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New Technology Usage for Sustaniable Dairy Cow Reproductive Perfomances

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Abstract: Technology gives many oppurtunites for cattle farmers for easier and effective herd management possibilities. New era provides many realistic applications using smart applications for farmers. Especially milking is very popular for engineering applications. Reproductive technologies can be seen as frontier applications. Reproductive performances of the dairy farms can be defined as number of calves for cows in a year. It means new material for meat and milk production. Because new female calf means new cow for her while male calf means new material for beef. If meat and milk production are to be increased, cow productivity, i.e. the number of calves produced lifetime must be improved and increased. Although varying among herds, annual average herd incidences of reproductive disorders and reproductive performance were similar to those reported. Managerial practices influenced incidences of retained placenta and uterine infection, days open of cows not bred and of all cows, services per conception and percentages of herd open more than 100 days and culled for low production. Good heat detection programs can have a major impact on overall herd reproductive performance. The best heat detection programs start with careful timing, good observation and the effective use of detection aids. Being able to distinguish and interpret cow behaviour and other signs is critical, so are good record keeping and training for the people responsible for heat detection. Generaly, farmers with the best heat detection results use a combination of observation and heat detection aids. Several options are available to aid heat detection and increase heat detection rates. Although a rich variety of methods have been introduced for the detection of oestrus, a more accurate and practical method is still required.

Key words: Technology, dairy farms, reproductive perfomances, sustainablity.

1. Introduction

Animal production is still depending on manpower and work conditions are very hard. Daily routine required detailed technical knowledge and efficient usage of the information for successful animal husbandry system. Many daily activities aim at ideal animal production. Many experts must visit farms and have to visual scoring at specific days for some managemental decisions. It takes time and requires experience and sometimes highly expensive methods. But recent development helps farmers for best and easy production way using smart facilities which is developed for using latest technologies. Now, fully automated systems continuously and quantitatively measure production, behaviour and health of animals using these technologic aids. Many technologic instruments focused on reproductive performances of cattle farms. Reproductive perfromances of the dairy farms can be defined as number of calves for cows in a year. It means new material for meat and milk production. Because new female calf means new cow for her while male calf means new material for beef. If meat and milk production are to be increased, cow productivity, i.e. the number of calves produced lifetime must be improved and increased. Although varying among herds, annual average herd incidences of reproductive disorders and reproductive performance were similar to those reported. The accurate heat detection is the most important factor to get successful reproductive perfromances. Fertility is the ability of male and female animals to produce viable germ cells, mate, conceive and deliver normal living young [1]. This decreases in reproductive

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efficiency conservatively cost $12,000 per year per herd if one assumes a $2 loss per each day open over 115 days and an average herd size of 135 cows. This is not even taking into consideration the additional losses of fewer replacements, increased labor, fewer cull cows, increased drug and veterinary expenditures [2]. Traditionally, oestrus detection is performed by visual observation of the dairy herd depending on the several signs of beginning oestrus. The productive efficiency of cows can be described in biological or economical terms. Biological efficiency is usually measured in terms of calf weight weaned per cow exposed per total digestible nutrients consumed, because this indirectly accounts for milk production, nutrition and reproduction [3]. Also, cow productivity index incorporates calf bodyweight at 6, 9 or 12 months and the bodyweight equivalent of milk produced. As used by Trail, J. C. M. and Gregory, K. E. [4], measures of reproductive performance, cow and calf viability, milk yield, growth and cow weight are combined to derive the cow productivity index (kg) per cow per year or per 100 kg liveweight of cow of breeding age maintained annually. Many equations are reported for calculation for cow production index [5]. In each case, cow reproductive performance (fertility) is very important. Richardson, F. D., et al. [6] estimated that 70% of the variability in cow productivity is attributable to calving rate.

