Risk factors for repeat breeder dairy cows and their impacts on reproductive performance

Jae-Kwan Jeong, Ill-Hwa Kim*
College of Veterinary Medicine, Chungbuk National University, Cheongju 28644, Korea

Abstract

The objective of this study was to identify risk factors for repeat breeder dairy cows and their impact on reproductive performance. The characteristics of 1,504 cows, including their peripartum health, nutrition, production, and reproduction, were collected. Cows with metabolic disorder were significantly more likely (odds ratio [OR], 2.47; p < 0.001) and cows with clinical endometritis tended to be more likely (OR, 1.35; p < 0.1) to become repeat breeders than cows without metabolic disorder and clinical endometritis, respectively. Cows initially inseminated > 80 days after calving were less likely (OR, 0.78; p < 0.05) to become repeat breeders than cows initially inseminated ≤ 80 days after calving. As a result, repeat breeding in dairy cows resulted in a 90 day longer (p < 0.0001) mean interval from calving to pregnancy. In conclusion, postpartum metabolic disorder, clinical endometritis, and a short interval from calving to initial insemination were risk factors for repeat breeder dairy cows, resulting in a severely impaired reproductive performance.

Keywords: repeat breeder cow; risk factors; postpartum disorder; breeding time; reproductive performance

Introduction

A repeat breeder is defined as a cow that fails to become pregnant after 3 or more consecutive inseminations within the same lactation period without any detectable abnormalities in the genital tract and with apparently normal estrous cycles [1–3]. This condition markedly reduces reproductive performance due to the increased number of inseminations and longer calving intervals, thereby increasing culling and replacement costs in dairy cows [4,5]. Because the causes remain unknown and/or may be covered by other symptoms, it is very difficult to determine methods to overcome this disorder. Likewise, methods of prevention and treatment have not yet been established, except for the administration of hormones, including gonadotropin-releasing hormone (GnRH) and progesterone, prostaglandin F2α (PGF2α), or combinations of these agents [3,6,7], or the use of embryo transfer techniques [8,9]. Thus, the identification of risk factors for repeat breeder cows might help to design effective measures to prevent and/or treat this reproductive disorder.

Previous studies have suggested that alterations in hormone concentrations, including high estradiol concentrations at estrus and reduced luteinizing hormone (LH) concentrations before peak LH or subluteal progesterone concentrations [10,11], are physiological factors associated with repeat breeder cows. Other phys-
iological factors include impaired oocyte competence [12,13], ovulation defects [11], early embryonic death [14], and an altered or impaired uterine environment [15,16]. In addition, peri- and postpartum diseases, such as dystocia, stillbirth, metritis, cystic ovarian disease, subclinical endometritis [17,18], delayed time to first estrus after calving [19], and short time from calving to initial insemination [20], have also been reported to be factors associated with repeat breeder cows.

Despite studies reporting risk factors for repeat breeder cows, the factors identified have been inconsistent, as they may be affected by management practices, such as intensive or extensive production systems; the productive and/or reproductive capacities of individual animals or herds; and/or geographic or regional characteristics. Despite poor housing conditions, such as limited space per cow and inadequate feeding, milk production per cow has increased annually in Korea using an intensive production system. These dairy management practices make it easier for cows to become repeat breeders, reducing their reproductive performance. However, the incidence of repeat breeder dairy cows in Korea has not been determined in recent years. Thus, the identification of risk factors for repeat breeder dairy cows maintained under intensive productive management and providing a high yield of milk may provide valuable information on methods to reduce the incidence of repeat breeder dairy cows. Therefore, the present study was designed to identify risk factors for repeat breeder dairy cows by analysing their peripartum disorders, nutrition, milk production, and reproduction, collected during periodic evaluations of herd health and reproduction.

Materials and Methods

Animals and health and reproductive management

This study was conducted on 12 dairy farms in Chungcheong Province, Korea. Each farm contained between 50 and 250 cows, which were maintained in loose housing systems and fed total mixed rations, and milked twice daily. The mean annual milk yields per cow on these farms ranged from 9,195 to 11,590 kg. Animal experiments were performed with the approval of the Institutional Animal Care and Use Committee of Chungbuk National University, Cheongju, Korea (CNBUA-1299-19-02).

