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The Sensor Technologies for More Efficient Cow Reproduction Systems

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Abstract –*In cattle breeding, efficient estrus detection is the main criteria for high pregnancy rate in order to obtain one calf in a year. Good reproduction management is a key factor for successful dairy farming. Inadequate and inaccurate estrus detection is frequently a cause of cows becoming repeat breeders. Sensor technologies are being used to monitor the production and physiological condition of the animals. Increasingly, these innovations are leading to a more efficient performance of dairy cows, in terms of both physiology and profitability. A number of both inexpensive to expensive aids and technologies are available to meet some but not all of these criteria. Although costs associated with computerized estrous detection are higher than other methods, the benefits may pay off with increased estrous detection accuracy. Several options are available to aid heat detection and increase heat detection rates. With the use of intelligent technological aids in oestrus detection, the grower has the opportunity to make more profitable production with less labor use, high fertility success and increased milk yield. Oestrus is the event when cows signal that they are receptive to be mated and unique behaviors associated with heat may last from six to thirty hours. Many type sensors are used to detect changes in cow behavior, changes in body fluids, and physiology during oestrus. Although there are many types of sensors, this study will focus only on sensors used in cow heat detection and their working principles. Therefore, the development of novel sensors with higher sensitivities is the goal of many recent research efforts. This paper will give an overview of the commercial sensor-based devices that are currently available in market. A survey was carried out with cattle farmers by using face-to-face interviewing method. New technology and scientific discoveries regarding cattle farming provide the basis for accelerated progress in performances for farmers which adopt these technologies in practice. The use of computers for farm management in dairy sector has started in as early in 1990's in Turkey. Hence, personnel computer was developed and the price have dramatically declined, more and more farmers began to use computers by themselves. Usually the use of technology is generally preferred, as it facilitates operational preference in large scale farms.*

***Key Words*:** Sensors, cow, oestrus, reproduction

1. INTRODUCTION

Sensing of cow functional state of fertility is latest critical research area for efficient cow reproduction. Dairy farm cow milk yield is increasing while fertilization rate is getting decrease. Cow estrus detection has many difficulties because of many reasons. Oestrus detection generally depends on behavioral changes of cows such as standing, mounting, walking, restlessness, chin pressing [1]. Traditionally, oestrus detection is performed by visual observation of the dairy herd but this procedure particularly difficult on large dairy farms because of short observation periods during feeding and milking [2]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 [3]. As a result of technical progress in monitoring cows using computers, automatic oestrus detection has become possible [4]. To aid farmers in detecting estrus and determining the optimal insemination time, many estrus detection tools have been developed. Performance of estrus detection tools varies between research results but is overall better than visual observation of estrus. The electronic systems are an electronic device that detects cows that stand to be mounted by a herd mate and provides a continuous monitoring of activity [5], radiotelemetry is a computerized estrus detection devices. Also patches give another possibilities using mounting activity of cows. If a cow mounts another cow then the transmitter is depressed and a signal sent to a receiver. During this time, date, time and duration of the mount stored and send to the main computer. On computer all these data evaluated and prepared for final decision. Results of oestrus detection varied depending on the many factor such as threshold value, cow number, barn style, and the statistical method for data analysis. The detection error rates between 17 and 55% and indicate a large number of false warnings [2]. Estrus detection errors can result huge economic loses for dairy farms. The economic loses vary $2–$6/day for dairy farms. But missing a cycle cost $42 to $126 for a cow. Using detection aids provide advantages because of the prevention of these losses [5]. Cows with high milk production (≥40 kg/day) have shorter oestrus duration (6.2±0.5h versus 10.9±0.7h); less total mounts per cow (6.3±0.4 versus 8.8±0.6) and shorter duration of total time standing to be mounted (21.7±1.9h versus 28.2±1.9h) than lower producing cows measured at the same conditions [6], Average calving interval in cattle farm is the best criteria for comparisons for reproductive performances of the farms which vary between 13 and 18 months [7; 8]. Heat detection efficiency vary between 30 and 50% in most dairy herds [9; 10].Research results showed that the 5–30% of the cows were not in or near oestrus when inseminated [1,5,7], (Galiç et al. [11] reported that the effect of herd size on milk yield, calving age, lactation number, and calving interval is significant ($P < 0.01$) and small farms are generally more successful in terms of these factors than large farms. Mean duration of oestrus was calculated by Schofield et al. [12] as 13.5 h with a standard deviation of 2.3 h. [13]. Roelofs et al. [14] found out that 90% of cows in estrus showed mounting behavior, whereas only 58% of cows in estrus showed standing-to-be-mounted behavior.

