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ESTABLISHING THE REFERENCE VALUES OF VAGINAL ELECTRICAL RESISTANCE FOR ESTRUS DETECTION IN BLACK BENGAL GOATS OF INDIA

Amit Kumar*[1], K.K. Kanaka[1], Navjot S. Thakur[2], Ganesh N. Aderao[1], Reena Kamal[3], Soumajit Sarkar[1], Soumen Naskar[1], Sakshi Kaith[1], Rangasai Chandra Goli[4], K.C. Nikhil[1] and Himanshu Mehta[5]

[1]*ICAR-Indian Institute of Agricultural Biotechnology, Ranchi - 834 003, Jharkhand (India)*
[2]*Department of Animal Husbandry, Mandi - 175 001, Himachal Pradesh (India)*
[3]*ICAR- Research Complex for Eastern Region, Patna - 800 014, Bihar (India)*
[4]*ICAR-National Dairy Research Institute, Karnal - 132 001, Haryana (India)*
[5]*Department of Animal Husbandry, Sangrur – 148001, Punjab (India)*
*****e-mail: *amitkajal7@gmail.com*

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ABSTRACT

Detecting estrus in goats becomes a challenging task in absence of male goats, as behavioural signs of estrus are often subtle and easily missed. Traditional methods such as visual observation of physiological changes like vulvar edema and cervical mucus discharge, may not always be reliable. To address this, the present study was aimed to evaluate the efficacy and establish reference values of vaginal electrical resistance (VER) for estrus detection in goats. A total of six goats (N = 6) were used, with their estrus cycles synchronized using progesterone sponges. Behavioural and physiological signs of estrus (*viz*., buck interest, cervical mucus and vulvar oedema) and VER were monitored for 22 days, extending through subsequent estrus cycle. The results revealed significantly lower (P < 0.001) VER values during estrus as compared to other phases of estrus cycle. The VER values recorded in units (10 units = 1 Ohm), observed during estrous cycle phases were 262.50 ± 12.28 in estrus, 501.33 ± 60.59 in metestrus, 535.64 ± 63.17 diestrus, and 488.33 ± 51.37 in proestrus. Further, PCA analysis revealed that buck interest and VER values play a more significant role in estrus detection as compared to the cervical mucus and vulvar edema. Also, VER across the estrus phase strongly correlated with the physiological estrus signs *viz*. buck interest and vulvar edema. Based on these findings, we conclude that a reference minimum VER value of 300 units (30 Ω) could be used for estrus detection in Black Bengal and other small-sized goats.

Keywords: Bengal, estrus detection, vaginal electrical resistance

INTRODUCTION

Estrus detection plays a crucial role in the reproductive efficiency in goats, especially for breeders and researchers involved in the genetic improvement and successful management of livestock (Das *et al*., 2024). Timely and accurate detection of estrus can significantly enhance reproductive outcomes, optimize breeding schedules, and reduce the costs associated with prolonged breeding intervals. In goats, traditional methods of estrus detection, such as visual observation of behavioral signs (e.g., restlessness, vocalization, and mounting behaviour), are commonly employed but are often unreliable and time-consuming (Sabbaghi *et al*., 2012). However, environmental and physiological factors pose substantial constraints in accurate estrus detection in animals (Arakawa, 2020). Therefore, there is a growing interest in developing more objective, efficient, and precise methods to monitor estrus in goats. One emerging technique is the use of vaginal electrical resistance (VER) for estrus detection.

The vaginal mucosa undergoes several physiological changes during the estrous cycle, particularly during estrus, which may be reflected in the electrical resistance of vaginal tissues, changes in vulvar cell density, fluid volume, and electrolyte content during estrus and diestrus (Rasad and Setiawan, 2017). Vulvar mesenchymal tissue is 74% heavier during estrus than during diestrus because of tissue hydration, resulting in decreased vaginal impedance (Purohit *et al*., 2019). These changes mainly happen because of shifts in electrolyte levels, water balance, and pH, which are driven by hormonal alterations during the estrous cycle (Maia *et al*., 2014). This technique involves the use of a probe that measures the electrical resistance of vaginal tissues, with lower resistance typically indicating estrus due to the increased hydration and changes in ion concentration (Pate *et al*., 2018). The use of vaginal electrical resistance as a diagnostic tool for estrus detection in various livestock species, including cattle (Higaki *et al*., 2019) and sheep (Theodosiadou *et al*., 2015), has shown promising results. The variations in VER values have been also associated with phases of the estrous cycle, providing critical information for efficient and effective breeding (Malakar *et al*., 2017). However, research focused on the use of VER for estrus detection in dwarf goat breeds, such as the Black Bengal, has not yet been documented. Therefore, the present study was designed for evaluating the efficacy of vaginal electrical resistance as a method for detecting estrus in Black Bengal goats.