Reproductive performance is the trait of outstanding importance in cattle enterprises. The best cows are clearly those that have their first calf at an early age, have minimum calving intervals and live a long time in a herd without problem. A cow must be inseminated in 80 to 85 days after calving to maintain a yearly calving interval. This is not easy work for dairy manager. With the nutrient priority of beef cattle being body maintenance, growth, lactation, fetal growth, breeding and body reserve, according to Short, R. E., et al. [7], research indicates that reproduction is low on the list. This parameter of a cow is influenced by many foctors and intensive systems required controlled of them. The complexity of the problem of low reproductive perfromences and the difficulties encountered in obtaining definite results are indicating the general headings of inheritance, nutrition, disease and management. But low reproductive performances in dairy cattle effect cattle farmers in many aspects and have a great economic loss to the farmers year after year. The actual loss in income from nonbreeding and slow breeding dairy cattle probably amounts to a million dollars each year. Many farms have to live with these loses. Managerial practices influenced incidences of retained placenta and uterine infection, days open of cows not bred and of all cows, services per conception and percentages of herd open more than 100 days and culled for low production. Veterinarian was the most consistent variable influencing herd reproductive performance [8]. The potential benefits of these systems for oestrus detection result from the opportunity to combine the strengths of the farmer and the computer based system. Many parameters can be taken from animals for making right decisions. Cattle body temperature, feed consumption, milk production, milk composition, blood parameters and behaviour can be measured and used for make reproduction management decisions.

2. Heat Detection

Heat detection is very critical subject for ideal reproductive performances of the cows. Many studies have been carried out for good heat detection methods. AI (Artificial Insemination) process will only be achieved if the insemination is done at the most appropriate time in relation to the oestrous period. Especially, oestrus detection is very limiting factor for AI timing and good result. Detection of estrus is the first step in getting a cow pregnant. The optimal time of insemination relative to ovulation was found to be 24 h to 12 h before ovulation [9]. Visual detection of estrus is still a key method. Good heat detection programs can have a major impact on overall herd reproductive performance. The best heat detection programs start with careful timing, good observation and the effective use of detection aids. Visual detection of estrus is a challenging job, to aid the farmer to made this hard work easiser. EDTs (Estrus Detection Tools), such as pedometers, neck mounted collars to measure activity and pressure sensing devices to measure standing estrus, have been developed till now [10-12]. Performance of EDTs varies between research results but is overall better than visual observation of estrus [12].

Being able to distinguish and interpret cow behaviour and other signs is critical, so are good record keeping and training for the people responsible for heat detection. Primary signs of osterus are to accepte mounting activity of cow. Standing to be mounted by herd mate or bull is the most definite and accurate sign that a cow is in heat. During the period of standing heat, cows stand to be mounted by other cows or move forward slightly with the weight of the mounting cow. But Roelofs, J. B., et al. [13] found that 90% of cows in estrus showed mounting behavior, whereas only 58% of cows in estrus showed standing-to-be-mounted behavior. The first mount was displayed on average 29 h before ovulation. Other secondary signs of heat are clear mucus discharge, restlessness, swelling and reddening of vulva, hair loss and dirt marks, blood stains on the tail or vulval area (metoestrous bleeding). These secondary signs of heat and may indicate that a cow is coming in heat, in which case closer attention should be given to her over the following 48 hours.

The duration of the oestrous cycle averages 21 days in cows within a normal range of 18-26 days [14, 15] and 20 days in heifers [16]. Published estimates of the duration of oestrus vary considerably. Detecting cows on heat has become increasingly difficult over the past few decades. Herd sizes have increased, the availability of skilled labour has decreased and there is evidence that cows are having shorter heats and their heats are of lower intensity. Timing of oestrus detection and oetsrus is not synchronized especially for intensive dairy farm at working hours. Because the onset of heat activity follows a distinct pattern with greatest activity in the early morning and late evening [17]. Many methods were used for heat detection all over the world. Technology gives many oppurtunites for cattle farmers for easier and effective herd management possibilities. New era provides many realistic applications using smart applications for farmers. Especially milking is very popular for engineering applications. Reproductive technologies also can be seen as frontier applications. The technology is designed to help find more animals in heat, which should increase insemination rates. For many years, researchers carried out many studies for heat detection and had offered the most accurate technique for predicting the optimal insemination moment of each cow. The new technologies are not directly diagnosing cows in heat. They use some signals of oestrus for detection. They are easier to use, require less maintenance once applied and can increase heat detection rates for high reproductive performances.

