J Anim Reprod Biotechnol 2023;38:263-267
pISSN: 2671-4639 • eISSN: 2671-4663
https://doi.org/10.12750/JARB.38.4.263

JARB
Journal of Animal Reproduction and Biotechnology
Check for updates

Original Article

A study on the correlation between vaginal conductivity and estrus in Hanwoo (*Bos taurus coreanae*) cows

Junkoo Yi[1,#], Jinyeon Park[2,4,#], Jaejung Ha[2], Daejung Yu[3], Woo-Sung Kwon[4,*] and Daehyun Kim[5,*]

[1]School of Animal Life Convergence Science, Hankyong National University, Ansung 17579, Korea
[2]Gyeongsangbuk-Do Livestock Research Institute, Yeongju 36052, Korea
[3]Chonnam Agricultural Research & Extension Services Livestock Institute, Gangjin 59213, Korea
[4]Department of Animal Science and Biotechnology, Kyungpook National University, Sangju 37224, Korea
[5]Department of Animal Science, Chonnam National University, Gwangju 61186, Korea

Received October 16, 2023
Revised October 25, 2023
Accepted October 25, 2023

***Correspondence**
Daehyun Kim
E-mail: kimdhbio@jnu.ac.kr
***Correspondence**
Woo-Sung Kwon
E-mail: wskwon@knu.ac.kr

[#]These authors contributed equally to this work.

Author's Position and Orcid no.
Yi J, Professor,
https://orcid.org/0000-0003-2593-6529
Park J, Researcher,
https://orcid.org/0000-0001-6143-8856
Ha J, Senior researcher,
https://orcid.org/0000-0001-6785-6346
Yu D, Senior researcher,
https://orcid.org/0009-0008-9870-9734
Kwon W-S, Professor,
https://orcid.org/0000-0002-0848-7189
Kim D, Professor,
https://orcid.org/0000-0002-4820-4438

ABSTRACT

Background: Estrus in cows can be detected through vaginal electrical resistance or conductivity. However, there are no studies measuring vaginal electrical resistance in Hanwoo cows. This study aims to measure the vaginal electrical resistance value in Hanwoo cows and compare it with estrus and ovulation.

Methods: Vaginal electrical resistance values of 73 Hanwoo cows were measured before and after estrus at the Gyeongsangbuk-do Livestock Research Institute. Measurements were taken on days -6, -3, -2, -1, 0, 1, 2, 3, and 6 of artificial insemination. Large follicles and ovulation were confirmed using transvaginal ultrasonography.

Results: The vaginal electrical resistance averaged 225.6 ± 6.3 Ω days before the artificial insemination date, decreasing until the day of artificial insemination. The average vaginal electrical resistance was 163.7 ± 4.6 Ω on the date of artificial insemination, and 188.8 ± 4.3 Ω one day after artificial insemination, when large follicles were observed. In addition, on the 6th day after artificial insemination, the vaginal electrical resistance averaged 231.4 ± 5.5, which was similar to the 6th day before artificial insemination (222.5 ± 6.3). Transvaginal ultrasonography showed that most of the cows ovulated one day after artificial insemination.

Conclusions: The accuracy of estrus is high if the vaginal electrical resistance is measured for cows with confirmed estrus, making is a potentially useful for determining the timing of artificial insemination.

Keywords: estrus, Hanwoo, ovulation, vaginal conductivity, vaginal electrical resistance

INTRODUCTION

It is important to check the estrus of the cows to increase the possibility of a successful pregnancy, However, the accuracy of visual estrus detection for large-scale breeding is relatively low (Williamson et al., 1972, Senger, 1994, Aoki et al., 2005, Lima et al., 2010, Lamb and Mercadante, 2016). In order to improve the accuracy of estrus detection, recent studies have reported that the estrus of cows can be predicted using necklace-type sensors