MATERIALS AND METHODS

Study location and agro-climatic conditions

The study was conducted in goat farm of ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand (India), during winter season (November) of 2024. The farm is located at coordinates 23.2886° N, 85.4092° E and falls under the subtropical highland climate zone, characterized by moderately cold winters and mild summers. The average temperature during the study period ranged from 8 to 20°C, with minimal rainfall. The region experiences a relative humidity of 60-80%, which is favourable for goat farming. The winter season provides an ideal environment for conducting reproductive studies in goats, as it minimizes the risks associated with heat stress and allows for effective estrus synchronization and monitoring.

Animals and selection criteria

Primiparous goats (n = 6), under 2 years age with a history of regular estrous cycles, were selected for this study. To ensure optimal reproductive performance, goats were maintained with body condition scores (BCS) ranging from 3.0 to 3.5 on 1-5 scale (Ghosh *et al*., 2019). The goats were dewormed using albendazole suspension and vaccinated against Peste des Petits ruminants (PPR) and foot & mouth disease. They were housed in clean, well-ventilated pens and fed a pelleted diet providing 200 g day^{-1}, containing 18% crude protein (CP). The fresh water was available *ad libitum*.

Estrus synchronization

Selected animals were synchronized using progesterone-coated sponge (AVIKESIL-S®, containing 350 mg natural progesterone), which was inserted into the vaginal cavity of each goat for ten days. On the day of sponge removal, each goat was administered 125 µg cloprostenol (0.5 mL Vetmate), a synthetic prostaglandin used to induce luteolysis and promote synchronized estrus. The synchronized goats were then monitored for estrus using VER and signs of estrus (cervical mucus, vulvar oedema) and teased with a buck for detection of induced estrus, and same was recorded from the time of induced estrus to the subsequent estrus cycle.

Monitoring and recording of physiological signs of estrus

During the study, several physiological signs, such as cervical mucus, swelling of the vulva, and the buck's interest in the female were recorded. These signs were chosen because they reflect increased oestradiol concentrations during estrus and are more accurate and consistent compared to behavioural signs (such as homosexual behaviour and nudging). Cervical mucus was observed daily by assessing its consistency on a probe during the VER measurement. Vulvar oedema was monitored by noting the disappearance of wrinkles in the vulvar tissue and the presence of full turgidity. Buck's interest was evaluated using a mature buck, with signs of interest in the female, such as sniffing of vulva, flehmens response, penile protrusion and mounting (Luginbuhl, 2015). All these parameters were measured daily from the induced estrus to the subsequent estrus in the selected goats.

Measurement of vaginal electrical resistance (VER)

The VER was measured using Draminski estrus detector for sheep and goats (EDS 2; Draminski®, Poland), which measures the conductivity of vaginal tissues and converts the readings into resistance values, presented in units (10 units = 1 Ω). For each reading, the detector probe was carefully inserted into the vagina at a 45º angle to prevent entry into the urethral orifice. In this study, no lubrication was applied during probe insertion to avoid any potential aberrations in VER readings (Talukder *et al*., 2018). The use of lubricants could have altered the electrical conductivity of vaginal tissues, potentially affecting the accuracy and consistency of VER measurements. The probe was slowly inserted and rotated gently to avoid causing trauma to the vestibule or vaginal walls. During each measurement, the probe was inserted to a depth of 9-10 cm to ensure accurate readings. The tip of probe was positioned against the external *os* of the cervix, and the average of three readings was recorded by the machine during each measurement. After each use, the probe was thoroughly cleaned with spirit and then with distilled water to prevent any risk of infection transmission. The procedure was carried out in a highly hygienic manner, and no cases of vaginitis were observed. Each reading was securely stored in the machine for further analysis. Like monitoring of physiological signs VER value was recorded for 22 days from induced estrus to subsequent estrus.

Statistical analysis

The data on VER and physiological parameters were subjected to statistical analysis, which includes correlation, principal component analysis and two-way ANOVA using in-house Python scripts (available at *https://github.com/kkokay07/VER*). Descriptive statistics such as mean, standard deviation and range of the VER were calculated during the estrus period. Correlation analysis was performed to assess the relationship between VER measurements and the observed physiological signs viz., buck interest, vulvar edema, and cervical mucus. A p-value of <0.05 was considered statistically significant for all analyses. Principal Component Analysis (PCA) was performed to assess the relationships between the various estrus detection parameters (VER and physiological signs). The data were visualized using appropriate graphs and plots to illustrate the trends and patterns of VER in Black Bengal goats.

