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Bio-impedance monitoring of genital tissues of cows as an aid in cattle reproductive management - a review

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ABSTRACT

Bio-impedance (BI) is the opposition of biological tissues to the flow of an alternating low electrical current. Tissue BI is quantitatively inversely related with tissue hydrational status.

Several reproductive events of importance in the management of the cow are characterized by changes in fluid content and electrolyte concentration of the genital tissues; these changes can be detected and quantified by genital tissue BI monitoring.

The objective of this presentation is to review existing and potential applications of monitoring genital tissue BI in cows as aids to cattle reproductive management.

The main application is genital BI monitoring to determine the optimal insemination time. It is based on the fact that intravaginal and vulvar tissue BI decline *ca* 10-30% during the peri-ovulatory stage of the ovarian cycle. Genital BI measurements can also be used to detect pending calving as well as *post-partum* reproductive disorders: vulvar BI, measured with chronically implanted electrodes, declines *ca* 15 d before, and remains low until calving. During *ca* 40d post-calving, vulvar BI increases gradually and stabilises at about the time of resumption of ovarian luteal cyclicity.

Intravaginal BI during the first 4-6 weeks post-calving is significantly lower in cows with reproductive disorders than in "normal" cows.

Preliminary studies indicate that embryo yield and quality from donor cows, and pregnancy rate of recipient cows, are quantitatively inversely related with the peri-oestrous decline of intravaginal BI.

Efforts are currently being made to develop bio-implantable telemetric and automatic genital BI monitoring devices as part of a general trend to automate cattle management systems.

INTRODUCTION

Bio-impedance (BI) is the opposition of biological tissues to the flow of an alternating low electrical current. Tissue BI is quantitatively inversely related with tissue hydrational status (for references see *Lehrer et al.,* 1991).

Several reproductive events of importance in the management of the cow are characterized by changes in fluid content and electrolyte concentration of the genital tissues; these changes can be detected and quantified by genital tissue BI monitoring.

The objective of this presentation is to review existing and potential applications of genital tissue BI monitoring as aids in cattle reproductive management.

Determination of optimum insemination time

The main application of genital BI monitoring, so far, is for determining optimum insemination time (Spahr and Lewis 1990; Lehrer *et al.,* 1991, 1992, 1993; Holtz and Meinhardt 1993; Senger 1994). Aizinbudas and Doviltis (1962, 1966) first reported that vulvar vestibule BI declines during peri-oestrus, and that conception rate and oestrous vestibule BI are quantitatively inversely related to each other. These findings were confirmed by numerous studies (see Lehrer *et al.,* 1991) in which electrodes fixed to the tip of a rod were used to monitor intravaginal bio-impedance (IVI) near the external cervical os; this location was found to be the optimal site for measurement (see Lehrer *et al.,* 1991).

A common operational failure with IVI probes is fluctuating erroneous readings due to unstable contact between the electrodes and the vaginal mucosa. This problem has been reduced substantially in recent studies, using a patent pending method (Kaim *et al.,* 1994; Lehrer and McMillan 1994).

Due to variation among cows in absolute IVI levels during the oestrous cycle, the peri-oestrous IVI decline can only be detected by comparison to the preceding di-oestrous levels within each cow. The excessive labour required for repeated (at least once daily) measurements, led to the use of electrodes chronically implanted in the vulvar or vaginal wall (Spahr and Lewis, 1990; Lehrer *et al.,* 1991). A schematic profile of hard-wired measurements of vulvar BI (VBI) from late gestation through calving, the *post-partum* period, its following oestrous cycles and subsequent early pregnancy, are presented in Figure 1. It can be seen that VBI declines *ca*15 d before, and remains low until calving. During *ca*40 d *post-partum,* VBI increases gradually and stabilises at about the time of resumption of *post-partum* ovarian luteal cyclicity. VBI declines around oestrus and does not decline at the expected time of subsequent oestrus following a fertile AI (for details and references see Lehrer *et al.,* 1991).

