) calf removal for a period of 96 h (CR96, $n = 10$). Experiment 2 involved 24 multiparous cows that were assigned to each of two treatments on Day 63 postpartum: (i) CR96 ($n = 12$); and (ii) CR96 plus 250 μg of GnRH administered on the day before calf return (CR96 + GnRH, $n = 12$). Experiment 3 was a 3 × 2 factorial experiment, involving 48 multiparous cows assigned to the experiment on Day 58 postpartum. The factors were C, CR96 and calf removal for 144 h (CR144), and 0 or 250 μg GnRH administered on the day prior calf return. In Experiment 1, the number of cows that ovulated within 12 days of calf removal was higher ($P < 0.05$) in CR96 group (3/9) compared to the C group (0/10). In Experiment 2, all 12 cows in the CR96 + GnRH group ovulated. In contrast only 4/12 cows in the CR96 group ovulated in response to calf removal. The diameter of the ovulatory follicle tended ($P = 0.06$) to be smaller in CR96 + GnRH cows (9.8 ± 0.3 mm) than in CR96 cows (11.3±0.9 mm). The maximum diameter attained by the corpus luteum (CL) also tended ($P = 0.08$) to be smaller for cows in the CR96 + GnRH than for cows in the CR96 group (12.1 ± 2.4 mm versus 16.7 ± 7.5 mm, respectively). Plasma progesterone concentrations 12 days after calf removal tended ($P = 0.06$) to be lower in CR96 + GnRH cows than in CR96 cows (0.66 ± 0.1 ng/ml versus 2.00 ± 1.1 ng/ml, respectively). Few cows in the CR96 + GnRH group regained normal cyclical activity and the interval from onset of calf removal to conception was longer ($P < 0.05$) compared to cows in the CR group (52.2 ± 5.7 days versus 20.0 ± 6.6 days). In Experiment 3, 5/8 cows on the CR144 group and all 8 cows in the CR144 + GnRH group ovulated. However, the interval from CR to conception was similar for all treatments. Temporary (96–144 h) calf removal, particularly

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in combination with GnRH treatment, can induce a high proportion of beef cows to ovulate, but the restoration of oestrous cycles may not be achieved.

Keywords: Beef cattle; Postpartum interval; Calf removal; GnRH; Ultrasonography

1. Introduction

Reproductive efficiency is key to the achievement of high productivity in cow–calf production systems. One of the major causes of poor reproductive efficiency in beef suckled cows is an extended postpartum anoestrous interval which, under range conditions similar to those described in the current study, can exceed 120 days (Quintans and Vázquez, 2002). There are several factors that affect the length of this interval, but nutrition and calf presence are considered to be the most significant (Short et al., 1990; Stevenson et al., 1997).

Under extensive grazing conditions, the control of calf presence and/or suckling frequency offers a low cost means to shorten the postpartum anoestrous period and to induce ovulation in suckler cows. However, the effect of temporary calf removal (CR) on the duration of anoestrous when calves are withheld for a 48–72 h period is variable (Wright et al., 1987; Rivera et al., 1994). Body-condition score (BCS) (Alberio et al., 1984), duration of calf removal (Shively and Williams, 1989), interval from calving to calf removal (Bonavera et al., 1990), and the stage of follicular development at the time of calf removal (Sinclair et al., 2002) may all combine to influence the outcome of this treatment.

Calf removal for 96 and 144 h induced 85 and 100% of cows to ovulate, respectively in the study of Shively and Williams (1989). Acute calf isolation and once-a-day suckling induced 70% of cows in moderate body condition to ovulate the dominant follicle (DF) of the first follicular wave after Day 21 postpartum (Sinclair et al., 2002). However, in the study of Salfen et al. (2001) the ovulatory response following 48 h calf removal was highly variable and not attributable to the stage of follicular growth at the time of calf removal. Treating cows with gonadotrophin releasing hormone (GnRH) can also induce ovulation (Lishman et al., 1979; Crowe et al., 1993) but the response may depend on the stage of the follicular wave. Dunn et al. (1985) reported that removing the calf for 72 h increased the subsequent LH response to GnRH treatment. Understanding the pattern of follicular growth during the anoestrous period of beef cows is necessary in order to develop better methods for shortening this interval (Stagg et al., 1995). However, follicular development in cows following temporary calf removal has not been well described. Consequently, the aim of the present study was to determine the pattern of follicular dynamics in cows of moderate body condition before and after a temporal calf removal, and to assess the effects of GnRH treatment on reproductive performance during the mating period.