Generaly, farmers with the best heat detection results use a combination of observation and heat detection aids. Several options are available to aid heat detection and increase heat detection rates. Technological aids to improve heat detection include the use of pressure activated heat mount detectors, radio telemetric devices, pressure sensitive mount count devices, sensors and pedometers.

Generaly, technology developed rapidly and many technologic developments made easier to understand and evaluate cow behaviour using computer possibilities and image analyses techniques interpreting and using for herd management. As a general observation of cow activity and behavior used for oetsrus detection, these technologies determined milk, blood, saliva, mucus, smell and voice changes of cows during oestrus period and used data for statisticaly analyse to interpret and report farmers for herd managing decisions. Each technologic aid depends on cow nature and uses for herd management.

Many farmers prefer observation and some technologic methods for better heat detection rate. Mounting activity is first visible, acceptable signs of oestrus for cows. Many methods use these signals looking for specific patterns of riding activity such as frequency, number and length for better heat detection. But accuracy rate is very variable depending on the conditions.

Heat mount detectors are more expensive than tail paint, but are easier to read, require less maintenance once applied and can increase heat detection rates [11].

Telemetric heat mount detectors record time and duration of mounts for individual cows, but are expensive. This includes use of a battery powered, pressure-sensitive transmitter, a signal receiver, a buffer for receiving and storing mounting activity data, and software for interpreting the information contained in the radio-telemetric signals and for generating reports using personal computer. Telemetric heat mount detector systems allow high heat detection rates to be achieved. A pressure-activated sensor is applied to the rear portion of the backbone of each cow [17]. Cows on heat will stand when mounted by herdmates or a bull and the pressure from the brisket of a mounting animal activates the sensor. These devices provide the time of onset of heat, which is useful in determining when to inseminate a cow. Patches hold the pressure-activated sensors on. Correctly applied patches remain on the cow indefinitely and are rarely dislodged. The sensor can be removed from the patch for use on other cows. Every cow to be mated requires a sensor, making this system more expensive in seasonal calving herds than in split and year-round calving herds.

Some disposable devices are used for monitoring cow heat behaviour continuously. When a heat is identified, flashmate flashes red for 26 hours, indicating the cow is ready for artificial insemination. The device continues monitoring for subsequent heats and if the cow does not return to heat after 25 days, it will begin flashing green to indicate that the cow is a 'non-return' and likely pregnant.

Components of the heat watch system are: (1) a miniaturized pressure-sensitive radio transmitter, powered by a lithium 3-volt battery and secured in a water resistant pouch attached to a nylon mesh patch; (2) a signal receiver; and (3) a buffer that stores activity data until it is downloaded to software that enables routinely generated management lists. Activation of the sensor sends a radio telemetric signal containing code for transmitter identification, date, time and duration of standing event [18].

Activity meters (including pedometers) can be integrated into computerised herd information systems, but they are expensive. These systems are electronic transponders that detect movement. Pedometers are one type of activity meter that is strapped onto the lower leg of each cow in the herd. Other meters hang around the cow's neck. Throughout the day, they record cow movement. Cows on heat walk more as they are restless and mount other cows. Walking is recorded and compared to the record of activity on previous days when the cow was not on heat.

Some brands make the comparison to the rest of the herd on the same day. At the dairy, the information is stored in a computer from which cows most likely to be on heat can be automatically drafted if facilities are installed. In general, heat detection using activity meters is likely to be slightly more accurate in housed cattle compared with grazing cattle and more accurate in cows milked routinely compared to voluntary automated milking systems [19].

The activity data were collected every hour for the cows. The data were analyzed using smart technologies and then filtered against usual activity of herd mate to recognize the cows in estrus. The system is compatible with ear tag identification system. The message for estrus alert may be received on mobile phone. This method of heat detection is recent updated and advanced except the cost of initial investment is high. Accuracy of the system is more than 82 percent.

The best results were reported as pedometers [20]. Results of oestrus detection varied depending on the used threshold value, the number of cows, housing and treatment of cows and the utilised method of time series analysis. The detection rate of most investigations is sufficiently high at 80-90%. Error rates between 17% and 55% and specificities between 96% and 98% indicate a large number of false positive oestrus warnings.