On farm applicability depends on telemetric, preferably automatic, monitoring. The first telemetric IVI monitoring by Leidl and Stolla (1976) in Germany, was followed recently by Holtz and Meinhardt (1993). Telemetric implantable VBI monitoring devices were developed in the USA and Israel (Spahr and Lewis, 1990; Lehrer *et al.,* 1991). Examples of telemetered IVI and VBI profiles during the ovarian cycle are

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presented in Figures 2 and 3, respectively. It can be seen that peri-ovulatory declines of IVI, and peri-oestrous declines of VBI, can be detected telemetrically.

FIGURE 1: A schematic profile of the vulvar bio-impedance in cows, from late gestation through subsequent early pregnancy (Lehrer *et al.*, 1991)

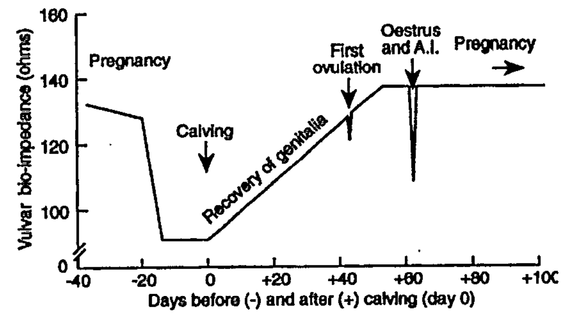


FIGURE 2: Radiotelemetered intravaginal bio-impedance (mean of 1 hourly readings ± SE) during 26 ovarian cycle in 9 cows, relative to mean pre-ovulatory plasma LH concentration (by permission from Holtz and Meinhardt, 1993).

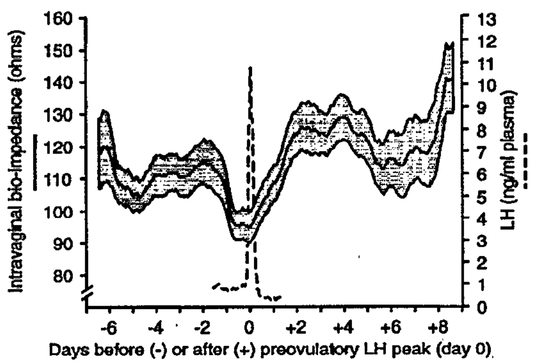
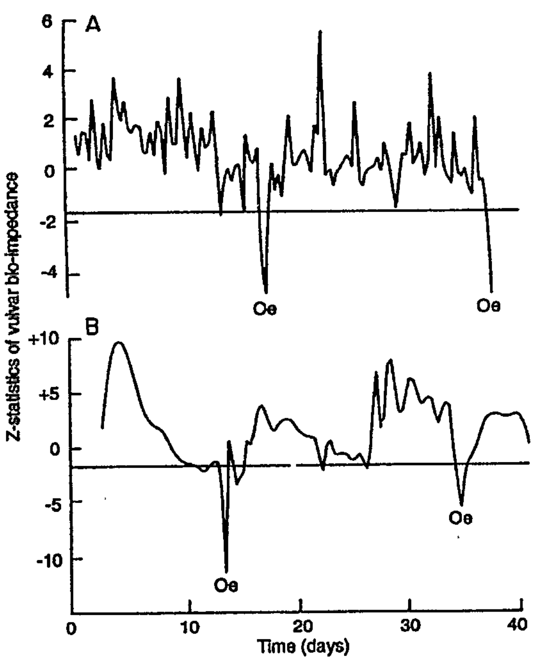


FIGURE 3: Z - statistics calculated from radiotelemetered vulvar bio-impedance during the oestrous cycle of two cows (oe = oestrus). Z-statistics ≤-1.65 were considered significant deviations from the rolling average (A. Spahr and Lewis, 1990 [USA]; B. Lehrer *et al.*, 1991 [Israel]).