RESULTS AND DISCUSSION

The evaluation of vaginal electrical resistance (VER) in Black Bengal goats revealed a significant decline in VER levels during estrus phase (Fig. 1). The phase-wise distribution revealed lowest VER level during estrus (262.5 ± 12.28 units), while the highest VER was observed during diestrus (535.64 ± 63.17 units) (Fig. 2; Table 1). The mean VER values during diestrus and proestrus were 501.33 ± 60.59 units and 488.33 ± 51.37 units, respectively. This cyclic pattern in VER aligns with findings in

Table 1: Distribution of VER across estrous cycle phases

	Estrus	Metestrus	Diestrus	Proestrus
VER reading (in units)	262.50 ± 12.28[a]	501.33 ± 60.59[b]	535.64 ± 63.17[b]	488.33 ± 51.37[b]

[a,b] Values (Means ± SD) with different superscripts in the column differ significantly (P < 0.001); N=6

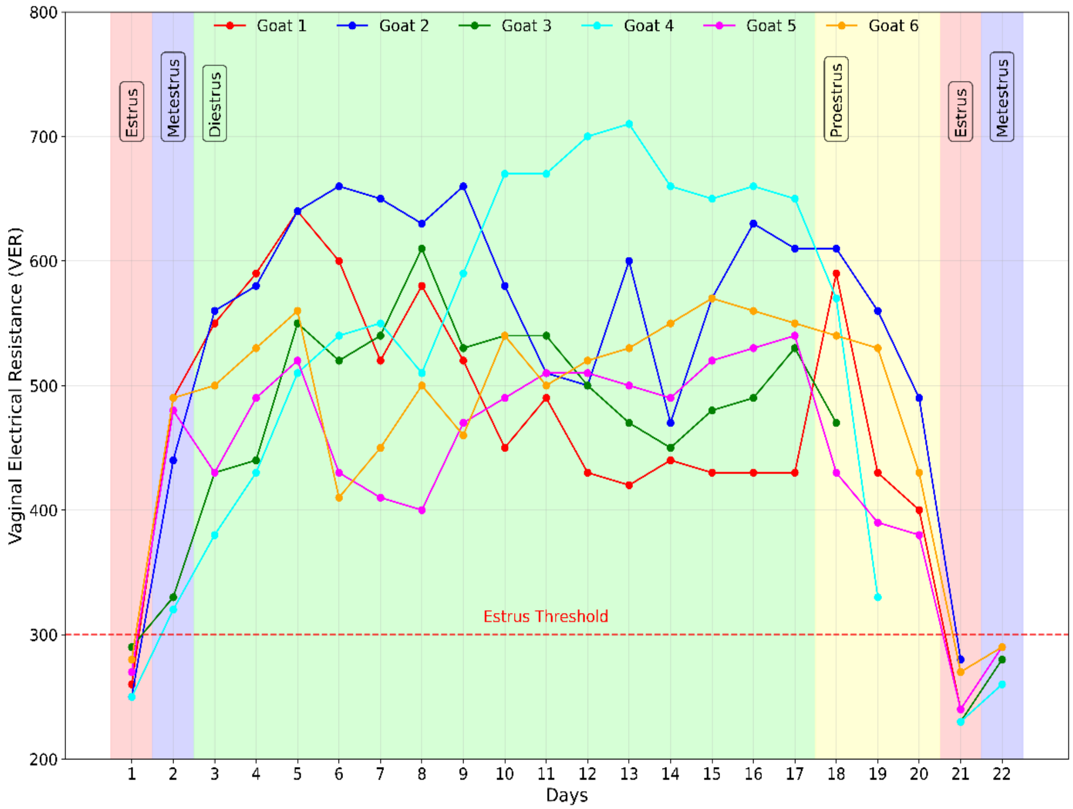

Fig. 1: Trend of VER (in units) in individual animals across the phases of estrous cycle

