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CowTrakker™ technology for improved heat detection

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ABSTRACT

Devices designed to detect motion (CowTrakker™, Bou-Matic, USA) were attached to Holstein-Friesian cows of either NZ or overseas origin. Animals of each strain either grazed pasture or were fed a total mixed ration. Milk samples were collected twice weekly and progesterone content analysed to identify ovulation events. Cows had tail paint applied from 2 weeks after calving, and were observed twice daily at milking for oestrous activity. Recording continued until 6 weeks after the planned start of mating (PSM). Cows were artificially inseminated following a progesterone-based synchrony programme at PSM. CowTrakker™ data were analysed using four algorithms (T3/1, T3/3, T10/1 and T10/3), which varied according to the period of the rolling average used (3 or 10 days) and the standard deviations from that average (1 or 3). These measurements were related to behavioural observations and the occurrence of ovulation. There was a significant number of false positive events detected by the CowTrakker with all algorithms (sensitivity: 12.3, 46.9, 62.3 and 81.5%; specificity: 67.1, 88.4, 95.4 and 99.0%, for T3/1, T3/3, T10/1 and T10/3, respectively) as compared to behavioural observations alone (sensitivity: 71.6%; specificity: 99.6%). The CowTrakker™ was a useful heat detection aid, but must be used in conjunction with careful behavioural observations in order to interpret the high proportion of false positive events that are recorded.

Keywords: dairy cow; oestrus; heat detection devices.

INTRODUCTION

Accurate detection of oestrous events in dairy cows is critical to achievement of high mating submission and pregnancy rates. In typical NZ seasonal herds managed under pasture-grazing systems, 82% of cows are submitted for breeding during the first 28 days of mating, and a pregnancy rate of 61% is achieved. In comparison, herds with proactive reproductive management programmes achieve rates of 91% and 64%, respectively (Hayes *et al.*, 1998). Nationally, submission rates show a downward trend associated with increasing herd size, overseas Holstein genotypes, and increased milk-harvesting efficiency, which has reduced daily contact time with cows (Burton *et al.*, 1999). Poor submission rates affect the economic performance of seasonally-based farm systems through fewer cow-milk days the following season, fewer cows bred to AI, and higher empty rates when the breeding season is finite. Novel systems that could improve heat detection efficiency need to be assessed.

In most NZ herds, heat detection is by behavioural observation, often assisted by the use of tail-paint (Macmillan *et al.*, 1988). Some herds use mount-detectors glued to the tail base (Kamar Heat Detector™ and Bovine Beacon™). Pedometers (devices attached to the leg that measure walking activity; Woolford *et al.*, 1993) and electronic mount-counting devices (HeatWatch™; Walker *et al.*, 1996) have not been widely adopted by NZ herd-owners. This is due to poor cost:benefit ratios and difficulties of maintaining surveillance when cows are grazed distant from the farm dairy.

The CowTrakker™ (Bou-Matic, USA) measures activity, and its ability to detect heat events is based on the assumption that cows in heat are more active. A unit containing a motion recorder is attached to a collar on the cow, so a range of activities contribute to the reading. Data is downloaded telemetrically as the cow walks through an antenna mounted at a point that the cow passes regularly. CowTrakkers™ were developed for intensive dairying

systems and have not been previously tested in NZ. The aim of the project was to compare the efficiency of heat detection between behavioural observations and the CowTrakker™.

MATERIALS AND METHODS

Holstein-Friesian cows of either overseas or NZ origin were managed with either all-pasture or total mixed ration (TMR: maize silage, grass silage and concentrate, with no pasture) in a 2x2 factorial design (Kolover *et al.*, 2000). In spring 2000, a total of 54 of these cows were assigned for this study. The cows, aged two to four years old, calved from 6 June to 26 August (mean calving date: 17 July). Reported results are observations of 50 animals with data from four cows excluded because they displayed abnormal oestrous cycles. Treatment groups comprised NZ/pasture

FIGURE 1: Cow fitted with a CowTrakker™ collar and recording device



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(n=13), overseas/pasture (n=10), NZ/TMR (n=13) and overseas/TMR (n=13).