2. Materials and methods

2.1. Location and herd management

Experiments were carried out at “Palo a Pique” Research Station of the National Institute of Agricultural Research (INIA), Treinta y Tres, Uruguay (35°S) during late spring and early summer (November–January). At this time of year the photoperiod is 14 h light/10 h darkness. All cows grazed on natural pastures. The mating period lasted 2 months commencing 14 days after the onset of treatments (72–77 days after calving), between the 1st of December until the 31st of January. Cows were naturally mated using one to two bulls of proven fertility per experimental group (giving an average of 30 cows per bull). Pregnancy was diagnosed 45 days after the end of the mating period by ultrasonography and the day of conception was estimated from progesterone profiles. The experiments were conducted in accordance with the Experimental Unit directive concerning the use of animals for experimentation.

2.2. Experiment 1

This experiment involved 20 multiparous Hereford cows with a post-calving live weight of (mean $\pm$ S.E.M.) 355 ± 7.3 kg and body-condition score of 4.0 ± 0.08 units ($1 =$ thin, 8 $=$ fat). The cows remained with their calves until 61.4 ± 1.6 days postpartum (designated Day 0), when they were assigned to one of two treatments: (i) each calf remained with and had free access to its dam (C; $n = 10$); (ii) each calf was completely removed from its dam for a period of 96 h (CR96; $n = 10$). During the period of separation calves were offered alfalfa hay and water on an ad libitum basis. Cow live weight and BCS were recorded at calving and at biweekly intervals from the start of the experimental period. Calves were weighed at the same time as their dams, and they were weaned at 6 months of age.

2.3. Experiment 2

This experiment involved 24 multiparous Hereford cows with a post-calving live weight of 383 ± 7.0 kg and BCS of 4.0 ± 0.08 units. The cows remained with their calves until 63.0 ± 1.6 days postpartum (designated Day 0), when they were assigned to one of two treatments: (i) each calf was completely removed from its dam for a period of 96 h (CR96, $n = 12$) (as for Experiment 1); and (ii) calf removal for 96 h plus 250 μg of GnRH (Fertagyl®, Intervet, Corporación Agropecuaria, Montevideo, Uruguay) administered intramuscularly on the day prior to calf return (CR96 + GnRH, $n = 12$). During the period of separation calves were offered alfalfa hay and water on an ad libitum basis, together with 200 g per head per day of a high protein (18% crude protein) supplement. Cow live weight and BCS, and calf weight were all recorded as described in Experiment 1.

2.4. Experiment 3

This experiment involved 48 multiparous Hereford cows with a post-calving live weight of 363 ± 5.0 kg and BCS of 3.9 ± 0.06 units. The cows remained with their calves until 58.0 ± 1.1 days postpartum (designated Day 0), when they were assigned randomly to a 3×2 factorial experiment consisting of six treatments, in which the factors were duration of calf removal (0, 96 and 144 h) and 0 or 250 μg of GnRH (Fertagyl®, Intervet, Corporación Agropecuaria, Montevideo, Uruguay) given the day prior to calf return ($n = 8$ cows per treatment). Calves were managed as in Experiment 2 during the period when they were separated from their dams. Cow live weight and BCS, and calf weight were all recorded as described in Experiment 1.

2.5. Ultrasound examinations

Follicle growth was monitored daily beginning 10 days before calf removal and lasting until 10 days after calf return. Ultrasonic examinations were carried out by the same operator using a real-time, B mode scanner with a 5 MHz transducer (Aloka SSD 500 Echo camera, Overseas Monitor Corp. Ltd., Richmond, BC). The position and diameter of all follicles ≥3 mm were determined for each ovary on each day. The time of ovulation was defined as the day when the largest identified follicle was no longer present. The day of emergence of a follicular wave was retrospectively identified as the day on which the largest follicle of that wave was 4 mm in diameter. The growing phase of the dominant follicle was defined as the period between its emergence and the day that it reached maximum diameter. The regression phase of the dominant follicle was defined as the period between the day it attained maximum diameter and the day it regressed to 4 mm in diameter. The life-span of the anovulatory follicle was defined as the period between the day of its emergence and the day that it had regressed to 4 mm in diameter. The life-span of the ovulatory follicle was defined as the period between the day of its emergence and the day of ovulation. The first rise in progesterone was defined as the first day during which plasma progesterone concentrations were greater than 0.5 ng/ml confirmed by disappearance of the dominant follicle by ultrasonography or the first of three consecutive samples with progesterone >0.5 ng/ml.