All cows in the participating farms underwent reproductive health checks every 2 to 4 weeks. These included an examination of their ovarian structures (follicle and corpus luteum [CL]) and uterus by transrectal palpation and ultrasonography. At the time of these examinations, the body condition scores (BCS) of these cows were evaluated using a previously developed visual technique [21].

Peri- and postpartum disorders were defined as described [22–24]. Dystocia was defined as calving requiring assistance. Retained placenta was defined as the retention of the fetal membranes for longer than 24 hours. Septicemic metritis was defined as a fever (rectal temperature ≥ 39.5°C) and a watery, fetid, red-brown uterine discharge. Ketosis was diagnosed as the occurrence of anorexia and depression, and the odor of acetone on the breath. Milk fever was diagnosed as the occurrence of nervousness, weakness, and recumbency after calving. Abomasal displacement was diagnosed by abdominal auscultation. Clinical endometritis was diagnosed as the occurrence of a mucopurulent uterine discharge and by transrectal palpation and ultrasonography. Cows diagnosed with septicemic metritis were subcutaneously administered antibiotics and supportive medication for 3 to 5 days. Ketotic cows were treated with propylene glycol, dextrose, or glucocorticoids, and those diagnosed with milk fever were treated with a calcium preparation. Abomasal displacement was corrected surgically by right or left flank laparotomy. Cows with clinical endometritis and CL were treated with PGF$_{2α}$, whereas cows with clinical endometritis but without CL were administered a single intrauterine infusion of 2% povidone-iodine solution, and were re-treated if necessary.

The voluntary waiting period from calving to the first artificial insemination (AI) was 40 days. In addition to estrus detection, herd reproductive programs, such as Ovsynch or 2 modified presynchronization-Ovsynch (modified Presynch-Ovsynch or Double-Ovsynch) were employed. For Ovsynch, cows were administered GnRH on day 65 (calving = day 0), PGF$_{2α}$ on day 72, and GnRH 56 hours later, followed by timed AI 16 hours later. For modified presynchronization-Ovsynch programs, cows were administered PGF$_{2α}$ (Presynch-Ovsynch) or GnRH (Double-Ovsynch) on day 45, followed by PGF$_{2α}$ on day 55 and GnRH on day 58, followed by Ovsynch 7 days later. Pregnancy was evaluated 31 and 48 days after AI. If cows did not conceive following the first AI, those that exhibited natural estrus were again inseminated according to the am–pm rule. Cows confirmed as not being pregnant by ultrasonography were resynchronized using Ovsynch, with the resynchronization programs continued until the cows became pregnant. Reproductive performance data were collected for a minimum of 210 days postpartum or until pregnancy or culling.

Data collection and statistical analyses

The characteristics of 1,504 dairy cows (574 primiparous and 930 multiparous) on 12 Holstein dairy farms were recorded.
Factors collected included detailed information regarding parity, the occurrence of peri- or postpartum disorders (e.g., dystocia, retained placenta, metabolic disorder including ketosis, milk fever or abomasal displacement, septicemic metritis, and clinical endometritis), BCS, milk yield during the first 3 months, and dates of previous calving, AI, and confirmation of pregnancy.

Data are expressed as the mean ± standard error of the mean (SEM). For statistical analysis, cows were categorized as either primiparous or multiparous, by herd size (≤ 60 or > 60 lactating cows), by BCS loss between calving and 30 days after calving (no or yes), by the interval between calving and first insemination (≤ 80 or > 80 days), and by mean milk yield during the first 3 months postpartum (≤ 40 or > 40 kg). All statistical analyses were performed using SAS ver. 9.4 (SAS Institute, USA).

The risk of repeat breeder cows was analysed by logistic regression using the LOGISTIC procedure. Factors in the logistic regression model included herd size, parity, dystocia, retained placenta, metabolic disorder, septicemic metritis, clinical endometritis, BCS loss between calving and 30 days after calving, interval (days) between calving and first insemination, milk yield, and interactions among these variables. Backward stepwise regression was used in all the models, with elimination performed based on the Wald statistic criterion when \( p > 0.10 \). Odds ratios (OR) and 95% confidence intervals were determined using logistic regression.