CowTrakkers™ were attached to 34 lactating cows on 1 August. The remaining cows were incorporated as they calved so that the final cow was enrolled on 27 August. Recording continued until bulls were joined (10 November). Data from the CowTrakkers™ were downloaded once daily as cows passed the recording device placed within the exit of the race where they received their magnesium drench.

Tail-paint was applied to cows 2 weeks after calving. Cows were observed twice daily at milking time for oestrous behaviour and tail-paint removal. The reproductive management plan incorporating whole herd synchrony was based upon a planned start of mating (PSM) of 28 September. Cows that had ovulated previously (n=44) were treated with an intravaginal progesterone-releasing device (CIDR, Pharmacia and Upjohn NZ Ltd., Auckland) for 8 days. An intramuscular (im) injection of 2mg oestradiol benzoate (ODB; CIDROL Injection, Bomac Laboratories, Auckland) was given at CIDR insertion, and 25mg dinoprost (Lutalyse, Pharmacia and Upjohn NZ Ltd, Auckland) was injected im at CIDR removal. Those cows that had not previously ovulated (n=6) were treated with a CIDR for 6 days. All cows received 1mg ODB, injected im, 24h after CIDR removal. Cows observed in oestrus during the 42 days from PSM were bred by AI, then bulls were joined. Pregnancy examination was carried out by transrectal ultrasonography 32 days after PSM.

Milk samples were collected twice weekly from 10 days after calving until 42 days after PSM. Each 30ml milk sample was mixed with 33mg potassium dichromate (Merck, Germany) as a preservative, and stored at 4°C for no more than 7 days before analysis. Concentrations of progesterone in milk were determined using a commercial RIA kit (Coat-A-Count™, DPC, CA, USA). Inter-assay CVs were 6.5%, 9.3%, and 3.7% while the intra-assay CVs were 9.8%, 7.8% and 18.8% for standard concentrations of 4.5, 3.0 and 0.4 ng/ml, respectively. Milk progesterone concentrations higher than 1.5 ng/ml were considered to indicate luteal activity (McDougall *et al.*, 1995), and day of each ovulation was estimated by examination of progesterone profiles.

Data transformation and activity algorithms

Activity data, a reference number for each device and the time and date were downloaded from the CowTrakkers™ once daily. Data were sorted into daily readings for each cow. As readings for pasture-fed cows were approximately 10-fold greater than those fed TMR, data were transformed to a standard normal distribution. Four algorithms (T3/1, T3/3, T10/1 and T10/3) were applied to the data from each cow to identify days of exceptional activity. Algorithms T3/1 and T3/3 used 3-day rolling averages, while algorithms T10/1 and T10/3 used 10-day rolling averages. Observations of exceptional activity were defined to have occurred when the reading for a particular day was greater than one (T3/1 and T10/1) or three (T3/3 and T10/3) standard deviations from the respective rolling average.

Statistical analyses:

Results are given as mean \pm sem. Data were examined

for the coincidence of days when ovulation occurred, when behavioural observations of heat were made, and when the CowTrakkers™ detected days of exceptional activity. Effects of breed strain, feeding, and their interaction were investigated for selected variables using GLM ANOVA (Minitab v.10Xtra, Minitab Inc., State College, Pennsylvania). Age was not considered in the analyses as the total number of cows was small. Proportional variables were tested using a chi-square test. The sensitivities, specificities and predictive values of both behavioural observations and the CowTrakker™ data derived from the four algorithms were compared with the same calculations for a "gold standard" of ovulation events as determined from milk progesterone data (Petrie & Watson, 1999).

