pISSN 1598-298X / eISSN 2384-0749
J Vet Clin 35(6) : 251-257 (2018)
http://dx.doi.org/10.17555/jvc.2018.12.35.6.251

Journal of Veterinary Clinics
www.ksvc.or.kr

Relationships between Calving Season and the Incidence of Postpartum Disorders, Milk Yield, and Reproductive Performance in Dairy Cows

Jae-Kwan Jeong, Hyun-Gu Kang and Ill-Hwa Kim[1]

Veterinary Medical Center and College of Veterinary Medicine, Chungbuk National University, Cheongju 28644, Korea

(Received: October 02, 2018 / Accepted: November 16, 2018)

Abstract : We determined the relationships between calving season and the incidence of postpartum disorders, milk yield, and reproductive performance in dairy cows. Data regarding cow parity, postpartum disorders, milk yield, and reproduction were collected from 1,478 lactations. The incidence of retained placenta was higher in spring- and summer-calving cows than in autumn- and winter-calving cows ($P < 0.05$). The incidence of septicemic metritis was highest in spring- and summer-calving cows, and was higher in autumn-calving cows than in winter-calving cows ($P < 0.05$). The incidence of metabolic disorders was higher in summer- calving cows than in autumn- and winter-calving cows ($P < 0.01$). The mean milk yield 1 and 2 months after calving was higher in spring-calving cows than in summer-calving cows ($P < 0.05$). The percentage of cows that had resumed cycling, defined by detection of a corpus luteum using ultrasonography 4 weeks after calving, was highest in autumn-calving cows, and was higher in summer- and winter-calving cows than in spring-calving cows ($P < 0.05$). The hazard of first insemination by 150 days after calving was higher in summer- and autumn-calving cows (hazard ratio [HR] = 1.19; $P < 0.05$) than in spring-calving cows. The hazard of pregnancy by 210 days after calving was also higher in summer-calving (HR = 1.24; $P < 0.05$) and autumn-calving (HR = 1.59; $P < 0.0001$) cows than in spring-calving cows. The probability of conception at the first insemination was higher ($P < 0.0001$) in autumn-calving (odds ratio [OR] = 1.96) and winter-calving (OR = 2.04) cows than in spring-calving cows. In conclusion, spring calving is associated with the worst, and autumn calving with the best, postpartum health and reproductive performance, whereas milk yield is higher in spring-calving cows than in summer-calving cows. Therefore, an effective strategy to support postpartum health and fertility should be instituted for spring-calving dairy cows kept in the Korean climate.

***Key words* :** calving season, heat stress, production, reproduction, dairy cow.

Introduction

Production and reproductive outcomes in dairy cows are affected by numerous factors, such as nutrition, health, characteristics of the animal, and environment, including farm facilities and climate/weather (13,14). Because Holstein dairy cows are vulnerable to hot weather, the adverse effects of heat stress on production and reproductive performance have been documented in previous studies (2,26). Heat stress may reduce dry matter intake (DMI) (30), thus aggravating negative energy balance (NEB) and impairing the immune response, especially during the transition period (11). Likewise, poor DMI leads to lower milk yield (6). Heat stress during the breeding period impairs fertility because it causes hormonal imbalances and abnormal follicular development, poor oocyte quality and retarded embryonic development, and embryonic and fetal death (1,29,31).

Global warming means that heat stress has become a challenging issue that threatens the profitability of the dairy industry (16,26). Indeed, the climate of Korea is gradually changing from temperate to sub-tropical. These climate changes might severely affect productivity in dairy herds (7), leading to severe economic losses (39). Moreover, milk yield has rapidly increased in Korean dairy herds over recent decades, which could aggravate the effects of heat stress on production and reproductive outcomes (17,19).

Environmental circumstances, as well as health and nutritional management during the dry and postpartum periods, are crucial for the postpartum health and productivity of dairy cows (3,12). For this reason, calving during different seasons in a temperate climate, especially during the hot summer season, might affect postpartum health and subsequent milk production and reproductive performance. Evaluation of the impact of calving season on the incidence of postpartum diseases, production, and reproductive outcomes might facilitate the preparation of countermeasures to avoid the economic losses due to adverse weather conditions, which are increasing in frequency with global warming. Therefore, the objective of this study was to determine the relationships between calving season and the incidence of postpartum disorders, milk yield, and reproductive performance in dairy cows.

