INTRAVAGINAL TEMPERATURE TELEMETRY IN FEMALE MAMMALS

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ABSTRACT

The four major management problems in female farm animals are identification, breeding timeliness, health monitoring and notice of parturition (delivery of young). Each of these has been solved with a single temperature-sensitive device placed in the vagina nonsurgically with a nylon anchor.

Remote sensing of deep-body (core) temperature in female livestock is a major breakthrough in husbandry of farm animals and important zoo animals. Development of a patented, vaginal radio implant has enabled the remote sensing and automated processing of animal temperature data for females. A natural component of the system is automated identification of each female wearing a transmitter.

The methodology of collecting and interpreting deep-body temperature depends upon using each female as her own basis of comparison. A temperature deviation of greater than 0.4* C relative to the average of the previous five day's temperatures taken at approximately the same time of day indicates a significant physiological event. Ultimately, the optimum configuration of this system will invoke the creation of artificial intelligence or, at least, an expert system.

INTRODUCTION

Husbandry of female breeding animals has been hampered by inadequate methods of identification, recognition of ovulation for artificial mating, recognition of disease and knowledge of parturition (delivery of offspring). The ordinary solutions to these four problems have required great investments of labor and they are fraught with error. As skilled labor becomes more scarce and more expensive in farm animal enterprises, the need for automated systems becomes ever greater.

The technology reported here is known as ZARTemp and is patented by New Mexico State University Foundation. It was developed as a means of simultaneously, with one unit, solving the four dilemmas posed above.

Identification is vital to accurate record keeping on livestock and also is advantageous in tracing the market path of an animal found to be diseased. Additionally, if electronic identification is used, animals can be sorted or isolated automatically, thereby reducing labor needs and stress on the animals. The National Pork Producers Association is eager to have on all market swine a mandatory identification that is easily automated so that trichina infected pigs can be traced to their origin to stamp out this parasitic source of disease.

Livestock, especially dairy cattle, are commonly bred artificially. This necessitates accurate knowledge of the time of ovulation in subject females. Of course, the prevention of pregnancy can also be facilitated through this knowledge - mostly important to humans and to pet owners. A temperature increase corresponds with ovulation and telemetry of deep-body temperature makes this understandable.

Disease, intoxication, and stress initiate temperature responses in animals. Deep-body temperature telemetry can reveal these conditions. Consequently, corrective measures can be taken, often earlier than could be possible when visual detection is the only means of recognizing these phenomena.

Parturition becomes a precarious time for both mother and fetus. In dairy operations, as many as 30 per cent of all cattle need assistance in delivering their offspring. Fetal mortality rates as high as 10 per cent are not uncommon if less than 24 h assistance is available to these cows. Valuable mares sometimes have $20,000 or more of stud fees contingent on the delivery of a live foal. When parturition labor in a female is unduly long, i.e. more than two hours, she and her offspring suffer stress that has prolonged effects over the following weeks. This reduces the viability of both of them and the subsequent return to fertility for the mother.

DEVELOPMENT OF THE METHODOLOGY

The original concept was to find a way of obtaining and recording at daily intervals the deep-body temperatures of lactating dairy cows. The purpose was to establish documentation of ovulation for assessment of early embryo loss, which was thought to be a major cause of apparent infertility in dairy cows.

Infra-red thermometry of dairy cow surfaces yielded interesting patterns of temperatures but did not locate body positions sufficient for the reading of deep-body temperature with the precision needed for ovulation detection.

Milk temperature recordings taken at various points in the milking machine were adequate for detecting high fever, but were not sufficiently insulated from environmental circumstances to consistently report deep rectal temperatures within a degree. It was apparent that, although possibilities existed, the complexity of engineering a system for monitoring milk temperature reflective of deep-body temperature was overwhelming. The milk temperature was highly related to flow volume and flow rate, both of which are relatively uncontrolled.