In livestock sector researches conduct studies for new smart technologic aids for improving cow reproduction performances. A number of both inexpensive to expensive aids and technologies are available to meet some but not all of these criteria [15]. Although costs associated with computerized estrous detection are higher than other methods, the benefits may pay off with increased estrous detection accuracy.

This paper will give an overview of the estrus detection sensor-based devices that are currently available in market.

Sensor technologies

Several options are available to aid heat detection and increase heat detection rates. With the use of intelligent technological aids in oestrus detection, the grower has the opportunity to make more profitable production with less labor use, high fertility success and increased milk yield. Oestrus is the event when cows signal that they are receptive to be mated and unique behaviors associated with heat may last from six to thirty hours [10]. The optimal time of insemination relative to ovulation was found to be 24 to 12 h before ovulation [16]. Heat detection requires accurate observation of physiological behavior patterns and parameters. The behavior meter continuously records the animal behavior for many purposes (lying time, lying bouts and the activity of the individual cows). The cow-behavior enables animal welfare assessment in different environmental conditions and stress situations, as well as reproductive and health status [4].

Sensor technologies are being used to monitor the production and physiological condition of the animals. Increasingly, these innovations are leading to a more efficient performance of dairy cows, in terms of both physiology and profitability [3]. 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. Three types of sensors used in this area; electrochemical sensors, chemoresistive gas sensors and chemoresistive sensor.

Chemoresistive gas sensors has received impulse great deal of attention because of its many advantages over other sensing technologies [17]. Over the last five decades, due to their simplicity, low cost, small size and ability to be integrated into electronic devices, Electrochemical sensors have seen an increase in their application to a variety of fields. Electrochemical sensors are becoming unpopular as they have a short lifetime, rendering them unacceptable for some applications. A chemoresistive sensor is based on a sensitive material, in bulk or deposited on a suitable support, upon which the molecular recognition process takes place. Chemoresistive gas sensors are very sensitive but not selective. Such a task can therefore not be performed by a single sensor. Classical Taguchi sensor have a sensitive material in the form of sintered porous ceramic body. Planar-type gas sensors are constituted of a sensing thick/thin layer deposited by chemical or physical methods onto a ceramic substrate with interdigital electrodes. Sensing nanomaterials may be quite unstable under thermal conditions due to their high surface energy leading to severe grain growth, which may result in the degradation of the device performances. Under such operations, the mechanical deterioration of electrodes can also lead to performance degradation due to the possible formation of micro-cracks on the electrode structure.

These sensors are used to detect changes in cow behavior, changes in body fluids, and physiology during oestrus. Although there are many types of sensors, this study will focus only on sensors used in cow heat detection and their working principles. In this part of the study, cow heat detection sensors and working principles will be grouped and given as subtitles.

Standing activity

Standing to be mounted is considered the main behavioral sign for identifying an estrous of cow and is used to determine the punctual time to inseminate. Both the physical activity and mounting activity induced by increased oestradiol production during the preovulatory follicular phase can be monitored in various ways. Roelofs et al. [18] found that only 58% of cows were observed in standing to be mounted can be monitored through the use of pressure sensors.