and ruminoreticular biosensors (Williamson et al., 1972, Senger, 1994, Aoki et al., 2005, Kim et al., 2017a, Kim et al., 2017b, Choi et al., 2020, Kim et al., 2021a, Kim et al., 2021b, Kim et al., 2021c, Kim et al., 2023), which detect increased activity during estrus and short-term activity increases before parturition (Titler et al., 2015). Notably, the accuracy of ruminoreticular biosensors for estrus confirmation was higher than that of visual observation, providing more opportunities for artificial insemination and improved reproduction rate (Kim et al., 2023). During the estrus, cows demonstrate characteristics such as mounting, increased body temperature and activity, and copious vaginal mucus discharge which is commonly observed around the vulva and in the tail (Talukder et al., 2018, Higaki et al., 2019). Recent studies measuring vaginal electrical resistance values in ewes, sows, female dogs, red foxes, and rats, and analyzed its correlation with estrus in Japanese Black heifers and cows have been reported (Talukder et al., 2018, Yatu et al., 2018, Higaki et al., 2019, Chesney et al., 2020, Lindh et al., 2020, Glencorse et al., 2023). However, there are no studies measuring vaginal electrical resistance in Hanwoo cows. This study thus aims to measure the vaginal electrical resistance in Hanwoo cows before and after artificial insemination, and analyze its relationship with estrus and ovulation.

MATERIALS AND METHODS

Animal management

Hanwoo cows (n = 73) raised according to the Hanwoo Korean Feeding Standard at the Gyeongsangbuk-do Livestock Research Institute with sufficient space and stanchions were included in the study. The study was approved by the Institutional Animal Care and Use Committee (IACUC) of the Gyeongsangbuk-do Livestock Research Institute.

Estrus synchronization

The cows were synchronized using a Gonadotropin-releasing hormone-based fixed-time artificial insemination method. Detailed hormone treatment methods are detailed in Fig. 1, and additional explanations are provided in the paper published by Kim et al (Kim et al., 2023).

Vaginal electrical resistance

Vaginal electrical resistance (ohm, Ω) was measured using an electronic estrous detector (DRAMINSKI ED2, Poland) on days -6, -3, -2, -1, 0, 1, 2, 3, and 6 of artificial insemination. To increase the accuracy, all the measurements were taken by the same evaluator at the same time.

Before using A, the device was washed in sterile distilled water, and then inserted into the vagina and rotated. The measurements were taken three times, and an average of the three values was recorded. A detailed measurement method was described previously (https://www.youtube.com/watch?v=eSZqcPSetO8, https://www.youtube.com/watch?v=tcIXI_5rVB4) (Talukder et al., 2018).

Ovulation test

Ovulation was evaluated using transvaginal ultrasonography. The diameters of the follicles (mm) are provided in Supplementary Fig. 1. If ovulation was not detected with ultrasound, the cow was excluded from the results (Supplementary Fig. 2).

Statistical analysis

One-way Analysis of variance (ANOVA) analysis was used to statistically analyze the magnitude of vaginal electrical resistance and follicle size in accordance with the estrus cycle through GraphPad Prism (version 8.0.1; GraphPad Software Inc., USA).

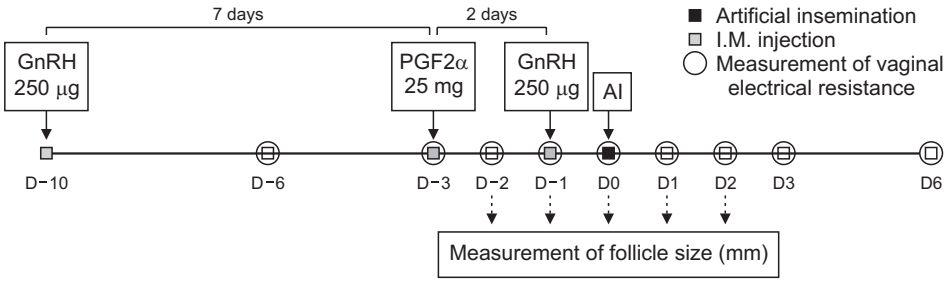

Fig. 1. Summary of experimental methods. Estrus synchronized by the GnRH based FTAI methods. vaginal electrical resistance was measured on days -6, -3, -2, -1, 0, 1, 2, 3, and 6 of artificial insemination. Follicle size was measured on days -2, -1, 0, 1, and 2.