Surgically implanted radio transmitters (mini-Mitter, model LN, Sun River, OR) were then employed to take temperature data from a point adjacent to the jugular vein. Many unexpected temperature conditions were revealed from this location but the blood temperature was not at all useful for detecting ovulation after the change occurring while passing through the head. Telemetry from under the skin on the rib area was also inadequate due to surface temperature modifications. However, surgical placement of the transmitter in the abdominal cavity on the right side (to avoid the rumen where food and water intake would greatly influence temperature conditions) produced excellent data.

At this point, it was recognized that the concept was valid but would never be acceptable for general use unless a nonsurgical approach could be developed. Even though abdominal placement worked excellently in terms of data quality, surgery would be too dangerous and too expensive for general purposes. After experimenting with the ear canal, it was concluded that the reproductive tract was a better cavity to get deep-body temperature readings. While the uterus was ineligible as a site due to contraceptive effects of an implant, the vagina was a natural location. An anchor method was needed to preclude the need for surgical placement. This led to the invention of a nylon anchor device described by Zartman et al.(2) which is a patented modification of a commercial implant known as Hei-Gro (produced by Agro Physics, San Francisco, CA). However, even though attachment of a transmitter to this device was simple, the free orientation of the transmitter caused difficulties with the external receiving antenna configuration under the constraints of maintaining low cost and working in an animal environment.

A transmitter design capable of unique identification of each female and computer operable was produced and manufactured by the Physical Sciences Laboratory at New Mexico State University. It was a low cost design and used a broad band a.m. frequency with a limited range of about two feet. Thus, the animal had to be near the receiving antenna and it was possible to eliminate interference among animals by passing them through a chute as they passed the antenna. Data thusly collected established the efficacy

of the intravaginal approach to deep-body temperature sensing as reported by Zartman (1) and Zartxnan et al. (2).

Solution to the antenna problem was a single wire wrapped three times around a chute through which the animal walked. This resembled a metal-detector chamber like those at airport security installations. The windings were about 50 cm apart. Subsequently, in response to the need for a more adaptable system, I invented another anchor shown on Figure 1. It was an improvement in that it maintained an orientation on the longitudinal axis of the animal and, due to its tubular structure, it housed the transmitter in a protected chamber. In fact, the transmitter was encased by wrapping it with electrical tape and placing it in the barrel of a 20 ml syringe that subsequently had a cap welded onto it by melting with a hot wire. Likewise, the needle end was sealed with a hot wire.

This design was tested in mares, cows and sows with great success. One mare which seemed to have little muscle tone in the vulvar area tended to lose the anchor occasionally. The problem was solved by lengthening the flanges on the anchor to widen its expanded diameter.

Placement of the anchor was so simplified that very little technical skill was required. The anchor was placed in a tubular speculum with a slightly larger diameter. The vagina of the female was cleansed and dried. Once lubricated with conventional ointment, the speculum was introduced into the vagina until it met the resistance at the anterior end where the cervix is located. The anchor was expelled from the speculum by pushing it out with a plunger while withdrawing the speculum. The female’s reaction was minimal and less evident than that of a normal mating.

While experimenting with the system, it was learned that temperature data could best be interpreted by establishing a rolling average of the previous five-day period for comparison with the current reading. It was important to take the readings at the same time of day with a one hour variance. Because of individual animal characteristics, each female had to serve as her own control for data comparison. That is, no particular absolute temperature could be selected to serve as the reference for comparison because each female had her own temperature set and this was confounded by seasonal adjustments to climate and environment. Following these criteria established from an experience base of over 20 cows wearing transmitters for times ranging from about 40 to 360 days, it was determined that whenever the temperature variation exceeded 0.4* C an important physiological event was surely occurring. Furthermore, after 12 years of experimentation involving some 100 cows, 15 mares and three sows, every known incidence of illness has been detected using these criteria. The efficiency of detecting ovulation has exceeded ordinary means, but cannot be exactly stated until improved means of precisely verifying ovulation are developed.