2.6. Blood sampling and hormone analysis

In all experiments blood samples were collected into heparinized tubes by jugular venipuncture twice weekly from the beginning of the scanning period until the end of the mating period. In Experiment 3 samples were also collected on a daily basis between Days 0 and 16. Blood samples were chilled at 4 °C and centrifuged within 3 h after collection and plasma stored at −20 °C until assayed. Progesterone concentrations were estimated by direct solid-phase RIA (DPC, Diagnostic Product Co, Los Angeles, CA, USA). The RIA had a sensitivity of 0.1 ng/ml, and the intra- and inter-assay coefficients of variation were 5 and 9%, respectively.

2.7. Statistical analyses

One cow from the calf removal group in Experiment 1 and one cow from the Control group in Experiment 3 had ovulated before treatments began and were subsequently eliminated from data analysis. In Experiments 1 and 2, treatment differences for live weight, body condition and follicular growth were analysed using the General Linear Model procedure within Minitab (Minitab Inc., 1994, State Collage, Pennsylvania, USA). The effect of treatments on postpartum intervals were analysed using the General Lineal Model procedure of the Statistical Analysis System (SAS, 1989). The proportion of cows ovulating in response to calf removal, the number of cows with short oestrous cycles and cyclic cows at the end of the mating period were analysed using Fisher's exact test. In Experiment 3 differences between treatments in postpartum intervals were determined by ANOVA where GnRH and calf removal were the main factors, and interactions between these factors were also examined. Duncan's multiple range test was used to determine significant group mean differences. Data are presented as means ± S.E.M.

3. Results

3.1. Experiment 1

Cows lost ($P < 0.05$) 0.4 units of BCS between calving and the initiation of temporal calf removal (from 4.0 ± 0.08 to 3.6 ± 0.08 units), but live weight was unaltered during this period (355 ± 7.3 kg at calving versus 373 ± 5.9 kg at calf removal). Cows in the C group ($n = 10$) averaged 2.4 ± 0.3 follicular waves during the 24 day period of ultrasound scanning. Dominant follicles emerged every 7.1 ± 0.6 days, grew at 1.4 ± 0.1 mm per day and attained a maximum diameter of 10.8 ± 0.1 mm 6.3 ± 0.8 days after emergence. The rate of DF regression was 0.9 ± 0.1 mm per day and the average DF life-span was 15.6 ± 1.0 days. In the CR group ($n = 9$), the maximum diameter of the DF was greater following than before calf removal (11.8 ± 0.5 mm versus 10.4 ± 0.2 mm; $P < 0.001$). The emergence of a new follicular wave occurred immediately prior to (in 4/9 cows) or during (in 5/9 cows) the period of calf removal. Only 3/9 cows ovulated during the 12 days that followed calf removal, and they all belonged to the CR96 treatment group (Table 1). These three cows ovulated 5, 8 and 11 days after the onset of temporary calf separation. The interval from the onset of treatment to the first increase in plasma progesterone concentrations did not differ between treatments. Plasma progesterone concentrations did not increase in two of the three cows in the CR group that were deemed to have ovulated by ultrasonography.

Live weight of calves did not differ between treatments at the beginning of the calf removal period (87 ± 3.8 and 80 ± 3.27 kg for Control and the CR96 groups respectively).

Table 1
Follicular dynamics and reproductive performance in postpartum beef cows suckled ad libitum (Control) or before and after a 96 h period of calf separation (CR96), (Experiment 1)

Parameters	Control	CR96
Maximum follicular diameter before CR (mm)	11.3 ± 0.5	10.4 ± 0.2
Maximum follicular diameter after CR (mm)	12.7 ± 0.6	11.8 ± 0.5
Timing of wave emergence around the day of CR (day)	−1.2 ± 0.8	−0.2 ± 0.6
Cows with follicles in the growing phase at CR	9/10	9/9
Number of cows ovulating within 12 days of CR	0/0 a	3/9 b
Days from onset of CR to ovulation (range)		8.0 ± 1.4 (5–11)
Days from onset of CR to first progesterone rise	30.5 ± 6.1	36.5 ± 5.7
Number of cows with short (<17 days) cycles	7/7	6/7
Days from onset of CR to conception	34.3 ± 4.8 ($n = 8/10$)	40.0 ± 4.8 ($n = 7/9$)
Non-pregnant cyclic cows at the end of the mating period	2/2	2/2

Means with different letters (a, b) within rows differ ($P < 0.05$).