RESULTS

A total of 73 cows were included in the study. The average vaginal electrical resistance was 225.6 ± 6.3 Ω 6 days before the artificial insemination, and continued to decrease until artificial insemination (Fig. 2 and Table 1). The average vaginal electrical resistance was 163.7 ± 4.6 Ω based on the artificial insemination date, and the average vaginal electrical resistance was 188.8 ± 4.3 Ω one day after the artificial insemination date, which corresponds with ovulation (Fig. 2 and Table 1). In addition, the vaginal electrical resistance increased on the 6th day after artificial insemination, with an average of 231.4 ± 5.5 Ω, which was similar to the 6th day before artificial insemination (Fig. 2 and Table 1). Notably, the vaginal electrical resistance measured on days -6, -3, -2, -1, 0, 1, 2, 3, 6 modification with one-way ANOVA was significantly different ($p < 0.001$). The follicular diameter was the largest at 12.8 ± 0.27 mm on day 0 and 4.7 ± 0.27 mm on day 1 of artificial insemination. It can be confirmed that the large follicles have ovulated 1 day after artificial insemination (Fig. 3).

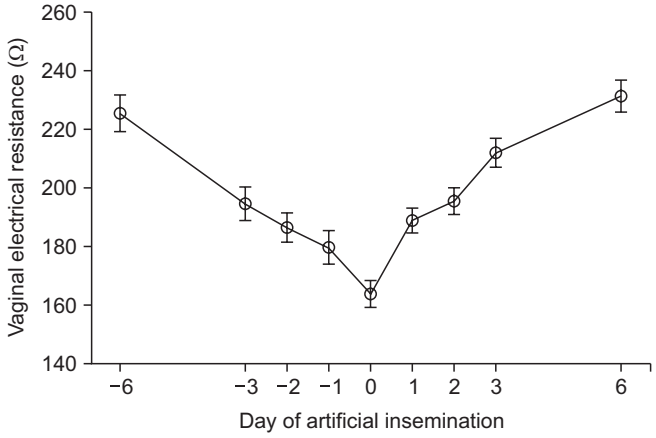

Fig. 2. Changes in vaginal electrical resistance in Hanwoo cows during the estrus cycle (n = 73). The black line connected by blank round dots (O) represents average of vaginal electrical resistance. Day 0 represents the time of artificial insemination. All results are presented as mean ± SEM. The statistical significance level was $p < 0.001$.

Table 1. Vaginal electrical resistance during the estrus cycle

Day of artificial insemination	No. of cows	Electric resistance (Ω) (Mean ± SEM)
−6	50	225.6 ± 6.3
−3	50	194.6 ± 5.8
−2	50	186.4 ± 5.0
−1	49	179.6 ± 5.8
0	92	163.7 ± 4.6
1	83	188.8 ± 4.3
2	50	195.4 ± 4.6
3	50	212.0 ± 4.9
6	49	231.4 ± 5.5

DISCUSSION

During estrus, vaginal electrical resistance value can be significantly lowered due to the large amount of mucus is present in the vagina. According to a study on of indigenous ewes, vaginal electrical resistance ranged from 370.0 ± 82.0 – 416.7 ± 51.3 Ω on the day of estrus, and increased significantly to 600 Ω during non-estrus periods (Talukder et al., 2018). The vaginal conductivity ratio of Japanese Black heifers and cows was very high on the estrus day compared to the non-estrus days (Higaki et al., 2019). It is difficult to accurately compare the vaginal conductivity ratio reported by Higaki et al. as it shows contradicting results on vaginal electrical conductivity (Higaki et al., 2019). However, vaginal electrical resistance is inversely proportional to vaginal conductivity ratio, so it can be seen that it eventually shows the same pattern. Similarly, the follicular diameter is the largest on the day of estrus. The follicle size decreases because ovulation occurs one day after estrus. In addition, in Japanese Black heifers and cows, the vaginal temperature and the vaginal