The usual questions asked about the intravaginal implant are: 1) Is it safe?, 2) How long can it be left in place?, 3) Does it affect conception or pregnancy? and 4) must it be removed for breeding? It is safe since no adverse affects have been seen in any animal where proper sanitation of the implant was practiced. In fact, the implant seems to have a health promoting affect in that more mucus is produced. Mucus has a flushing action and it carries antibodies which are protective of mucus membranes. The implant can be left in place for an unlimited time. Several females have worn the implant for well over a year. It will be spontaneously expelled at the time of delivery in a pregnant female. Conception rates are equal to or better than those resulting from normal management and pregnancies have all been carried uneventfully. The implant can and should be left in place for artificial insemination. A cow, a sow and six mares have received natural service from males without difficulty. Conception rates under natural copulation have not yet been established with the implant.

The system has been improved consistently over the period of the study. The current transmitter, manufactured by Biomedical Electronics, Inc., El Cajon, CA, is a hybrid transponder / transmitter. It requires about half a second to interrogate a passing implant in the body of an animal and reset for the next implant. As each female passes in single file, the transponder is activated by the antenna signal and it then activates the transmitter which reports the identification and the temperature of the transmitter twice for verification. Validation of the response is done by a computer system near the antenna before transmission to the master computer where data files are maintained. The antenna is a dipole configuration positioned vertically beside a chute the animals pass through singly at a normal pace of movement. There is a clock in the computer which enables the logging of data by time.

APPLICATIONS

Identification coupled with the time of observation has produced important management information. For example, in dairy cattle it is now possible to have recorded the precise time at which cows were milked and whether they were in fact brought into the barn. These facts are important in knowing where a cow was at a certain time and whether or not employees were conducting the recommended work schedule. This is also useful to the government operated program for genetic improvement of dairy cattle in that it is necessary to have accurate identification of all cattle on test and to know the intervals between milkings to properly adjust the records of milk production.

The reproductive performance of dairy cattle has been shown to suffer from two dilemmas with the system. The first dilemma is known as silent heat. When a cow has an ovulation but she presents no outward signs of sexual interest, it is impossible to know that she should be bred. The ZARTemp system has revealed temperature spikes of a

character associated with ovulation which show that during the first 100 days following a prior pregnancy a herd of cows will have about 41 per cent silent ovulations. That means temperature reporting can provide an opportunity to get more cows pregnant in a shorter period of time which should save considerable operating cost. The second dilemma involves the cow that is in “standing heat” (a condition of active sexual interest) without actually ovulating within 24 h. Such a cow would not be expected to conceive from a breeding at that time. It has been shown from temperature data that 38 per cent of the standing heats are false signs of ovulation and are, under those conditions, useless when used as a signal for breeding. Semen and labor costs can therefore be avoided on those hopeless events. The conclusion from these results is that no more than 60 per cent of breedings can be successful when done without the temperature system for indicating true ovulation.

Simultaneously, cows with various reproductive disorders have been discovered so that early corrective measures could be taken to either correct their problems or eliminate them from the breeding herd. Great cost savings resulted. All other known instances of disease were detected before clinical symptoms appeared. This enabled early isolation of the disease and early treatment was possible which facilitated less illness and a quicker recovery in most cases. More profound was the discovery of an unseen epidemic of fever in a large herd of cows. Milk production suddenly dropped three pounds per cow per day - a cost of about $680 per day in that herd. Unknown to the herdsman but clearly evident to the investigator with the telemetry system was a low-grade fever in about 68 per cent of the cattle with implants. This indicated a contagious infection was present in the herd.