A Cox’s proportional hazard model and the PHREG procedure were used to compare the probability of pregnancy by 210 days postpartum between repeat breeders and non-repeat breeders. This yielded an estimate of the likelihood of a cow being pregnant at a given time. The time variable used in this model was the interval in days between calving and pregnancy. Cows that died, were sold, or were not pregnant by 210 days postpartum were not included in the analysis. The Cox model included herd size, parity, dystocia, retained placenta, metabolic disorder, septicemic metritis, clinical endometritis, BCS loss between calving and 30 days after calving, interval (days) between calving and first insemination, milk yield, and interactions among these variables. Proportional hazards were determined based on interactions between explanatory variables and time, and by evaluating Kaplan-Meier curves. The median and mean number of days to pregnancy was determined by survival analysis in the Kaplan-Meier model using the LIFETEST procedure within the SAS software. A survival plot was generated using the Survival option of MedCalc software (ver. 11.1; MedCalc Software, Belgium). A \( p \)-value ≤ 0.05 was considered statistically significant, whereas a \( p \)-value > 0.05 but < 0.1 was considered to indicate a trend.

**Results**

**Reproductive and productive characteristics of the cows**

The 1,504 cows included in this study had a mean ± SEM parity of 2.23 ± 0.04. The incidence rates of dystocia, retained placenta, metabolic disorder, septicemic metritis, and clinical endometritis were 5.3%, 10.1%, 0.9%, 4.2%, and 11.2%, respectively. The mean BCSs at calving and 30 days after calving were 41.5 ± 0.2 kg, and 40.4 ± 0.2 kg, respectively, with an average of 40.6 ± 0.2 kg. The pregnancy rates per AI after the first, second, and third inseminations were 35.0%, 27.7%, and 38.3%, respectively.

The overall mean incidence rate of repeat breeder dairy cows was 30.0%. Table 1 shows the overall descriptive statistics for the incidence of repeat breeder cows.

**Risk factors for repeat breeder dairy cows**

Table 2 shows the risk factors for repeat breeder dairy cows. The occurrences of a metabolic disorder and clinical endometritis, as well as a shorter time between calving and first insemination, were found to be risk factors for repeat breeder dairy cows. Cows that had metabolic disorder were significantly more likely (OR, 2.47; \( p < 0.001 \)) to become repeat breeders than cows without metabolic disorder. In addition, cows that had clinical endometritis tended to be more likely (OR, 1.35; \( p < 0.05 \)) to become repeat breeders than cows without endometritis. Furthermore, cows initially inseminated > 80 days after calving were significantly less likely (OR, 0.78; \( p < 0.05 \)) to become repeat breeders than cows initially inseminated ≤ 80 days after calving. By contrast, herd size, parity, dystocia, retained placenta, septicemic metritis, BCS loss between calving and 30 days postpartum, and milk yield were not risk factors for repeat breeder dairy cows (\( p > 0.1 \)).

**The impact of repeat breeding on reproductive outcomes in dairy cows**

Table 3 shows the factors that affected the likelihood of pregnancy by 210 days after calving. Repeat breeder cows were less likely to become pregnant (hazard ratio, 0.08; \( p < 0.0001 \)) than non-repeat breeder cows, significantly extending (\( p < 0.0001 \)) the mean interval between calving and pregnancy by 90 days.
Table 1. Factors associated with the incidence of repeat breeder dairy cows

| Variable                         | Level                                      | Repeat breeder+ | Repeat breeder- |
|----------------------------------|--------------------------------------------|-----------------|----------------|
| Dystocia                         | No                                         | 420             | 1,005          |
|                                  | Yes                                        | 31              | 48             |
| Retained placenta                | No                                         | 405             | 947            |
|                                  | Yes                                        | 46              | 106            |
| Metabolic disorder               | No                                         | 419             | 1,022          |
|                                  | Yes                                        | 32              | 31             |
| Septicemic metritis              | No                                         | 446             | 1,044          |
|                                  | Yes                                        | 5               | 9              |
| Clinical endometritis            | No                                         | 390             | 946            |
|                                  | Yes                                        | 61              | 107            |
| Herd size                        | ≤ 60 lactating cows                        | 167             | 410            |
|                                  | > 60 lactating cows                        | 284             | 643            |
| Parity                           | Primiparous                                | 180             | 394            |
|                                  | Multiparous                                | 271             | 659            |
| Body condition score loss        | No                                         | 224             | 556            |
|                                  | Yes                                        | 227             | 497            |
| Interval between calving and     | ≤ 80 days                                  | 306             | 663            |
| first insemination               | > 80 days                                  | 145             | 390            |
| Milk yield during the first 3    | ≤ 40 kg                                    | 220             | 501            |
| months postpartum                | > 40 kg                                    | 231             | 552            |