Mean daily live-weight gains during the period of calf separation were lower ($P < 0.05$) for those calves that were separated from their dams than for those calves that retained free access (0.18 ± 0.1 kg per day versus 1.20 ± 0.1 kg per day). Moreover, differences in live weight were still present at the time of weaning (182 ± 5.4 kg versus 205 ± 6.3 kg, for the CR96 and Control groups respectively, $P < 0.05$), when the calves were 6 month of age.

3.2. Experiment 2

Cows gained BCS (from 3.96 ± 0.08 to 4.2 ± 0.08 units; $P < 0.05$) and live weight (from 383 to 402 kg; $P = 0.06$) between calving and the initiation of temporary calf removal. The combination calf removal for 96 h and GnRH treatment 24 h before calf return ensured that all cows ovulated. In contrast, fewer (4/12; $P < 0.05$) cows ovulated that did not receive GnRH treatment. For cows that did ovulate within 12 days of calf removal, the mean interval from onset of CR to first ovulation, determined by ultrasonography, was similar for cows in the CR96 + GnRH and CR96 treatment groups (5.4 ± 0.3 days versus 3.8 ± 0.8 days). The diameter of the ovulatory follicle tended to be smaller for cows in the CR96 + GnRH (9.8 ± 0.3 mm) than in CR96 (11.3 ± 0.9 mm; $P = 0.06$) treatment group. The maximum diameter of the corpus luteum (CL) also tended to be smaller for cows in the CR96 + GnRH (12.1 ± 2.4 mm) than in the CR96 (16.7 ± 7.5 mm; $P = 0.08$) treatment group. Consequently, the maximum concentrations of progesterone in peripheral circulation within 14 days of calf removal tended to be lower ($P = 0.06$) for cows in the CR96 + GnRH (0.66 ± 0.1 ng/ml) than in the CR96 (2.0 ± 1.1 ng/ml) treatment group. Cows in the CR96 group conceived earlier during the mating period than cows in the CR96 + GnRH group (Table 2).

For cows in the CR96 treatment group, the diameter of the DF that emerged during the period of calf removal was greater ($P < 0.05$) than the diameter of the DF that emerged immediately prior to calf removal (11.3 ± 0.4 mm versus 9.9 ± 1 mm). Moreover, the maximum diameter of the DF during the 4 days of calf removal was greater ($P < 0.05$) in

Table 2
Follicular dynamics and reproductive performance in postpartum beef cows before and after a 96 h period of calf separation (CR96) or calf separation for 96 h with 250 μg GnRH given on the day prior to calf return (CR96 + GnRH), (Experiment 2)

Parameters	CR96	CR96 + GnRH
Maximum follicular diameter before CR (mm)	9.9 ± 1.5	10.0 ± 0.3
Maximum follicular diameter after CR (mm)	11.3 ± 0.4	10.1 ± 0.3
Timing of wave emergence around the day of CR (day)	-1.6 ± 0.8	-1.8 ± 0.5
Cows with follicles in the growing phase at CR	10/12	9/12
Maximum diameter of the ovulatory follicle (mm)	11.3 ± 0.9	9.8 ± 0.3
Number of cows ovulating within 12 days CR	4/12 a	12/12 b
Days from onset of CR to ovulation	3.8 ± 0.8	5.4 ± 0.3
Days from onset of CR to first progesterone rise	17.2 ± 5.0	7.6 ± 3.9
Number of cows with short (<17 days) cycles	4/4	12/12
Days from onset of CR to conception	20.0 ± 6.6 a ($n = 3/12$)	52.2 ± 5.7 b ($n = 4/12$)
Non-pregnant cyclic cows at the end of the mating period	2/9	0/8

Means with different letters (a, b) within rows differ ($P < 0.05$).

those cows that subsequently ovulated than in those that failed to ovulate (11.5 ± 0.7 mm versus 9.6 ± 1.1 mm).