RESULTS

The observation period began on 11 August, due to the need for an initial 10 days of recording to establish the T10/1 and T10/3 algorithms, and lasted until 9 November. This comprised 90 days for 34 cows, and shorter observation periods for 16 cows (minimum: 63 days; overall mean: 85.4 days per cow). The total number of cow-observation days was 4272. The synchronised breeding programme resulted in 49 cows being bred within 2 days of PSM. Milk progesterone profiles indicated that all except one (false heat) had ovulated at this time. The non-responder and the false heat cow both exhibited oestrus and ovulated within 10 days of PSM. Twenty-two cows conceived to this mating.

During the study period, 162 ovulations occurred (overall mean: 3.24 ± 0.16 ovulations/cow; range: 1-7 ovulations/cow). There was no effect of breed strain or feed, and no interaction, on the number of ovulations/cow. There were 116 observed heats that corresponded to ovulations (true heats; overall mean: 2.32 ± 0.17 true heats/cow; range: 1-5 true heats/cow). There was no effect of breed strain or feed, and no interaction, on the number of true heats/cow. The probability that true heats would be observed was greater ($P < 0.02$) for the TMR-fed cows than for the pasture-fed cows.

There were 46 ovulations that did not correspond to an observed oestrus (silent heats; overall mean: 0.92 ± 0.12 silent heats/cow). For 18 cows there were no silent heats. Silent heats occurred at the first ovulation after calving in 22 cows, and 10 of these went on to have one or more additional silent heats. The remaining cows that had silent heats had either already ovulated at least once before the study period (n=4), or remained anoestrous until PSM (n=6). One, two and three silent heats occurred in 19, 11 and 2 cows, respectively. There was no effect of breed strain or feed, and no interaction, on the number of silent heats/cow. Eighteen heat observations did not coincide with an ovulation event (false heats; overall mean: 0.36 ± 0.01 false heats/cow; range: 0-2 false heats/cow). There was no effect of breed strain or feed, and no interaction, on the number of false heats/cow.

The four algorithms varied in their sensitivity to identify days of exceptional activity. The T3/1 algorithm identified 34% of all cow-observation days as having exceptional activity, but less than 1% were identified with T10/3. Feed type had a significant effect on the mean number of days with exceptional activity for algorithms T3/3, T10/1 and T10/3, with TMR fed cows showing more days with

exceptional activity than pasture-fed cows (Table 1). Certain extraneous events were associated with days recorded as having exceptional activity, e.g., 7 and 5 cows showed exceptional activity that was not connected to an oestrous or ovulation event on 7 and 10 October, respectively. These events were associated with other management activities for these cows.

TABLE 1: Overall mean (sem), and adjusted means and statistical significance (P) of the feed-type treatments, for the proportion of all observation days that exceptional activity was detected by each algorithm (T3/1, T3/3, T10/1 and T10/3).

Algorithm	Overall activity	TMR	Pasture	P (feed-type)
T3/1	29.7 (0.6)	28.9 (0.8)	30.7 (0.8)	NS
T3/3	11.5 (0.4)	12.5 (0.5)	10.3 (0.6)	P<0.01
T10/1	5.3 (0.4)	6.9 (0.4)	3.5 (0.4)	P<0.001
T10/3	0.8 (0.2)	1.5 (0.2)	0.1 (0.2)	P<0.001

The proportion of days of exceptional activity that coincided with ovulation events varied by algorithm, with 81%, 62%, 47% and 12% of all ovulations coinciding with exceptional activity days for algorithms T3/1, T3/3, T10/1 and T10/3, respectively. Similarly, the proportion of observations of true heats that coincided with days of exceptional activity varied by algorithm (81%, 60%, 51% and 19% for T3/1, T3/3, T10/1 and T10/3, respectively) as did false heat observations (61%, 28%, 6% and 0% for T3/1, T3/3, T10/1 and T10/3, respectively).