Table 2. Odds ratios for variables included in the logistic regression model for the risk of repeat breeder dairy cows

| Variable                      | Odds ratio | 95% confidence interval | p-value |
|-------------------------------|------------|-------------------------|---------|
| Metabolic disorder*           | No         | Reference               |         |
|                               | Yes        | 2.47                    | 1.480–4.107 | < 0.001 |
| Clinical endometritis        | No         | Reference               |         |
|                               | Yes        | 1.35                    | 0.962–1.903 | < 0.1   |
| Interval between calving and  | ≤ 80 days  | Reference               |         |
| first insemination            | > 80 days  | 0.78                    | 0.618–0.992 | < 0.05  |
| Dystocia                      |            |                         | > 0.1   |
| Retained placenta             |            |                         | > 0.1   |
| Septicemic metritis           |            |                         | > 0.1   |
| Herd size†                    |            |                         | > 0.1   |
| Parity                        |            |                         | > 0.1   |
| Body condition score loss‡    |            |                         | > 0.1   |
| Milk yield§                   |            |                         | > 0.1   |

*Metabolic disorders included ketosis, milk fever, and abomasal displacement.
†Herd size was categorized as ≤ 60 or > 60 lactating cows.
‡Body condition score loss between calving and 30 days after calving was categorized as no or yes.
§Milk yield during the first 3 months postpartum was categorized as ≤ 40 or > 40 kg.

(Fig. 1). In addition, herd size, dystocia, metabolic disorder, interval between calving and first insemination, and milk yield affected the likelihood of pregnancy by 210 days after calving.

Discussion

This retrospective study identified risk factors for repeat breeder dairy cows and their impact on reproductive perfor-
Table 3. Factors affecting the probability of pregnancy by 210 days postpartum, identified using the PHREG procedure

| Variable                              | Hazard ratio | 95% confidence interval | p-value |
|---------------------------------------|--------------|-------------------------|---------|
| Repeat breeder                        |              |                         |         |
| No                                    | Reference    |                         |         |
| Yes                                   | 0.08         | 0.062–0.090             | < 0.0001|
| Herd size                             |              |                         |         |
| ≤ 60 lactating cows                   | Reference    |                         |         |
| > 60 lactating cows                   | 1.26         | 1.117–1.420             | < 0.001 |
| Dystocia                              |              |                         |         |
| No                                    | Reference    |                         |         |
| Yes                                   | 0.7          | 0.527–0.936             | < 0.05  |
| Metabolic disorder*                   |              |                         |         |
| No                                    | Reference    |                         |         |
| Yes                                   | 0.52         | 0.367–0.739             | < 0.001 |
| Interval between calving and first insemination | | | |
| ≤ 80 days                             | Reference    |                         |         |
| > 80 days                             | 0.6          | 0.526–0.674             | < 0.0001|
| Milk yield                            |              |                         |         |
| ≤ 40 kg                               | Reference    |                         |         |
| > 40 kg                               | 0.85         | 0.725–0.996             | < 0.05  |
| Retained placenta                     |              |                         | > 0.1   |
| Septicemic metritis                   |              |                         | > 0.1   |
| Clinical endometritis                 |              |                         | > 0.1   |
| Parity                                |              |                         | > 0.1   |
| Body condition score loss†            |              |                         | > 0.1   |

*Metabolic disorders included ketosis, milk fever, and abomasal displacement.
†Body condition score loss between calving and 30 days after calving was categorized as no or yes.

Fig. 1. Survival curves for the interval between calving and pregnancy in repeat breeder (n = 451) and non-repeat breeder (n = 1,053) dairy cows. The probability of pregnancy by 210 days postpartum was significantly lower (p < 0.0001) in repeat breeder (hazard ratio, 0.08) than in non-repeat breeder dairy cows. The mean intervals between calving and pregnancy were 198.2 ± 1.1 days and 108.0 ± 1.2 days in repeat breeder and non-repeat breeder dairy cows, respectively (p < 0.0001).

Cows that had postpartum metabolic disorder or clinical endometritis were more likely to become repeat breeders than those that did not, whereas cows that underwent initial AI > 80 days after calving were less likely to become repeat breeders than cows that underwent initial AI ≤ 80 days after calving. Reproductive performance was more impaired in repeat breeder than in non-repeat breeder cows, with the mean interval between calving and pregnancy extended by 90 days.