In addition to the behavioural changes, physiological changes also occur during the estrous cycle. These changes can be summarized as uterine contractions, vaginal cytology, cellular water content of the vulva tissues, protein content of the edema fluid, blood flow increases to the uterus and chemical changes in the cervical mucus. Some other methods used these variables as a indicator of eaostrus.

Milk progesterone analysis can be a tool to help herd managers and veterinarians troubleshoot causes of poor reproductive performance, especially problems associated with heat detection. Progesterone concentrations can be used to verifyinig the cow is in/or near heat. Milk progesterone testing may be useful in verifying cow oestrus [21, 22].

The concentration of progesterone in blood is correlated closely with levels found in milk. The relative relationship between milk and blood concentrations is the same [23]. Progesterone is low during proestrus and during heat. It begins to rise slowly after ovulation as the CL (Corpus Luteum) develops.

2.1 17β-estradiol and P in Milk

EIA (Enzyme Immune Assay) based on determination of pre-ovulatory estradiol in raw milk sample is precise method to describe cows in heat along with P isolation and quantification [21]. It is reliable, rapid, economic and a precise method to describe cow heat.

2.2 Vaginal Temperature

Vaginal temperature increases before ovulation [23]. Recently, studies were done to see whether infrared thermography could be used to detect estrus and predict time of ovulation. Radio telemetry based on vaginal temperature measurement was also used with reliable results.

2.3 The Ruminal Temperature

Electronic intra-ruminal sensors and telemetry offer new opportunities for remote monitoring of the rumen environment [24]. Sensors capable of measuring pH, temperature and pressure were subjected to laboratory and intra-ruminal evaluation in rumen-fistulated cows offered baleage indoors or hay with pasture outdoors. The ruminal temperature also raised during time of estrus measured by sensor based on intra ruminal electronic radio-telemetric bolus.

2.4 Infrared Thermography of the Vulva and Muzzle

In one study, sensitivity of 75% was found with infrared thermography of the vulva and muzzle every four hours. This sensitivity was higher than the sensitivity with six times daily visual observations (67%). Specificity and PPV (Positive Predicted V-value), however, were lower with infrared thermography (57% and 69% respectively) compared with visual observations (86% and 89% respectively, [24]). A study done by the same group in which eye, vulva and muzzle temperature were measured using infrared technology showed poor performance for detecting estrus [25].

2.5 Vaginal pH

pH is good indicator of animal in estrus. The pH falls from 7.0 to 6.72 one day before estrus which further fall to a level of 6.45 immediately before ovulation.

2.6 Vaginal Smear

The differential staining properties of vaginal smears shows cytoplasmic lipids in vaginal smear and urinary sediments. Smear also shows increase in cornified acidophil cells during estrous period. NMR (Nuclear Magnetic Resonance) can be used for detecting changes in vaginal mucus associated with estrus. But price of the equipment, collection of mucus from cows, and purification of the sample before analysis is very problem for fiel applications.

2.7 UWB (Ultra-Wide Band) Technology

A novel approach to detect estrus is the use of ultra-wide band technology. This technology can measure 3-dimensional positioning and could be used to monitormounting and standing-to-bemounted behavior. In a study, 9 out of 9 possible cows were detected in estrus automatically by UWB technology and 6 out of 6 cows were correctly identified as not in estrus [26].

2.8 Cow Smell

The device is based on detection of pheromones. The heat of the pheromones is the natural olfactory signal for bull that cow is in heat. Trained dogs were having the ability to detect estrus odour correctly in approximately 80 percent of estrus cow. Dog can detect estrus by urine and milk, after being trained with vaginal fluid samples [27]. The odour is not emitted by vaginal mucus or urine was also reported [28]. The pheromones are actually released by the dung of cow in estrus. Pheromones are volatile fatty acids i.e., AA (Acetic Acid), PA (Propionic Acid) and 1-iodoundecane [21]. The synthetic compounds (volatile fatty acids) were rubbed on to dummy cows, and bulls has shown similar response, however, only two volatile chemicals i.e., AA and PA isolated later in faeces estrous cow [28]. It is up to 90 percent efficient. Still the project is running in future if successful further development steps are anticipated.