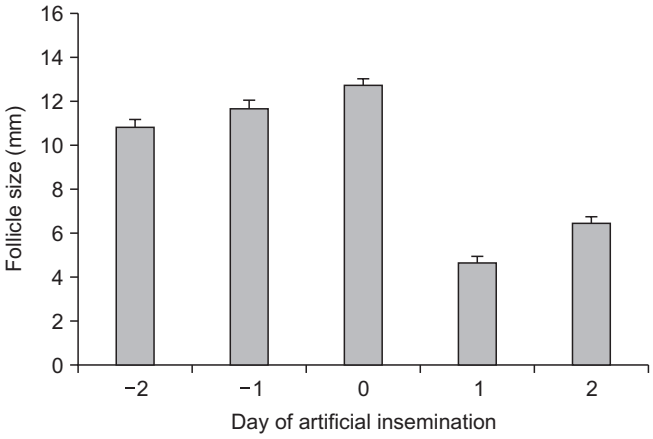

Fig. 3. Changes in follicle size of in Hanwoo cows during the estrus cycle (n = 73). The gray bars represent the average follicle size (mm). Day 0 represents the time of artificial insemination. All results are presented as mean ± SEM. The statistical significance level was $p < 0.001$.

conductivity ratio throughout the duration of the estrus cycle were compared, and both increased on the day of estrus. We also previously reported that the ruminoraticular temperature increased for about 24 hours in the estrus cycle (Kim et al., 2023). Similarly, the present study shows that the ruminoraticular temperature increases and the vacuum electrical resistance decreases on the day of estrus.

CONCLUSION

It can be useful to determine the timing of artificial insemination if the vaginal electrical resistance is measured for cows with confirmed estrus signs such as mounting, increased body temperature and activity, and mucus secretion. This can be used as raw data for the future development of biosensors that simultaneously measure vaginal electrical resistance, vaginal temperature, and vaginal activity, which can be used as a tool to determine the optimal timing of artificial insemination.

Author Contributions: Conceptualization, J.Y., J.P., J.H., D.Y., W-S.K., and D.K.; methodology, J.Y., J.P., J.H., D.Y., W-S.K., D.K.; investigation, J.Y., J.P., J.H., D.Y.; data curation, J.Y., J.P., J.H., D.Y.; writing—original draft preparation, J.Y., J.P.; writing—review and editing, W-S.K., D.K.; supervision, W-S.K., D.K.; project administration, W-S.K., D.K.; funding acquisition, W-S.K., D.K.

Funding: None.

Ethical Approval: This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Animal Care and Use Committee (IACUC) of the Gyeongsangbuk-do Livestock Research Institute, Yeongju, Korea (protocol code GAEC/140 approved on December 14, 2021).

Consent to Participate: Not applicable.

Consent to Publish: All authors agreed to the terms outlined in this document and approved it's submission of this manuscript for publication.

Availability of Data and Materials: The data analyzed or generated during this study are available upon request from the corresponding author.

Acknowledgements: None.

Conflicts of Interest: No potential conflict of interest relevant to this article was reported.

SUPPLEMENTARY MATERIALS

Supplementary material can be found via https://doi.org/10.12750/JARB.38.4.263

REFERENCES

Aoki M, Kimura K, Suzuki O. 2005. Predicting time of parturition from changing vaginal temperature measured by data-logging apparatus in beef cows with twin fetuses. Anim. Reprod. Sci. 86:1-12.

Chesney KL, Chang C, Bryda EC. 2020. Using vaginal impedance measurement to identify proestrus in rats given luteinizing hormone releasing hormone (LHRH) agonist. J. Am. Assoc. Lab. Anim. Sci. 59:282-287.

Choi W, Ro Y, Hong L, Ahn S, Kim H, Choi C, Kim H, Kim D. 2020. Evaluation of ruminal motility using an indwelling 3-axis accelerometer in the reticulum in cattle. J. Vet. Med. Sci. 82:1750-1756.