For all algorithms there was a significant effect of feed type on the number of times/cow that exceptional activity coincided with ovulation. This number was always greater in the TMR-fed cows, e.g., using T3/3, the adjusted means were 2.89 ± 0.18 and 2.31 ± 0.19 coincidental events/cow for TMR and pasture, respectively (P<0.001). Similarly, the number of times/cow that exceptional activity coincided with true heat observation was greater for TMR-fed cows, e.g., using T3/3, the adjusted means were 1.89 ± 0.15 and 0.78 ± 0.17 coincidental events/cows for TMR and pasture, respectively (P<0.001).

Sensitivities, specificities and predictive values for the detection of ovulation occurrences, using both behavioural observations and CowTrakker™ data for each algorithm, were calculated using detection of ovulations based on milk progesterone data as the “gold standard” (Table 2). The proportion of all observations at which an ovulation event occurred (prevalence) in the milk progesterone data was 3.8%.

TABLE 2: Sensitivities, specificities, and positive and negative predictive values for behavioural observations and days of exceptional activity recorded by CowTrakkers™ analysed for each of the four algorithms (T3/1, T3/3, T10/1 and T10/3), using detection of ovulation from milk progesterone data as the “gold standard”.

	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Observation	0.716	0.996	0.866	0.989
Algorithm T3/1	0.815	0.671	0.089	0.989
Algorithm T3/3	0.623	0.884	0.175	0.983
Algorithm T10/1	0.469	0.954	0.285	0.979
Algorithm T10/3	0.123	0.990	0.328	0.966

DISCUSSION

Our aim was to compare the efficiency of heat detection

using traditional behavioural observations (with tailpaint) with a novel heat detection technology, the CowTrakker™. Both the algorithms T3/3, based on a 3-day rolling average with exceptional data being 3 standard deviations from the mean, and T10/1, based on a 10-day rolling average with exceptional data being 1 standard deviation from the mean, were reasonably specific (88.4% and 95.4%, respectively) but were lower than the specificity of behavioural observations (specificity: 99.6%). Negative predictive values were similar to those of behavioural observation, but positive predictive values were lower (17.5%, 28.5% and 86.6% for T3/3, T10/1 and behavioural observations, respectively). In the light of these results, the CowTrakker™ must be considered as an adjunct to heat detection, not as a replacement. The results suggest that CowTrakker™ data may be of most value in reducing the occurrence of false heat observations, although it will not allow all of these instances to be discriminated. It may be also possible to derive an algorithm, other than those used here, which can reach an optimal compromise between positive and negative predictive values. Additionally, interrogation of the CowTrakker™ more than once daily may improve its performance relative to visual observation.

The efficiency of heat detection varied between the two feeding systems. The probability of correct heat detection based on behavioural observation was greater in the TMR-fed animals. The CowTrakkers™ identified fewer days of exceptional activity in the pasture-fed animals. Overall higher activity averages in the pasture-fed cows may have masked oestrus-related exceptional activity despite standardisation of the data. However, there was also a significant effect of feed type on the number of days on which exceptional activity coincided correctly with both ovulations and true heats, with observations in TMR-fed cows being more likely to be correct. When considered along with the observation that the pasture-fed cows had fewer days of exceptional activity, this suggests that the pasture-fed cows were less likely to display increased activity or exhibit other behavioural change when ovulating. It has been postulated that the modern high-producing dairy cow has a higher incidence of silent heats, and that this is associated with periods of inadequate dietary intake. Negative energy balance may lead to reduced trophic and paracrine support for the ovary with consequent reduction of the steroidogenic capacity of ovulatory follicles and impaired expression of oestrus (Lucy, 2000). Dietary intakes for the TMR-fed cows more closely matched their energetic requirements (Kolver *et al.*, 2000), hence, the lower probability of detecting ovulation events in the pasture-fed cows may arise through a similar path.

In conclusion, we have demonstrated that the CowTrakker™ can operate as a useful heat detection aid, but that it must be used in conjunction with careful behavioural observations to interpret false positive events until more accurate systems for usage and algorithms are determined.

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