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Comparison of three devices for the automated detection of estrus in dairy cows

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ABSTRACT

Considerable technological advances have been made in the automated detection of estrus in dairy cattle, but few studies have evaluated their relative performance on the same animals or assessed cow-related factors that affect their performance. Our objective was to assess the performance and reliability of three devices commercially available in France for cow estrus detection. The devices were a pedometer (PM; Afitag) and two activity meters (AM1; Heatime-RuminAct, and AM2; HeatPhone). Two algorithms were tested for AM2. We fitted 63 lactating Holstein cows with the three detectors from calving to 90 days after calving. The onset and pattern of cyclicity were monitored from 7 to 90 days postpartum measuring progesterone concentration in milk twice weekly. A total of 211 ovulations were identified. Cyclicity was classified as normal in 60% of cows (38/63). Calculated over the operating period of all the devices (179 periods of estrus), the sensitivities and positive predictive values were, respectively, 71% and 71% for PM, 62% and 84% for AM1, 61% and 67% for the first algorithm of AM2, and 62% and 87% for the second algorithm of AM2. Both activity meters had a lower sensitivity but a higher positive predictive value than the PM ($P < 0.05$). For all devices, the performance in estrus detection was much poorer at the first postpartum ovulation than at subsequent ovulations ($P < 0.05$). Lactation rank and milk production affected some devices ($P < 0.05$). These devices could be used to reinforce visual observations, especially after 50 days postpartum, the minimum recommended delay to insemination. However, their full benefit remains to be verified in different farming systems and taking into account the specific objectives of the dairy farmer.

1. Introduction

The efficiency and accuracy of estrus detection is one of the most important factors that influence the reproductive performance and profitability of dairy herds that rely on artificial insemination [1,2]. An improvement in the estrus detection rate of 0.30 to 0.50 would increase profit by €53 per cow per year [3]. The traditional method for estrus detection is visual observation. The accuracy of detection is highly dependent on the intensity of estrus, on the experience of the observer, and the frequency of observations. A cow standing to be mounted is the most specific and accurate sign of estrus [4], but 37% to 54% of detected ovulations are not accompanied by standing estrus in Holstein cows [5–8]. Moreover, the intensity of estrus and

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its duration have dramatically decreased over the last decades [5,9], making detection more difficult for farmers. In the Holstein breed, the duration of estrus was about 18 to 20 hours in the 1980s but, since the early 2000, it has shortened to only 4 to 8 hours between the first and the last standing mount, or 11 to 14 hours if all signs of estrus are taken into account [7,9,10]. The expression of estrus is influenced mainly by the number of cows in estrus at the same time [4,7]. Many other factors could interfere with the intensity of estrus (for review, see [11]), particularly cow factors (the rank of postpartum ovulation, parity, milk production, lameness) and environmental conditions (nutrition, housing, temperature, and humidity).

The rate of successful estrus detection by visual observation varies from 38% to 86% [1,10,12], but it is generally thought that a farmer is able to detect, on average, 50 to 60% of the cows in estrus, depending on the frequency and time of observation, the estrus signs considered, and the experience of the observer. The methods of visual observation have been described, and they include slight signs of sexual behavior, such as sniffing the vagina of other cows and resting a chin on the backs of other cows [5,9]. However, because of the herd size that has increased and the use of skilled manpower that has decreased in contemporary French dairying, the time and expertise available for accurate detection of estrus by visual observation are now compromised [2,13].

The need for this critical but time-consuming task can be avoided altogether by using hormonal induction of estrus, a practice that is now widespread, particularly in the United States [14]. These programs aim to induce synchronous ovulation and thus allowing fixed-time insemination without the need for heat detection. In Europe, the use of hormonal programs to synchronize estrus is not so widespread because of the cost of treatment and because of the reluctance of European consumers to accept products from animals treated with hormones and/or antibiotics [15]. These issues have driven interest in the development of alternative systems that avoid the use of hormones and antibiotics. Particular attention has been paid to the development of inexpensive, reliable, and accurate systems to automatically detect estrus and/or ovulation. They are based on the automated detection of signs of estrus (standing heat and increased ambulatory activity) or ovulations estimated using automated online milk analysis of progesterone (P_4) [16–19]. The performance of automated estrus detectors is generally higher than 75% [12,16,19–21], depending on the settings for the threshold and the reference period in the algorithm used to define the estrus. However, only a few studies have directly compared the performance among devices on the same cows, or assessed the cow-related factors that affect their efficiency and accuracy. The aims of our study were as follows: (1) to assess the comparative performance of three automated devices for the detection of estrus; a pedometer (PM) and two activity meters, and (2) to estimate the influence of cow-related factors, such as ovulation rank, lactation rank, postpartum cyclicity, and the various criteria of milk production, on the performance of these three devices. An "estrus" was deemed to be correctly or incorrectly detected by the automated devices on the basis of P_4 concentrations in milk.

2. Materials and methods

2.1. Animals

The experiment was conducted on an experimental farm in France (longitude: 0°22′ W; latitude: 47°34′ N). Sixty-three Holstein cows were housed in individual stalls during the whole study and fed individually using a total mixed ration based on maize silage and concentrates. The cows had all calved between August 28 and November 8, 2011. Of the 63 cows, 25 were primiparous (40%), 18 were in their second lactation (29%), and 20 were in third or higher lactation (32%). Milking took place twice a day starting at 06.45 and 16.45 hours. On average, peak milk production was 38 ± 6 kg per day, and the minimum content of milk protein calculated for the three first months postcalving (an indicator of negative energy balance) was 29 ± 2 g/kg.

At calving, each cow was fitted with three estrus detection devices. The AfiTag PM (AfiMilk, distributed in France by Packo France) was fixed on a back leg. Tags of the two activity meters, Heatime-RuminAct (AM1; SCR Engineers, distributed in France by Créavia SAS) and HeatPhone (AM2; Medria, France), were placed on the same neck collar.

2.2. Description of automated estrus detectors

The PM records the number of steps taken by a cow per time unit. The data were transmitted twice a day (morning and evening milking) by radio telemetry to a receiver, sited at the exit of the milking parlor. The data were then automatically forwarded to a database on a central computer. The software created an estrus alert for any cow that had a recent activity that exceeded over 70% the prior 10-day average.

The two activity meters detect estrus based on accelerometer technology that records the general activity of the cow in three dimensions. For AM1, data were collected in blocks of 2 hours and transmitted by an infrared connection to an antenna at the exit of the milking parlor and above the drinking troughs.

For AM2, data were collected in blocks of 5 minutes and transmitted by radiofrequency to a receiver on the farm, from where they were forwarded every 30 minutes to a central server *via* the mobile communications network. This system works with a cloud-computing network where data from sensors of all equipped farms are stored. Algorithms and alerts are directly implemented and calculated in this cloud before they are sent to the farmers. Therefore, when the algorithms evolve, it can be validated on a part of the stored data. In this experiment, the manufacturer proposed two different algorithms to be tested (named here AM2 and AM2_2).

For both activity meters, an estrus alert was generated when the weighted activity, calculated using the proprietary algorithm developed by the manufacturers, surpassed a defined threshold.

2.3. Recorded data

For each cow, the data collected were as follows: date of calving, lactation number, milk production, and milk