Mounting activity

The cheap mounting activity system is available in the markets which is not required a computer or software to process and display the data. This tool is effective but to increase sensitivity the needs of smart aid is a pressure sensitive device mounted on the back of each cow, which can be triggered when the cow stands for mounting. Pressure sensitive device is a smart system and programmed when a certain number of valid mounts have been recorded alight give signals. The second one is effective aids for detecting standing estrus is a mark error teaser animal. Marker animals are worn marking device. When an animal in standing estrus is mounted by the marker animal, the chin-ball marker will rub against the animal in standing estrus, leaving marks on her back and rump. Mounting and standing activity are effective methods for estrus detection [19]. Electronic mounting activity detectors fit into a patch placed on the animal's tail head; when the animal is in standing estrus, the detector will send a radio signal to computer, that records the time and duration of each mount.

Walking activity

Walking speed differed among the cattle breeds studied, and in the ease with which they can be driven. The latter may be related to the docility of the animal. Preferences of flooring and lighting influence walking behavior, foot health and cow movement. Foot placement, length of stride, step and walking speed provide indicators of cow health and the

quality of the environment. Cows show an indirect increase in walking activity during estrus [20]. Increased walking activity has been used to identify a cow in estrus. When in heat cycle, a cow shows increased activity which allows to determine estrus event automatically.

Automated techniques include pressure sensor for detecting mounting activity, pedometer sensor for walking [21], and activity monitoring for cows. Some of these devices can be attached to a leg or to the neck as well. Collar sensors also continuously monitor animal's activity and transmits the data for a distance from 2 to 5 km. Collar sensor tag can be swapped from one cow to another anytime. But keeping the sensor transmitters attached to the cows required considerable maintenance; a more secure method of attaching transmitters to the cows would improve efficiency of the system immensely [22].

The pedometer, attached to a leg, detects an increase in the number of steps taken per hour during oestrus. Pedometers are used to detect the estrus by storing past physical activity the current physical activity and comparing it previous activity data. After analyzing data, programs prepare cow list which is accepted as estrus. This list send to farmers as telephone message or computer signals to control this cows for insemination [15]. Pedometers also used for estrus detection attached to the leg of the cow to measure the amount of her activity over a unit time span. Many pedometric systems are commercially available in the market. Also standing activity detection systems is commercially available in the markets. Standing activity activated by the mounting cow. Radio signal picked up by receiver and relayed to a buffer and a personal computer to analyze the data this system record and report cows number, standing time, standing [15]. Lpez-Gatius et al. [21] reported that increased parity and milk production, and insemination during the warm period were associated with lower pedometer measurements. No significant effects of the herd, estrous synchronization, and lactation stage were observed. The link between walking activity and fertility was determined by applying logistic regression models. It was reported no significant effects of herd, milk production, estrous synchronization, lactation stage, and inseminator on pregnancy rate. A higher lactation and insemination number and insemination during the warm period were negatively correlated with the pregnancy rate. Their findings indicated that cow and management factors contribute intensely to walking activity at estrus, and also reveal a close link between increased walking activity and fertility. The data on activity are registered continuously and transmitted to a receiver by radiotelemetry or infrared light at regular time intervals or at the entrance of the milking parlor. From this receiver, the data are automatically forwarded to a database in a central computer or to a cell phone via the GSM network. The software supplied with each device compares the activity of each animal with that of a previous reference period (of a various number of days depending on the algorithm) and, in some cases, with the average activity of the herd. The performance of pedometers for heat detection might be affected by the environmental conditions, as walking activity of dairy cows has been shown to vary according to the type of housing and the herd management system.

Restlessness

Watanabe et al [23] present novel methods for detecting estrus and predicting calving-time in dairy cattle, by using a wireless network with an acceleration sensor. Their method focuses on the habit of cows in estrus to become restless. A simple index, the hourly durations when the minute-based standard deviation of the acceleration sensor values for a leg is high, was experimentally proved to be effective at recognizing estrus. Acceleration data of cattle have to be corrected with presence of bugs as mosquitoes, flies and horse-flies. Also cow behavior changed at high ambient temperatures causing heat stress result in physical lethargy and reduced oestrus detection efficiency in cows. Restlessness of cow is effected many factors such as housing, floor surface, yield, lameness and number of herd mates in oestrus simultaneously [24].