Potential clinical applications

Genital BI may be used as a clinical diagnostic aid, particularly of genital inflammatory conditions. The latter are associated with deviations from the normal hydrational status of the tissue, which are detectable by tissue BI monitoring. For example, a single IVI measurement on day 30 post-partum identified 98% of reproductively disordered cows, with 6% false positive diagnoses (n = 87) (Davidson *et al.*, 1982; Lehrer *et al.*, 1991). More recently Kaim *et al.*, (1994) reported that IVI measurements on days 2-3 post-partum prospectively diagnosed 85% of reproductively disordered cows, with 8% false positive diagnoses (n = 26).

According to McCaughy (1981) IVI can be used for early pregnancy diagnosis. Ninety seven out of 98 cows diagnosed as pregnant, based on plasma progesterone concentrations on day 21 after AI, were also diagnosed pregnant by an IVI measurement on that day.

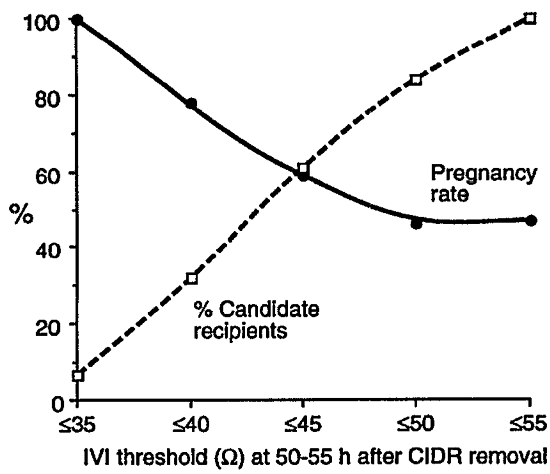
Potential applications in embryo transfer

The quantitative relationship between IVI and conception rate has led to preliminary testing of the relationships between IVI and reproductive variables of embryo donor and recipient cows.

As presented in Table 1, embryo quality and recovery rate of in vivo derived embryos, as well as pregnancy rates of the recipients to which these embryos were transferred, were quantitatively inversely related with peri-oestrous IVI of the donor cows (Müller, 1988; Leiding *et al.*, 1988).

As presented in Figure 4, a preliminary study on a small number of recipient cows (Lehrer and McMillan, 1994) showed that pregnancy rate after embryo transfer was quantitatively inversely related with their peri-oestrous IVI.

FIGURE 4: Relationships between peri-oestrous intravaginal bio-impedance (IVI) and pregnancy rate of recipient cows (n = 28) (after Lehrer and McMillan, 1994).



CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

IVI monitoring can be used to determine the optimum insemination time, and for prospectively identifying cows with low, average and high chances of pregnancy after AI. However, due to high labour requirement, the large scale

TABLE 1: Flushing results of donor cows with normal and abnormal intravaginal bio-impedance (IVI) profiles around oestrus (after Müller, 1988).

IVI profile	No. of cows	No. of ova + embryos recovered		Fertilization rate	Transferrable embryos	
		Total (n)	per cow	(% of n)	% of n	% of recovered embryos
Normal	118	1,222	10	81	59	73
Abnormal	32	203	6	51	28	55
Overall	150	1425	9	76	54	70

application of manual IVI monitoring for these purposes is unlikely, particularly in large herds.

Manual IVI monitoring might be practically useful in cases where a single or a few measurement(s) is/are required. Diagnosis of post-partum reproductive disorders, verification of insemination time when signs of oestrus are unclear, and early pregnancy diagnosis are potential applications that need to be investigated further.

Substantial research is required to verify the usefulness of IVI monitoring for screening candidate donor cows on their potential embryo yield and quality, and candidate recipient cows on their potential preganancy rate.

The technological reliability of IVI manual probes has been improved considerably. Work is in progress to improve the technological performance and reliability of telemetric chronically implanted VBI monitoring devices.

Research efforts should also be placed on integrating telemetric genital bio-impedometry with pedometry, or other telemeterable behavioural or physiological variables, in order to increase the efficiency and accuracy of on-farm telemetric determination of insemination time (Spahr and Lewis, 1990; Lehrer *et al.*, 1992; Senger, 1994).

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