The mean live weight of calves at the start of the calf removal period did not differ between treatment groups (71 ± 1.5 kg versus 69 ± 2.1 kg for CR96 and CR96 + GnRH groups, respectively). Mean daily live-weight gains were also similar for calves from each treatment group (0.29 ± 0.3 kg per day versus 0.22 ± 0.3 kg per day for CR96 and CR96 + GnRH groups, respectively). Consequently, live weight at weaning was also similar for calves from each group (144 ± 3.2 kg versus 139 ± 4.1 kg, for CR96 and CR96 + GnRH groups, respectively).

3.3. Experiment 3

Cows gained ($P < 0.05$) live weight between calving and the initiation of temporary calf removal (from 363 ± 5.0 to 400 ± 5.0 kg), but BCS was unaltered during this period (3.9 ± 0.06 units at calving and at calf removal). Calf separation for 144 h resulted in 5/8 cows ovulating compared with no cows ovulating in the Control group and 2/8 cows in 96 h calf removal group. The administration of GnRH resulted in 16/24 cows ovulating compared with only 7/23 cows ovulating when no GnRH was administered ($P < 0.05$). However, most cows were unable to maintain oestrous cyclicity and became anoestrous again. Although not statistically significant, 3/5 cows in the CR144 group were able to maintain ovarian cyclicity. This was in contrast to the other treatments where only 1–2/8 cows became cyclic (Table 3). These observations are supported by differences in the length of the period between first and second progesterone increase (induced and natural ovulation). This period averaged 20.8 days for cows in the CR144 group. In contrast corresponding periods for the remaining cows on the experiment were 58, 42.5, 52, and 32.6 days for the GnRH, CR96, CR96 + GnRH and CR144 + GnRH, treatment groups respectively; $P = 0.06$). However, no difference in conception date was observed between cows in each of the treatment groups. The maximum diameter of the corpus luteum formed after induced ovulation was smaller ($P < 0.05$) for cows receiving GnRH only (12 ± 1.9 mm, n=2) than for cows on the CR96 (20 ± 1.9 mm, $n = 2$), CR96 + GnRH (18 ± 1.1 mm, $n = 6$), CR144 (19 ± 1.3 mm, $n = 5$) and CR144 + GnRH (20 ± 0.9 mm, $n = 8$) treatment group.

Table 3
Reproductive performance in postpartum beef cows after calf removal and/or GnRH administration (Experiment 3)

	Number of cows ovulating within 12 days after treatment	Number of cows cycling after first induced ovulation	Diameter of ovulatory follicle (mm)	Interval from onset of CR to first P4 rise (day)	Interval from onset of CR to conception (day)
Control	0/7 a	–	–	53.2 ± 9.4 a	58.2 ± 6.2
GnRH	2/8 a	0/2	9.5 ± 0.5 a	35.8 ± 7.9 ac	52.4 ± 5.2
CR 96	2/8 a	0/2	10.5 ± 1.5 ab	43.2 ± 8.6 ab	61.3 ± 5.6
CR 96 + GnRH	6/8 b	1/6	10.2 ± 0.5 a	18.8 ± 8.6 bcd	65.2 ± 5.6
CR 144	5/8 ab	3/5	12.2 ± 0.6 b	18.4 ± 7.9 cd	55.0 ± 5.2
CR 144 + GnRH	8/8 c	2/8	10.4 ± 0.5 ab	9.2 ± 7.4 d	49.2 ± 6.2

Means with different letters (a–d) within columns differ ($P < 0.05$).

The mean live weight of calves at the beginning of the calf-removal period did not differ between suckling treatments (77 ± 3.2, 79 ± 2.9 and 83 ± 4.5 kg for ad libitum suckling, 96 and 144 h calf removal, respectively). Mean daily live-weight gains were different for calves from each treatment group during the period of temporary calf removal (1.25 ± 0.2, 0.60 ± 0.4 and −0.02 ± 0.1 kg per day for ad libitum suckling, 96 h and 144 h temporary calf removal, respectively; $P < 0.05$). However, live weight at weaning was similar for calves from each treatment group (175 ± 4.3, 180 ± 4.5 and 181 ± 7.4 kg, for ad libitum suckling, 96 and 144 h calf removal, respectively).