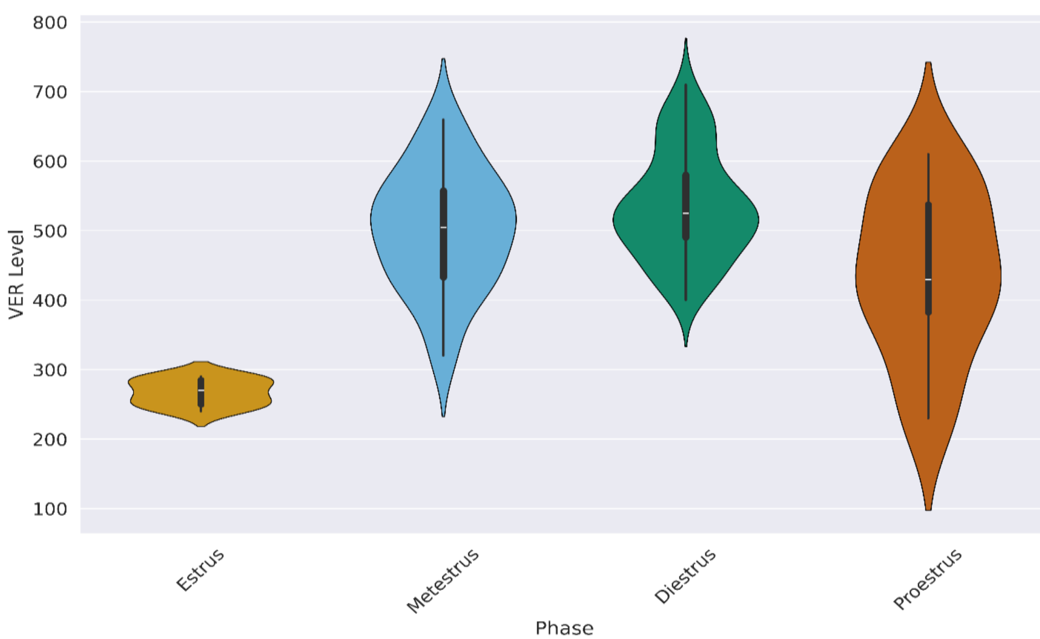

Fig. 2: Phase-wise distribution of VER (in units) in the studied experimental goats

Bangladeshi water buffaloes (Juvena *et al*., 2015) and Beetal goats (Murtaza *et al*., 2020), where VER significantly declined during estrus and peaked in later phases. A notable transition in VER was observed between estrus and metestrus, as well as from proestrus to estrus, with negative and positive shifts, respectively (Fig. 3). This transition is consistent with observations in Gaddi ewes, where a sharp increase in VER was recorded after the initial drop during early estrus (Tyson *et al*., 2023). Such changes suggest that VER is a reliable marker for different phases of the estrous cycle, aiding in precise estrus detection.

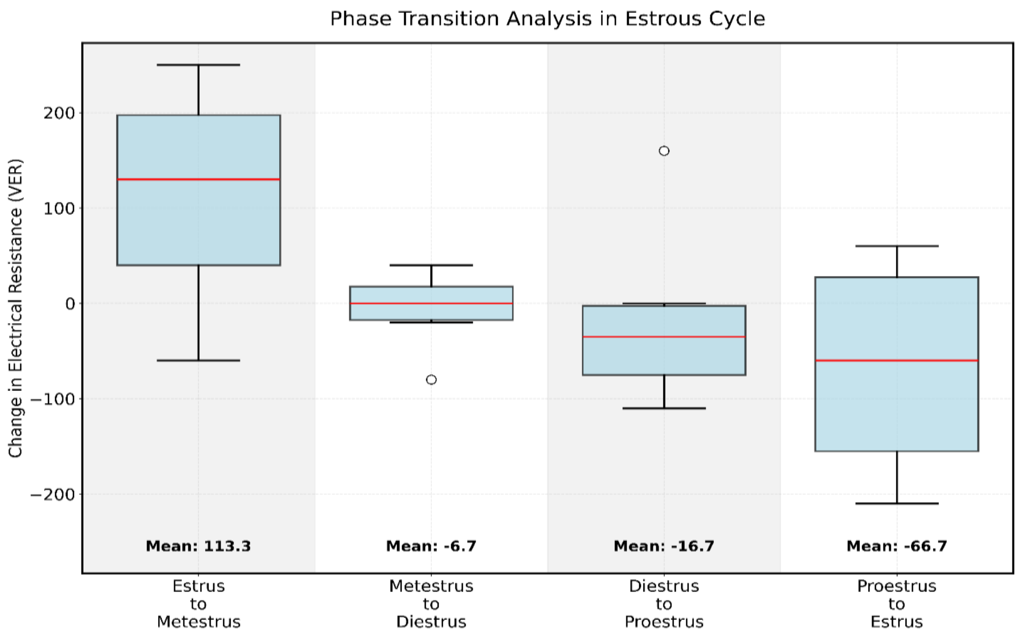

Fig. 3: Box and whisker plot representing change in VER during different phase transitions across estrous cycle