2.9 Cow Sound

Ikeda, Y. and Ishii, Y. [29] claimed that the vocalization of a cow contains information not only about the animal's extraordinary condition, such as pain, oestrus, separation from her calf and hunger or thirst, but also about the animal's individuality. Consequently, vocalization can be used as a signal for the detection of these conditions by objective, non-contact and remote sensing techniques. Chung, Y., et al. [30] reported that the efficient data mining solution for the detection of oestrus is avaible to use the sound data. In this method, reserachers extracted the mel frequency cepstrum coefficients from sound data with a feature dimension reduction, and used the support vector data description as an early anomaly detector (Fig. 1). Their results show that this method can be used to detect oestrus both economically (even a cheap microphone) and accurately (over 94% accuracy), either as a standalone solution or to complement known methods.

2.10 Automated Heat Detection Systems

Computerised milking systems have spawned a number of electronic monitoring devices, which can be used to aid heat detection. This makes activity readings an excellent indicator of heat. Most automated heat detection systems work by monitoring changes in cow behaviour. The simplest sensors have a ball or mercury switch inside a chamber that moves from side to side creating a total activity count. More advanced sensors measure both the direction and the intensity of movement in three different planes: side to side, up and down, and front to back. Cow motion is monitored multiple times per second to help identify different activities such as lying, standing, mounting, walking or grazing. The sensor sits inside a waterproof housing that also includes a battery, a miniature processor for processing the data, a memory device for temporary data storage (usually up to 24 hrs) and a data transmitter. The monitoring device is attached to the cow by a leg strap or a neck collar (which may be weighted to keep the device in position). Earlier devices downloaded activity counts in 12 hour blocks each time the cow passed through the milking shed, allowing comparison of cow activity

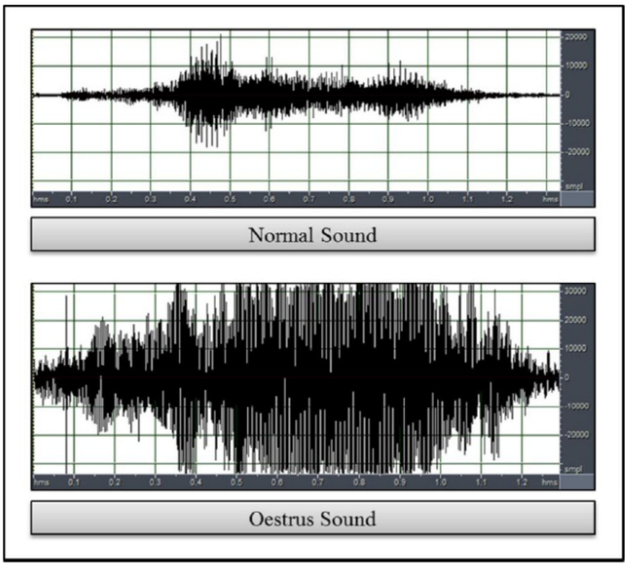

Fig. 1 Spectrums of oestrus sound and normal sound, respectively [30].

only twice daily. More recent devices divide the activity data into 2 h, 1 h or 15 min time blocks, allowing for more precise identification of increases in cow activity and an indication of the optimal time for insemination of each cow. Some systems allow the activity thresholds to be optimised for the individual farm. In systems with automated drafting facilities, there are normally options to create auto drafting rules for cows identified as at risk of being on heat. The information on the base computer may also be accessible remotely by another computer, smart phone or tablet device connected to the internet. The remote device may only retrieve information or it can also input information and control the program's decision making abilities such auto drafting [19].

Video camera and recording systems are unique for heat observation and data recording of herd. Television cameras hooked up to a monito in the house or office can be of assistance in watching for cows in heat, and extend the times at which the cows can be observed. Using time lapse and fast play back, the estrous activity of the night can be viewed in half an hour. It is applicable in intensive system of housing (close housing), however, the range of camera may either miss cows because they are not within view of the camera. This method may not be applied in loose house and range system.

Williams, W. F., et al. [31] reported that efficiency of estrous cycle detection (as defined by changes of progesterone concentration in plasma) ranged from 67% to 74%. Combinations of heat mount detectors, and pedometers techniques ranged in efficiency from 84% to 93%. Also, accuracy of estrus detection (based on changes in progesterone concentration) varied widely, from 29% to 95%. Cavalieri, J., et al. [32] reported that tail-paint, heat mount detectors, pedometers and heat wacth provide a high sensitivity (> 80%) and positive predictive value (> 85%) of detecting oestrus.