The incidence rate (30.0%) of repeat breeder dairy cows in the present study was higher than previously reported rates (14.0% to 24.0%) [4,5,20]. Although the reasons for the higher incidence rate in the present study remain unknown, unfavorable farm conditions, such as their facilities, available space, and management system, and differences in the productive and/or reproductive characteristics of the animals, may be associated with incidence rate. These findings suggest the need for more careful attention to the higher incidence of repeat breeder cows under an intensive productive system, and the need for suitable strategies to prevent this disorder.

The present study found that metabolic disorders and clinical endometritis were risk factors for repeat breeder dairy cows.

https://doi.org/10.14405/kjvr.20220003
though metabolic disorders have not been previously reported to be a risk factor for repeat breeder cows, postpartum metabolic disorders, including abomasal displacement and milk fever, were found to adversely affect subsequent reproductive performance in dairy cows [25,26]. Because a large proportion of cows with metabolic disorder in the present study had abomasal displacement, the sequela of the abomasal displacement might be associated with the increased incidence of repeat breeders. Cows with abomasal displacement were found to have higher neutrophil counts in the uterus, increasing the risk of concurrent clinical endometritis, which was associated with impaired reproductive performance [25].

Our finding, that clinical endometritis was a risk factor for repeat breeder cows, is supported by results showing that cytological endometritis not only significantly decreased reproductive performance but also increased the incidence of repeat breeder dairy cows [18]. Although the exact mechanism responsible for the association between endometritis and repeat breeders has not been determined, endometritis has been reported to suppress the releasing of GnRH and LH, to inhibit ovulation of a dominant follicle, and/or to impair the uterine environment [16,27]. However, other studies showed that cytological endometritis was not significantly associated with the incidence of repeat breeder cows [2,28]. These differences between studies using uterine cytology may be due to differences in thresholds (the percentage of neutrophils among total endometrial cells) and/or the time of collection of the uterine samples (i.e., during the voluntary waiting period or before AI) used to define cytological endometritis. By contrast, long-term infertility in repeat breeders may be associated with alterations in endometrial function, induced by changes in endometrial gene expression [15,29].

Our finding, that cows with a longer interval between calving and first insemination were less likely to become repeat breeders than those that had a shorter interval, is consistent with a previous study [20]. The mechanism responsible for the association of a shorter interval between calving and first insemination and a high risk for repeat breeder cows remains unclear. However, a longer interval between calving and first insemination may be associated with improved uterine health, reduced systemic inflammation, and more time to resume ovarian cyclicity [30].

The present study also found that reproductive performance was significantly lower in repeat breeder than in non-repeat breeder cows, with cumulative pregnancy rates by 210 days postpartum of 34.8% and 97.0%, respectively (data not shown). This resulted in a 90 day longer mean interval between calving and pregnancy in repeat breeder dairy cows. The cumulative pregnancy rate by 210 days postpartum in repeat breeder cows in the present study was similar to findings showing that only 31.4% of repeat breeder dairy cows conceived within 210 days postpartum [20]. Another study showed that the calving-to-conception interval was 187 days longer in repeat than in non-repeat breeder cows [31]. Moreover, the OR of pregnancy in repeat compared with non-repeat breeder cows was 0.73 [5]. The higher incidence of repeat breeder cows increased the interval from calving to conception and increased culling in dairy herds, leading to severe economic losses [4,17,32].

A marked alteration in BCS during the postpartum period was found to adversely affect reproductive performance [33,34], whereas the effect of milk yield during the early lactation period on reproductive performance remains unclear [35,36]. The present study found that BCS loss did not affect the likelihood of pregnancy by 210 days postpartum, whereas a higher milk yield had a negative effect on the likelihood of pregnancy, suggesting that milk yield during the early lactation period affected long-term but not short-term fertility, as milk yield was not a risk factor for repeat breeder cows.

In summary, the present study has identified the risk factors for repeat breeder dairy cows and their impact on reproductive performance. Metabolic disorder, clinical endometritis, and a shorter interval between calving and first insemination were associated with the likelihood of becoming repeat breeders, severely impairing reproductive performance. An appropriate health strategy to prevent postpartum disorders, especially metabolic disorder and clinical endometritis, may reduce the likelihood of becoming repeat breeders. In addition, initial insemination at the proper time, not too early during the postpartum period, might reduce the incidence of repeat breeder dairy cows, enhancing their reproductive performance.