4. Discussion

Calf removal for 96 h at Day 60 postpartum induced ovulation in around one-third of cows in moderately low body condition at calving. Calf removal for a further 48 h (144 h in total) induced ovulation in around two-thirds of cows of similar body condition at calving. The absence of large follicles did not appear to be the factor limiting resumption of ovulation in those cows that failed to respond to calf separation since, in all experiments, cows achieved DF greater than 9 mm in diameter. Alternatively, the acute increase in LH pulse frequency in response to weaning (not determined in the present study) or calf separation (Sinclair et al., 2002) can be markedly attenuated by the premature return of the calf (Shively and Williams, 1989), and this may have been the reason for ovulation failure in some cows in the present study. Administration of GnRH 24 h prior to calf return in the second and third experiments of the current study overcame this problem and was effective in inducing almost all cows to ovulate, although it was unable to induce all cows to cycle normally thereafter.

Results from the present study are broadly in agreement with those of others. On the basis of previous reports (Walters et al., 1982; Wright et al., 1987) one might expect that 48 h of calf separation would be sufficient to lead to a significant increase in LH pulse frequency. However, it has also been reported that intact weaned females require up to 6 days to exhibit an increase LH pulse frequency sufficient to induce ovulation (Shively and Williams, 1989). This large natural variability in the time required for LH pulse frequency to increase following calf separation may have contributed to the poor response to temporary calf separation in the present study. Factors that could explain this variability include body-condition score (Alberio et al., 1984), the interval from calving to calf separation (Bonavera et al., 1990), and the stage of follicular development at the point of calf separation (Sinclair et al., 2002). Alberio et al. (1984) observed an increase in pregnancy rate following 72 h calf separation for cows in good body condition but not for cows in poor body condition. Similarly, in the study of Sinclair et al. (2002) 70% of cows in moderate body condition at calving ovulated the first dominant follicle to emerge after Day 21 postpartum in response to calf separation and once-daily suckling. In contrast, only 25% of cows in poor body condition at calving responded to restricted suckling in that study.

The average interval from the GnRH administration to ovulation, detected by ultrasonography, was 58 ± 8.6 h, but 75% of the cows ovulated 48 h after GnRH injection. These results are in agreement with those of McDougall et al. (1995), who reported that all suckling cows ovulated between 24 and 48 h following GnRH administration under conditions similar to those in the present experiment, and in close agreement with those of Crowe et al. (1993)

who reported an average interval of 53 h between GnRH treatment and ovulation of the first DF postpartum in beef cows.

The percentage of cows with short cycles in the current study was high but consistent with that reported by Murphy et al. (1990) (78%) and Stagg et al. (1995) (82%) in postpartum beef cows. The reader should exercise some caution, however, in that the twice-weekly blood-sampling regimen employed in the first two experiments limit the precision of such analysis. Nevertheless, the incidence of short cycles appeared not to be affected by calf removal or GnRH treatment in the present study. Previous studies (e.g. Thompson et al., 1999) have shown that the incidence of short cycles can be dramatically reduced and conception rates improved if GnRH administration is combined with progestin treatment. Pre-treatment of anoestrous cows with progestin implants increases GnRH-induced LH release and the proportion of GnRH-induced ovulations in suckled cows (Troxel et al., 1993; Thompson et al., 1999), and alters the timing of $PGF_{2\alpha}$ release during the subsequent oestrous cycle in a manner conducive to cycles of normal length (Cooper et al., 1991; Zollers et al., 1991). In contrast, although calf removal and GnRH treatment induced all cows to ovulate in the present study, only 33% of cows were able to maintain cyclical activity and/or become pregnant; a finding consistent with that of McDougall et al. (1995) in postpartum dairy cows. The tendency of cows that received GnRH in Experiments 2 to have smaller CLs and lower concentrations of plasma progesterone, and the reintroduction of calves within 4–6 days of treatment initiation, may have also contributed to the failure of cycle restoration and pregnancy establishment in these animals.

The weaning weight of calves in Experiment 1 was compromised by temporary separation from their dams. This was neither the case in Experiments 2 and 3 nor in the study of Dunn et al. (1985) where calves were supplemented with a high protein concentrates during the period of separation. Six days of calf removal in the current study did not compromise the maternal bond because cows recognised their calves and allowed them to suckle.

In conclusion, this study has shown that, under range conditions, cows in moderately low body condition at calving respond poorly to a temporary calf removal, but GnRH treatment in combination with calf removal can induce a high proportion of cows to ovulate. The subsequent restoration of normal oestrous cycles following such treatment is an area for further research.

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