The correlation analysis between VER and key reproductive parameters demonstrated a strong association between VER and external estrus signs (Fig. 4). Buck interest exhibited the highest positive correlation with VER (r = 0.79), followed by vulvar edema (r = 0.61) and cervical mucus (r = 0.37). These findings indicate that VER serves as an effective predictor of estrus intensity when combined with external observations. Similar to the present findings, the mean VER in control and synchronised groups ranged from 337 ± 26 to 633 ± 122, and 405 ± 39 to 788 ± 160, respectively, in West African dwarf goats (Olawole *etal*., 2024). However, there was not

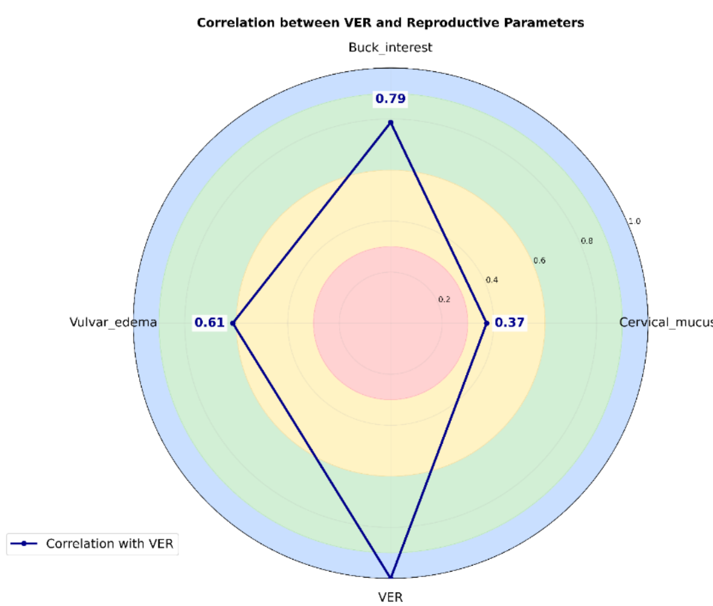

Fig. 4: Radar plot displaying correlation of VER with physiological signs of estrus such as buck interest, cervical mucus and vulvar edema

a significant difference between the two groups. Further low values observed in estrus in present study are in agreement with earlier studies by Theodosiadou *et al*. (2015) and Rahman *et al*. (2020), which reported that lower VER values were associated with higher conception rates and estrus intensity. Principal Component Analysis (PCA) identified VER and buck interest as the most influential criteria for estrus detection, with an inverse relationship between them. The first two principal components explained more than 85% of the variation in the dataset (Fig. 5), reinforcing the importance of these parameters in determining estrus. Similar findings in crossbred cows and heifers (Ningwal *et al*., 2018) and ewes (Naher *et al*., 2016) suggest that increasing impedance is associated with successful conception, highlighting VER as a potential tool for optimizing breeding timing.