Acknowledgments

This work was conducted during the research year of Chungbuk National University in 2021.

ORCID

Jae-Kwan Jeong, https://orcid.org/0000-0002-8379-3194
Ill-Hwa Kim, https://orcid.org/0000-0002-2092-0264

References

1. Båge R. Conception rates after AI in Swedish red and white...
1. Risk factors for repeat breeder dairy cows

2. Pohmann H, Prunner I, Wagener K, JaureguiBern M, de la Sota RL, Erber R, Aurich C, Ehling-Schulz M, Drillisch M. The prevalence of subclinical endometritis and intrauterine infections in repeat breeder cows. Theriogenology 2015;83:1249–1253.

3. López-Gatius F, Yániz JL, Santolaria P, Murugavel K, Guijarro R, Calvo E, López-Béjar M. Reproductive performance of lactating dairy cows treated with cloprostenol at the time of insemination. Theriogenology 2004;62:677–689.

4. Bartlett PC, Kirk JH, Mather EC. Repeated insemination in Michigan Holstein-Friesian cattle: Incidence, descriptive epidemiology and estimated economic impact. Theriogenology 1986;26:309–322.

5. García-Ispierto I, López-Gatius F, Santolaria P, Yániz JL, Nogareda C, López-Béjar M. Factors affecting the fertility of high producing dairy herds in northeastern Spain. Theriogenology 2007;67:632–638.

6. López-Gatius F, García-Ispierto I. Treatment with an elevated dose of the GnRH analogue diphereline in the early luteal phase improves pregnancy rates in repeat-breeder dairy cows. Theriogenology 2020;155:12–16.

7. Kim UH, Suh GH, Hur TY, Kang SJ, Kang HG, Park SB, Kim HS, Kim IH. Comparison of two types of CIDR-based timed artificial insemination protocols for repeat breeder dairy cows. J Reprod Dev 2007;53:639–645.

8. Dochi O, Takahashi K, Hirai T, Hayakawa H, Tanisawa M, Yamamoto Y, Koyama H. The use of embryo transfer to produce pregnancies in repeat-breeding dairy cattle. Theriogenology 2008;69:124–128.

9. Son DS, Choe CY, Cho SR, Choi SH, Kim HJ, Hur TY, Jung YG, Kang HG, Kim IH. A CIDR-based timed embryo transfer protocol increases the pregnancy rate of lactating repeat breeder dairy cows. J Reprod Dev 2007;53:1313–1318.

10. Sood P, Zachut M, Duhe H, Moallem U. Behavioral and hormonal pattern of repeat breeder cows around estrus. Reproduction 2015;149:545–554.

11. Pérez-Marín CC, España F. Oestrus expression and ovarian function in repeat breeder cows, monitored by ultrasonography and progesterone assay. Reprod Domest Anim 2007;42:449–456.

12. Sood P, Zachut M, Dekel I, Duhe H, Jacoby S, Moallem U. Preovulatory follicle characteristics and oocyte competence in repeat breeder dairy cows. J Dairy Sci 2017;100:9372–9381.

13. Kurykin J, Waldmann A, Titarats T, Kaart T, Jaakma U. Morphological quality of oocytes and blood plasma metabolites in repeat breeding and early lactation dairy cows. Reprod Domest Anim 2011;46:253–260.

14. Kasimanickam RK, Kasimanickam VR, Kumar N, Reisenaure C. Day 7 embryo quality and suboptimal uterine environment influence morphometry of day 16 conceptus in dairy cows. Theriogenology 2021;163:10–17.

15. Hayashi KG, Hosoe M, Kizaki K, Fujii S, Kanahara H, Takahashi T, Sakamoto R. Differential gene expression profiling of endometrium during the mid-luteal phase of the estrous cycle between a repeat breeder (RB) and non-RB cows. Reprod Biol Endocrinol 2017;15:20.

16. Hill J, Gilbert R. Reduced quality of bovine embryos cultured in media conditioned by exposure to an inflamed endometrium. Aust Vet J 2008;86:312–316.

17. Bonneville-Hébert A, Bouchard E, Tremblay DD, Lefebvre R. Effect of reproductive disorders and parity on repeat breeder status and culling of dairy cows in Quebec. Can J Vet Res 2011;75:147–151.