Glencorse D, Grupen CG, Bathgate R. 2023. Vaginal and vestibular electrical resistance as an alternative marker for optimum timing of artificial insemination with liquid-stored and frozen-thawed spermatozoa in sows. Sci. Rep. 13:12103.

Higaki S, Miura R, Suda T, Andersson LM, Okada H, Zhang Y, Itoh T, Miwakeichi F, Yoshioka K. 2019. Estrous detection by continuous measurements of vaginal temperature and conductivity with supervised machine learning in cattle. Theriogenology 123:90-99.

Kim D, Ha J, Moon J, Kim D, Lee W, Lee C, Kim D, Yi J. 2021a. Increased ruminoreticular temperature and body activity after foot-and-mouth vaccination in pregnant Hanwoo (*Bos taurus coreanae*) cows. Vaccines (Basel) 9:1227.

Kim D, Kwon WS, Ha J, Moon J, Yi J. 2023. Increased accuracy of estrus prediction using ruminoreticular biocapsule sensors in Hanwoo (*Bos taurus coreanae*) cows. J. Anim. Sci. Technol. 65:759-766.

Kim D, Moon J, Ha J, Kim D, Yi J. 2021b. Effect of foot-and-mouth disease vaccination on acute phase immune response and anovulation in Hanwoo (*Bos taurus coreanae*). Vaccines (Basel) 9:419.

Kim DH, Ha JJ, Yi JK, Kim BK, Kwon WS, Ye BH, Kim SH, Lee Y. 2021c. Differences in ruminal temperature between pregnant and non-pregnant Korean cattle. J. Anim. Reprod. Biotechnol. 36:45-50.

Kim H, Oh S, Ahn S, Choi B. 2017a. Real-time monitoring method of cattle's temperature for FMD prevention and its case studies. J. Korean Inst. Inf. Technol. 15:141-150.

Kim H, Oh S, Ahn S, Choi B. 2017b. Real-time temperature monitoring to enhance estrus detection in cattle utilizing ingestible bio-sensors: method & case studies. J. Korean Inst. Inf. Technol. 15:65-75.

Lamb GC and Mercadante VR. 2016. Synchronization and artificial insemination strategies in beef cattle. Vet. Clin. North Am. Food Anim. Pract. 32:335-347.

Lima FS, De Vries A, Risco CA, Santos JE, Thatcher WW. 2010. Economic comparison of natural service and timed artificial insemination breeding programs in dairy cattle. J. Dairy Sci. 93:4404-4413.

Lindh L, Lindeberg H, Banting A, Banting S, Sainmaa S, Beasley S, Korhonen HT, Peltoniemi OAT. 2020. Administration of aromatase inhibitor MPV-2213ad to blue fox vixens (Vulpes lagopus) as a model for contraception in female dogs. Theriogenology 152:53-63.

Senger PL. 1994. The estrus detection problem: new concepts, technologies, and possibilities. J. Dairy Sci. 77:2745-2753.

Talukder MRI, Hasan M, Rosy TA, Bari FY, Juyena NS. 2018. Monitoring vaginal electrical resistance, follicular waves, and hormonal profile during oestrous cycle in the transition period in Bangladeshi sheep. J. Vet. Res. 62:571-579.

Titler M, Maquivar MG, Bas S, Rajala-Schultz PJ, Gordon E, McCullough K, Federico P, Schuenemann GM. 2015. Prediction of parturition in Holstein dairy cattle using electronic data loggers. J. Dairy Sci. 98:5304-5312.

Williamson NB, Morris RS, Blood DC, Cannon CM. 1972. A study of oestrous behaviour and oestrus detection methods in a large commercial dairy herd. I. The relative efficiency of methods of oestrus detection. Vet. Rec. 91:50-58.

Yatu M, Sato M, Kobayashi J, Ichijo T, Satoh H, Oikawa T, Sato S. 2018. Collection and frozen storage of semen for artificial insemination in red foxes (Vulpes vulpes). J. Vet. Med. Sci. 80:1762-1765.