Materials and Methods

Animals

This study was performed on ten dairy farms located in

[1]Corresponding author.
E-mail : illhwa@cbu.ac.kr

Chungcheong Province. Each farm housed 80-200 milking cows, which were maintained in loose housing systems. They were fed total mixed rations and milked twice daily. A total of 1,478 lactations, with 2.4 ± 1.3 lactations (mean ± standard deviation; range: 1-8 lactations), were included in the study. All the cows underwent reproductive health checks every 2-4 weeks by veterinarians in the research team, including an examination of their ovarian structures (follicle and corpus luteum) and uterus, by transrectal palpation and ultrasonography. All experiments were performed with the approval of the Institutional Animal Care and Use Committee of Chungbuk National University.

Data collection and case definition

Data were collected from 1,478 lactations, including cow parity, postpartum disorders, reproductive health data (derived from examination of their ovarian structures), and the dates of insemination, pregnancy, and calving. Milk yield data were collected monthly from the Korean Animal Improvement Association. The definitions of postpartum disorders that were used in the present study were similar to those described in previous publications (8,37). Retained placenta was defined as the retention of the fetal membranes for longer than 24 h. Septicemic metritis was defined by the presence of fever (≥ 39.5ºC) and a watery, fetid uterine discharge during the first 10 days after calving. Endometritis was diagnosed on the basis of the presence of a visible mucopurulent vaginal discharge and/or rectal palpation and ultrasonography 4 weeks after calving. Ketosis was diagnosed on the basis of the following clinical signs: anorexia, depression, and an odor of acetone on the breath. Milk fever was diagnosed if weakness and recumbency occurred after calving. Abomasal displacement was diagnosed by a "ping" sound during abdominal auscultation by veterinarians in the research team.

Reproductive management

Resumption of cyclicity was defined by the detection of a corpus luteum by transrectal ultrasonography 4 weeks after calving.

The voluntary waiting period from calving to the first artificial insemination was 40 days. In addition to estrous detection, Ovsynch synchronization was performed by administration of gonadotropin-releasing hormone (GnRH) on Day 0, prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) on Day 7, and GnRH on Day 9. Cows that exhibited estrus naturally were inseminated according to the am-pm rule, whereas cows that underwent Ovsynch received timed artificial insemination. Pregnancy was diagnosed 35-40 days after insemination by transrectal ultrasonography. Data regarding reproductive performance were collected for a minimum of 210 days postpartum or until pregnancy or culling.

Study design and statistical analyses

The incidence of postpartum disorders (retained placenta, septicemic metritis, endometritis, and metabolic disorders) and mean milk yield (1 and 2 months after calving) were compared among cows that calved during spring, summer, autumn, and winter. In addition, reproductive performance (the percentage of cows with resumption of cyclicity by 4 weeks after calving, hazards of first insemination by 150 days and pregnancy by 210 days after calving, and the probability of conception after the first insemination) were also compared.

Data are expressed as mean ± standard error of the mean. For statistical analyses, cow parity was categorized as 1 or ≥ 2, while calving season was categorized as spring (March to May), summer (June to August), autumn (September to November), or winter (December to February). Metabolic disorders include ketosis, milk fever, and abomasal displacement. Statistical analyses were performed using SAS software (version 9.4, SAS Inst., Cary, NC, USA).

The incidence of postpartum disorders (retained placenta, septicemic metritis, endometritis, or metabolic disorders) and the percentage of cows that had resumed cycling by 4 weeks after calving were compared among the calving seasons using the chi-square or Fisher's exact test. Statistical analysis of mean milk yield 1 and 2 months after calving was carried out using the general linear model procedure. The model included farm, calving season, and cow parity as variables.

Cox's proportional hazard model with the PHREG procedure was used to compare the hazards of first insemination by 150 days and pregnancy by 210 days after calving among the calving seasons. This estimated the hazard of a cow being inseminated or pregnant at a given time. The time variables used in this model were the intervals in days between calving and first insemination, and between calving and pregnancy. Cows that died, were sold, not inseminated by 150 days, or not pregnant by 210 days after calving were excluded. Cox models included calving season, cow parity, and postpartum disorders as variables, and cow and farm were included in the model as random effects. The proportional hazard rate was determined on the basis of interactions between explanatory variables and time.