2.11 Infrared Spectroscopy and Magnetic Resonance Spectra

NI (Near Infrared) reflectance spectroscopy is generaly used for feed analyses. These instruments could enable direct measurements of the live animal [33]. Infrared spectroscopy and nuclear magnetic resonance spectra are carried out to detect estrus related change (inflammatory reaction) in vaginal mucus, vulva and vestibule [33]. Results reported that NI analysis of the live cow is possible and changes in the vulva and vestibular tissue during the estrous cycle can be detected but not practical because of results variability.

2.12 Laparoscopic Technique

Laparoscopy is a surgical diagnostic procedure used to examine the organs. It's a low-risk, minimally invasive procedure for cow health. It is used for examining organ situations in general and especially ovary. Laparoscopy uses an instrument called a laparoscope to look at the abdominal organs. A laparoscope is a long, thin tube with a high-intensity light and sometimes a high-resolution camera at the front of the instrument. Although the technique is used for heat detection timely and accurately, it is not economical to be used by farmers in field condition [34].

2.13 Endometrial Biopsy

During the post partum period, the uterine environment is dynamic with tissue involution, and infectious and inflammatory processes occurring simultaneously. Endometrial biopsy sampling has attracted concern regarding potential animal health and fertility. It shows rise in phosphate activity around estrus. Uterine biopsy was performed in cows exhibiting signs of estrous cyclicity to specifically monitor the expression of oxytocin receptors [35, 36]. Chapwanya, A., et al. [37] reported that if this technic is carried out appropriately, bovine endometrial biopsy is a safe and reliable technique for assessing postpartum uterine function or health.

2.14 Vaginal Conductivity

The decrease in electrical resistance or rise in conductivity of the vaginal tissues and discharges during estrus were well reported. Vaginal probe approach also includes intra-vaginal or implantable resistance devices with transponder to send the information directly to computer. Measurement of vaginal conductivity requires repeated insertion and repeated measurement. This application can produce inflammation which may affects the reading. Vaginal resistance can vary with site of probe in animal i.e., measurement of resistance in posterior vagina is less reliable than anterior vagina [34].

2.15 The Cervical Mucus Discharge

The cervical mucus viscosity decreases depending on the time of estrus. The cervical mucus discharge is collected from cow suspected of heat; it is smeared on slide and evaluated changes of this slide appearance [34].

2.16 Cervical Mucus Glucose Content

The level of glucosidases is significantly different between spontaneous and induced oestrus groups. Conversely, ALP and α-amylase activity were similar. Lactatede hydrogenase activity did not differ between spontaneous and PGF2α-induced oestrus groups. The glucose test is more positive on day of estrus than on the other day [34, 38].

2.17 Sensors Based Fuzzy Logic System

Researchers proposed a mounting detection method using a laser sensor. From the experiments, researchers confirmed that this system could detect a mounting by 100% in normal conditions and 91.6% for detection of standing behavior. However, they need to improve the robust of method under night time vision. The standing cows remain briefly motionless for several seconds when repeatedly mounted by mounting cow. This system measures the highs and distances of mounting and standing cows by detecting the movement signals of mounting behavior [39]. When signal of the sensor exceeds a threshold value, the system determines achieving the goal of estrus detection.

3. Conclusiions

In cattle breeding in 1960s, technological aids developed many inventions. Effective oestrus detection is important for improved reproduction. Commonly, oestrus detection is performed by visual observation, but this is particularly difficult on large dairy farms because of short observation periods during feeding and milking. As a result of technical progress in monitoring cows using computers, automatic oestrus detection has become possible. In many studies, different traits have been analysed for utilisation in automatic oestrus detection. Technological aids to improve heat detection include the use of tail paint, oestrous synchronisation, vasectomised bulls, pressure activated heat mount detectors, radio telemetric devices, pressure sensitive mount count devices, sensors and pedometers. Although a rich variety of methods have been introduced for the detection of oestrus, a more accurate and practical method is still required.

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