Vocalization

Cattle vocalization generally can be categorized into two different states as hungry and weaning states. But researchers try to recognition estrus specific voice of cows. Vocalization can be suggested as oestrus signal for remote sensing techniques [25;26]. Chung et al. [27]. reported that voice identification processing can be used to detect estrus both economically (simple microphone) and accurately (over 94% accuracy), either as a stand-alone solution. They propose the new solution for the detection of oestrus, using the sound data of Korean native cows. For this purpose researcher extracted the melfrequency cepstrum coefficients from sound data with a feature dimension reduction, and use the support vector data description as an early anomaly detector. Their results show that this method can be used to detect oestrus economically.

Odour

The attempt to mimic the sense of smell is termed an electronic nose. This is defined as 'an instrument which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognizing simple or complex odours' [28;29). The pheromones are actually released by the dung of cow in estrus. Pheromones are volatile fatty acids i.e., Acetic Acid (AA), Propionic Acid (PA) and 1- iodoundecane [30]. A number of research groups worked on devices that mimic the biological olfactory system. Odour detection is also another oestrus detection solution for sensor technology. Dog can detect estrus by urine and milk, after being trained with vaginal fluid samples [31]. And isolated later in feces estrous cow [29]. Principle of the odour sensors is based on detection of pheromones related to heat. Pheromones are the natural olfactory signal for bull that cow is in heat. Odorant plumes are invariably heterogeneous,

chaotic, turbulent, and temporally variable, and therefore their physical structure is impossible to define completely. The electronic nose is an array of chemical sensors, connected to a pattern-recognition system that responds to odors passing over it. Different odours cause different responses in the sensors, and these responses provide a signal pattern characteristic of a particular aroma. The computer evaluates the signal pattern and can compare the aromas of different samples, using pattern recognition. This type of sensor instrument mimics the olfactory system in the bull nose. The instrument consists of an array of gas sensors with different selectivity patterns, a signal collecting unit, and data analysis software, which analyses the signal by pattern-recognition methods, such as principal component analysis, discriminate function analysis, cluster analysis, and artificial neural networks [29]. But odor measurements from cows still were different because of many reason. Result highly variable.

Body temperature

Several automated systems of body temperature measurement with radio telemetric transmission are currently marketed for calving detection and health monitoring in cows. Some devices are ingested as a bolus and measure the temperature in the reticulum, whereas others are placed in the vagina days before oestrus and then increases at the time of the LH peak. In cows, the body temperature declines slightly. Fisher et al. [31] reported tat elevation of body temperature 0.48°C (ranging from 0.40 to 3.22°C) was observed on the day of estrus at the time of the LH peak depending on the hormonal activity.

But some other factors such as outside temperature, disease related hyperthermia and/or some systemic or local inflammation also increased body temperature which can increase false positives alert.

Chemical sensors

Different chemical sensors developed for in-line measurement for metabolites and hormone concentration in milk. This system was used twice or once weekly in herds equipped with this technology to detect hormone concentration in milk [18]. This technology depend on the attachment of progesterone antibodies to the surface of quartz crystal. But this technology is still expensive for large scale application [32]. There are many other methods available on the system such as cervical mucus, vaginal characteristics, temperature, blood flow, and hormone changes in blood and milk, but these methods not applicable on the farm level. Researchers suggest that some spesific chemical compounds may be used as estrus indicator in bovine.

Measurements cows using the electronic device were highly variable. While heat detection has become increasingly difficult farmers and consumer demand more precise and comfortable oestrus detection system. Herd sizes and demand increased, the availability of skilled labor decreased and there is evidence that cows are having shorter heats and their heats are of lower intensity. Latest research focused on electronic devices have been used for the detection of substances indicating cow estrus. These electronic devices are capable of detecting different types and sources of chemical species and mixtures of compounds.

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