The probability of conception at the first insemination was analyzed by logistic regression using the LOGISTIC procedure. The logistic regression model included calving season, cow parity, and postpartum disorders. Cow and farm were included in the model as random effects. Backward stepwise regression was used for all models, and elimination was performed on the basis of the Wald statistic criterion when $P > 0.11$. Odds ratios (ORs) and 95% confidence intervals (CIs) were determined by logistic regression. Results are presented as percentages, and ORs with their respective 95% CIs. $P < 0.05$ was considered to represent statistical significance.

Results

Relationships between calving season and the frequency of postpartum disorders

Table 1 shows a comparison of the incidence of postpartum disorders among the calving seasons. The incidences of retained placenta and septicemic metritis were higher ($P < 0.05$) in spring- and summer-calving cows than in autumn- and winter-calving cows. The incidence of septicemic metritis was highest in spring- and summer-calving cows, and was higher in autumn-calving cows than in winter-calving cows ($P < 0.05$). The incidence of metabolic disorders was higher

Table 1. Comparison of the incidence of postpartum disorders in each calving season

Calving season	Postpartum disorders %			
	Retained placenta	Septicemic metritis	Endometritis	Metabolic disorders[1]
Spring (n = 335)	20.0[a]	9.3[a]	19.1	11.3[de]
Summer (n = 504)	21.4[a]	12.5[a]	18.3	13.5[d]
Autumn (n = 378)	14.3[b]	5.0[b]	16.7	6.1[f]
Winter (n = 261)	11.1[b]	1.5[c]	23.8	6.9[ef]

[1]Metabolic disorders include ketosis, milk fever, and abomasal displacement.
[a,b,c]Means with different superscripts differ with $P < 0.05$ between groups.
[d,e,f]Means with different superscripts differ with $P < 0.01$ between groups.

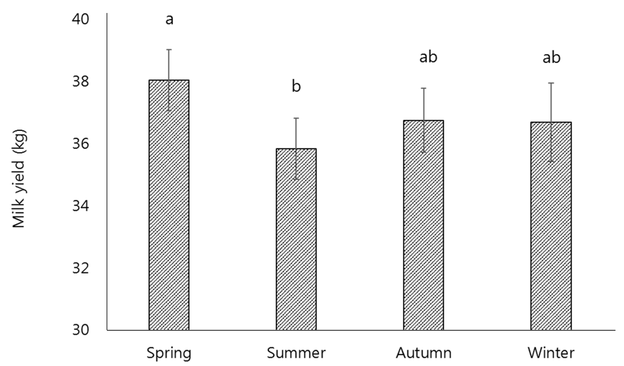

Fig 1. Comparison of mean milk yield 1 and 2 months after calving among calving seasons.
[a,b]Means with different superscripts differ with $P < 0.05$ between groups.

in summer-calving cows than in autumn- and winter-calving cows ($P < 0.01$). However, the incidence of endometritis did not differ among the calving seasons ($P > 0.05$).

Relationships between calving season and milk yield

Fig 1 shows a comparison of mean milk yield at 1 and 2 months after calving among the calving seasons. The mean milk yield 1 and 2 months after calving was higher ($P < 0.05$) in spring-calving cows than in summer-calving cows.

Relationships between calving season and reproductive performance

Fig 2 shows a comparison of the percentage of cows that had resumed cycling, defined by the detection of a corpus luteum using ultrasonography 4 weeks after calving, among the calving seasons. The percentage of cows with resumption of cyclicity 4 weeks after calving was highest in autumn-calving cows, and was higher in summer- and winter-calving cows than in spring-calving cows ($P < 0.05$).

Table 2 shows the factors affecting the hazard of insemination by 150 days after calving, as analyzed using the PHREG procedure. The hazard of first insemination by 150 days after calving was higher in summer- and autumn-calving cows (hazard ratio [HR] = 1.19; $P < 0.05$) than in spring-calving cows. In addition, cows with postpartum disorders were less likely to have been inseminated for the first time by 150 days after calving (HR = 0.74; $P < 0.0001$) than those without postpartum disorders.