Heat stress from high temperature and high humidity conditions is a serious deterrent to animal health and condition. It has been documented via telemetry that when cows are subjected to extreme temperature and humidity circumstances, they lose control of body temperature stability. This is a highly stressful condition which reduces appetite and milk production falls drastically. The thyroid gland must respond to drastic changes in ambient conditions by altering the rate and volume of thyroxine production which regulates the rate of cellular metabolism. This has been shown consistently to take three or four days.

As a parturition alarm, the telemetry system has reported the 0.5* C or greater temperature drop of about 12 h duration that signals the respiratory maturity of the fetus. Birth regularly took place from 12 to 72 h later. When labor reached high intensity, the transmitter was naturally expelled. A signal generator was built into the transmitter which is activated when the large temperature drop occurs as the transmitter leaves the vulva. The signal will be picked up by an antenna, amplified and sent to an alarm system which will call a herdsman to the scene to assist the mother.

FUTURE APPLICATIONS

Automated identification will be taken into the animal's conventional environment where it can be coupled with data collection and animal sorting processes. For example, accurate milk production records for every milking would greatly improve several management aspects such as milk inventory, cow health, feed distribution and genetic evaluation. Additionally, if there were a need to separate one or more cows from the herd, an automated gate could be controlled by the cow identifier to sort cows out as they approach the gate while traveling down a lane.

Embryo transfer promises to become increasingly important for animal reproduction. Establishment of the stage of a cow's estrous cycle for optimum results in induced superovulation has been difficult. It has also been difficult to synchronize the embryo donor with the recipient for greatest probability of success. Temperature telemetry can substantially improve the matching of females for the transfer.

Fetal stress syndrome in humans is characterized by a sudden temperature increase in the fetus during prolonged labor. It calls for an immediate Caesarean section delivery. With temperature telemetry, the present system of a thermister clipped to the fetal scalp could be replaced.

SUMMARY AND CONCLUSIONS

Radiotelemetry of identification and deep-body temperature in female livestock has accomplished the solution of the four great management problems of animal husbandry. This has been done nonsurgically and at a reasonable cost. The system can be managed by hand or it can be automated through use of a computer. The data are reported in such a fashion that they are understandable by typical farm operators. However, much improvement in the automated computer interpretation of data remains to be accomplished. An expert system which is part of artificial intelligence is needed to arrive at the best recommendation when a female has a temperature spike.

REFERENCES

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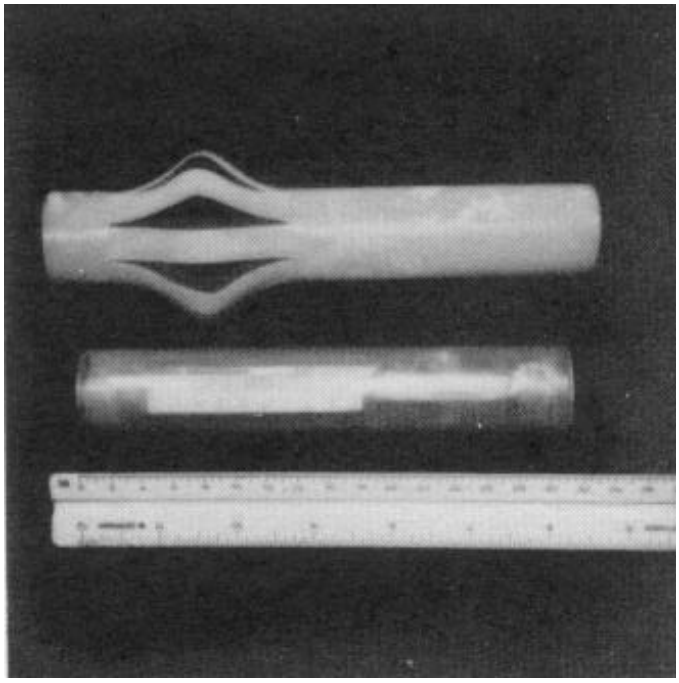

Figure 1. The anchor and transmitter chamber used presently for intravaginal placement in cows and mares.