18. Salasel B, Mokhtari A, Taktaz T. Prevalence, risk factors for and impact of subclinical endometritis in repeat breeder dairy cows. Theriogenology 2010;74:1271–1278.

19. Moss N, Lean IJ, Reid SW, Hodgson DR. Risk factors for repeat-breeder syndrome in New South Wales dairy cows. Prev Vet Med 2002;54:91–103.

20. Yusuf M, Nakao T, Ranasinghe RB, Gautam G, Long ST, Yoshida C, Koike K, Hayashi A. Reproductive performance of repeat breeders in dairy herds. Theriogenology 2010;73:1220–1229.

21. Edmonson AJ, Lean IJ, Weaver LD, Farver T, Webster G. A body condition scoring chart for Holstein dairy cows. J Dairy Sci 1989;72:68–78.

22. Cook N, Oetzel G, Nordlund K. Modern techniques for monitoring high-producing dairy cows 1. Principles of herd-level diagnoses. In Pract 2006;28:510–515.

23. Duffield TF, Leslie KE, Sands D, Lissemore K, McBride BW, Lumsden JD, Dick P, Bagg R. Effect of a monensin-controlled release capsule on cow health and reproductive performance. J Dairy Sci 1999;82:2377–2384.

24. Sheldon IM, Lewis GS, LeBlanc S, Gilbert RO. Defining post-partum uterine disease in cattle. Theriogenology 2006;65:1516–1530.

25. Brodzki P, Brodzki A, Kurek L, Marczuk J, Tatare MR. Reproductive system condition in dairy cows with left-sided displacement of the abomasums. Ann Anim Sci 2015;15:359–371.

26. Loeffler SH, de Vries MJ, Schukken YH. The effects of time of disease occurrence, milk yield, and body condition on fertility of dairy cows. J Dairy Sci 1999;82:2589–2604.
27. Sheldon IM, Cronin J, Goetze L, Donofrio G, Schuberth HJ. Defining postpartum uterine disease and the mechanisms of infection and immunity in the female reproductive tract in cattle. Biol Reprod 2009;81:1025–1032.
28. Bogado Pascottini O, Hostens M, Opsomer G. Cytological endometritis diagnosed at artificial insemination in repeat breeder dairy cows. Reprod Domest Anim 2018;53:559–561.
29. Kasimanickam R, Kasimanickam V, Kastelic JP. Mucin 1 and cytokines mRNA in endometrium of dairy cows with postpartum uterine disease or repeat breeding. Theriogenology 2014;81:952–958.
30. Stangaferro ML, Wijma R, Masello M, Thomas MJ, Giordano JO. Extending the duration of the voluntary waiting period from 60 to 88 days in cows that received timed artificial insemination after the Double-Ovsynch protocol affected the reproductive performance, herd exit dynamics, and lactation performance of dairy cows. J Dairy Sci 2018;101:717–735.
31. Yusuf M, Nakao T, Long ST, Gautam G. Analysis of some factors affecting fertility levels in a high-producing dairy herd in south-western Japan. Anim Sci J 2010;81:467–474.
32. Deka RP, Magnusson U, Grace D, Randolph TF, Shome R, Lindahl JF. Estimates of the economic cost caused by five major reproductive problems in dairy animals in Assam and Bihar, India. Animals (Basel) 2021;11:3116.
33. Carvalho PD, Souza AH, Amundson MC, Hackbart KS, Fuenzalida MJ, Herlihy MM, Ayres H, Dresch AR, Vieira LM, Guenther JN, Grummer RR, Fricke PM, Shaver RD, Wiltbank MC. Relationships between fertility and postpartum changes in body condition and body weight in lactating dairy cows. J Dairy Sci 2014;97:3666–3683.
34. Morton JM, Auldist MJ, Douglas ML, Macmillan KL. Associations between milk protein concentration, milk yield, and reproductive performance in dairy cows. J Dairy Sci 2016;99:10033–10043.
35. Buckley F, Dillon P, Rath M, Veerkamp RF. The relationship between genetic merit for yield and live weight, condition score, and energy balance of spring calving Holstein Friesian dairy cows on grass based systems of milk production. J Dairy Sci 2000;83:1878–1886.
36. Carthy TR, Ryan DP, Fitzgerald AM, Evans RD, Berry DP. Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. J Dairy Sci 2016;99:1286–1297.