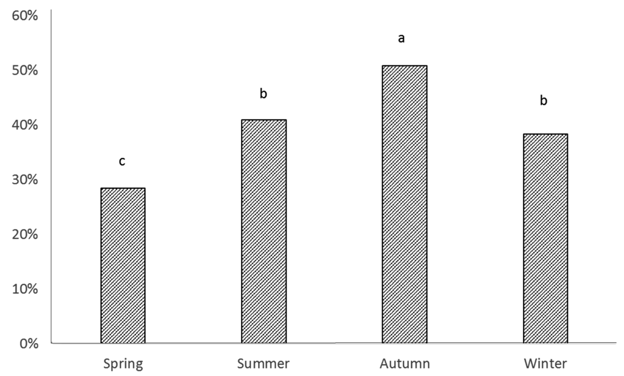

Fig 2. Comparison of the percentage of cows with resumption of cyclicity, evaluated by detection of a corpus luteum using ultrasonography 4 weeks after calving, among calving seasons.
[a,b,c]Means with different superscripts differ with $P < 0.05$ between groups.

Table 2. Factors affecting the hazard of insemination by 150 days after calving, as analyzed using the PHREG procedure

Variable	Level	Hazard ratio	95% CI[1]	*P*-value
Calving season	Spring	Reference		
	Summer	1.19	1.018-1.385	< 0.05
	Autumn	1.19	1.006-1.396	< 0.05
	Winter	1.03	0.860-1.230	> 0.05
Cow parity				> 0.05
Postpartum disorders[2]	No	Reference		
	Yes	0.74	0.658-0.836	< 0.0001

[1]Confidence interval.
[2]Postpartum disorders include retained placenta, septicemic metritis, endometritis, and metabolic disorders (ketosis, milk fever, and abomasal displacement).

Table 3 shows the factors affecting the hazard of pregnancy by 210 days after calving, as analyzed using the PHREG procedure. The hazard of pregnancy by 210 days after calving was also higher in summer-calving (HR = 1.24; $P < 0.05$) and autumn-calving (HR = 1.59; $P < 0.0001$) cows than in spring-calving cows. This hazard was lower in multiparous cows than in primiparous cows (HR = 0.86, $P < 0.05$) and was lower in cows with postpartum disorders than in cows without postpartum disorders (HR = 0.67; $P < 0.0001$).

Table 4 shows ORs for variables included in the logistic regression model of the probability of conception following the first insemination after calving. The probability of conception at the first insemination was higher ($P < 0.0001$) in autumn-calving (OR = 1.96) and winter-calving (OR = 2.04) cows than in spring-calving cows. Multiparous cows were

Table 3. Factors affecting the hazard of pregnancy by 210 days after calving, as analyzed using the PHREG procedure

Variable	Level	Hazard ratio	95% CI[1]	*P*-value
Calving season	Spring	Reference		
	Summer	1.24	1.038-1.478	< 0.05
	Autumn	1.59	1.322-1.914	< 0.0001
	Winter	1.16	0.948-1.430	> 0.05
Cow parity	Primiparous	Reference		
	Multiparous	0.86	0.744-0.985	< 0.05
Postpartum disorders[2]	No	Reference		
	Yes	0.67	0.581-0.765	< 0.0001

[1]Confidence interval.
[2]Postpartum disorders include retained placenta, septicemic metritis, endometritis, and metabolic disorders (ketosis, milk fever, and abomasal displacement).

Table 4. Adjusted odds ratios (OR) for variables included in the logistic regression model of the probability of conception after the first insemination

Variable	Level	Adjusted OR	95% CI[1]	*P*-value
Calving season	Spring	Reference		
	Summer	1.32	0.958-1.808	> 0.05
	Autumn	1.96	1.412-2.725	< 0.0001
	Winter	2.04	1.428-2.904	< 0.0001
Cow parity	Primiparous	Reference		
	Multiparous	0.78	0.607-0.990	< 0.05
Postpartum disorders[2]	No	Reference		
	Yes	0.63	0.497-0.799	0.0001

[1]Confidence interval.
[2]Postpartum disorders include retained placenta, septicemic metritis, endometritis, and metabolic disorders (ketosis, milk fever, and abomasal displacement).

less likely to conceive after their first insemination (OR = 0.78; $P < 0.05$) than primiparous cows. In addition, cows with postpartum disorders had a lower probability of conception after the first insemination (OR = 0.63; $P = 0.0001$) than those without postpartum disorders.