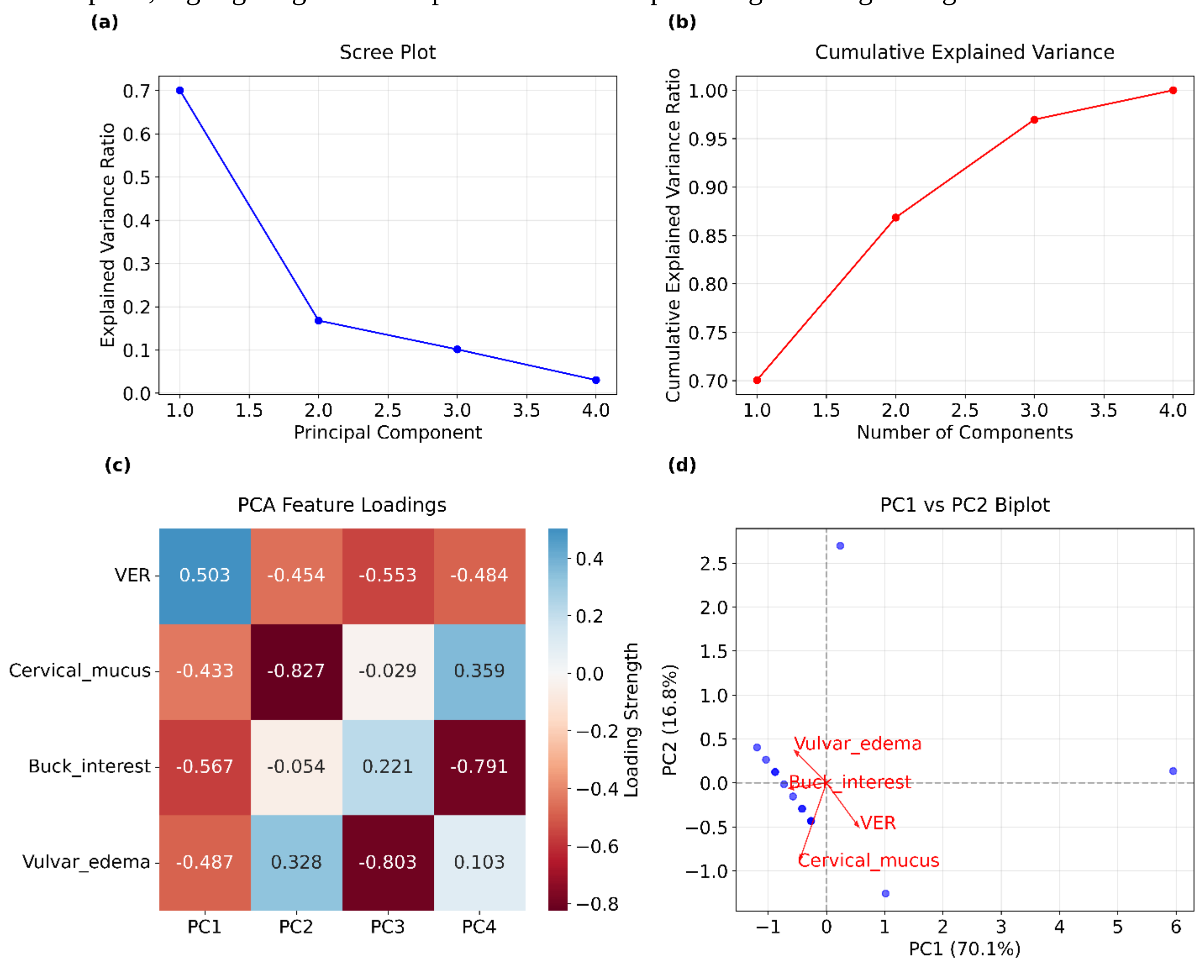

Fig. 5: Principal component analysis (PCA) performed to identify key features explaining variations in estrus, represented by (A) scree plot, (B) cumulative explained variance, (C) PCA feature loadings, and (D) PC1 vs PC2 bi-plot

The observed significant drop in VER at 12 h post-estrus onset in Beetal goats, correlating with the highest pregnancy rate, underscores its role in precise AI timing (Murtaza *et al*., 2020). Additionally, Malakar *et al*. (2017) reported increased VER values (320-370 Ω) at 19-22 days post-AI as a reliable marker for early pregnancy detection. This aligns with the present study, where VER peaked during metestrus and diestrus, suggesting its potential application for both estrus detection and early pregnancy diagnosis. Despite its reliability, some limitations remain, as noted by Zuluaga *et al*. (2008) and Ghoneim *et al*. (2015) that VER measurements alone may not be sensitive enough to differentiate females with or without large preovulatory follicles. Combining VER with endocrine markers, such as serum progesterone levels, could enhance accuracy in estrus detection (Rahman *et al*., 2020). Nonetheless, the observed cyclic variation in VER, along with its strong correlation with reproductive parameters, supports its practical application in precision reproductive management in Black Bengal goats.

Conclusion: The present study corroborates previous research and highlights the practical applicability of VER measurements in reproductive management in Black Bengal breed. This study has provided a maximum threshold of VER i.e. 300 units or 30 Ohms for the detection of estrus in small-sized goats. Moreover, our findings revealed that a low VER value was positively associated with buck interest and behavioural signs (cervical mucus and vulvar edema), highlighting its robust positive predictive ability for detecting estrus in goats. This method has proved to be a non-invasive, real-time method for detecting estrus and can enhance breeding efficiency and reproductive outcomes in livestock species. However, the results need to be further correlated with endocrinological and ultrasonographic studies to extrapolate the applications for monitoring ovulation and pregnancy in small ruminants.

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Competing interests: The authors declare no competing interests.

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