Discussion

We determined the relationships between calving season and the incidence of postpartum disorders, milk yield, and reproductive performance in dairy cows. We found that spring calving is worst, and autumn calving is best, in terms of postpartum health and reproductive performance, whereas milk yield is higher in spring-calving cows than summer-calving cows.

The incidences of retained placenta and septicemic metritis were higher in spring- and summer-calving cows than in autumn- and winter-calving cows, and metabolic disorders were more common in summer-calving cows than in autumn- and winter-calving cows. These findings suggest that heat stress due to hot weather during the peripartum period might lead to poorer DMI, aggravating NEB, and resulting in a weakened immune response to postpartum contamination, which increases the risk of postpartum metabolic and reproductive disorders. Consistent with our findings, a previous study showed that the incidence of retained placenta is higher during warmer than during colder seasons (21). Similarly, another study showed that the incidence of metabolic disorders, including parturient paresis and ketosis, is highest in March and April (32). Contrary to our results, however, a third study showed that the incidences of retained placenta and septicemic metritis are higher in autumn- and winter-calving cows than in spring-calving cows (18). This discordance might be due to differences in climate and regional geography among the studies.

The mean milk yield 1 and 2 months after calving was higher in spring-calving cows than in summer-calving cows in the present study, which is consistent with the findings of several previous studies (15,28,35). A decrease in milk yield in cows under heat stress might be explained not only by a reduction in DMI in heat-stressed animals, but also by a lower milk energy output resulting from higher basal metabolic requirements (43).

The percentage of cows that had resumed cycling 4 weeks after calving was highest for those that had calved in autumn, and was higher in summer- and winter-calving cows than in spring-calving cows. Consistent with our findings, a previous study showed that the percentage of cows that resumed cycling is higher among those that calved in autumn than among those that calved in winter and spring (42). However, another study showed that the percentage of cows that resumed cycling is higher in summer- and autumn-calving cows than in winter- and spring- calving cows (41). Taken together, these findings imply that autumn calving may be advantageous because it is associated with earlier resumption of cyclicity than spring and winter calving, probably because of the colder weather. However, the slowest resumption of cyclicity was associated with the highest milk yield during early lactation in spring-calving cows. It has been suggested that heat stress may result in endocrine changes and lower follicular activity, leading to delayed resumption of cyclicity after calving (20,36). Contrary to our findings, a study of cows in central Chile showed that autumn calving is associated with a lower incidence of estrus detection than calving during the other three seasons (24). However, in the region where this study was conducted, autumn was the least favorable season, characterized by changes in the weather, the beginning of the colder rainy season, and the formation of mud, which might have negatively affected estrus (24).

The hazards of insemination by 150 days and pregnancy by 210 days after calving were higher in summer- and autumn-calving cows than in spring-calving cows in the present study. This might be explained by a large proportion of the cows calving during spring being inseminated during hot weather, as shown in a study from USA (25). Likewise, delayed breeding and a lower conception rate during hot weather months might have caused the lower hazards of insemination and pregnancy in our study. A previous study showed that cows calving in spring and summer have poorer reproductive performance, as assessed using the calving interval and the number of services required per conception, than those calving during other seasons (27), which is in agreement with our findings. However, in contrast with our findings, another study showed that cows calving in spring and winter have a shorter interval to first service than those calving in summer and autumn (9). In addition, a study from southwestern Japan found no association between calving season and the interval from calving to first insemination (45), and the overall incidence of pregnancy does not differ among the seasons during which cows calve in central Chile (24).

The probability of conception at the first insemination was higher in autumn- and winter-calving cows than in spring-calving cows, which is consistent with the findings of a previous study (38). This might be partly explained by the weather conditions during the four seasons in Korea. A higher probability of conception at the first insemination in autumn- and winter-calving cows may be due to favorable weather conditions for conception. Consistent with our data, another study showed that cows that calve in winter are more likely to conceive than those that calve in spring and summer (22). However, the majority of cows that calve in spring would be exposed to hot weather, which is unfavorable for insemination and conception, from late spring to summer.

Moreover, the delayed adverse effect of heat stress also might impair fertility (44). A previous study showed that the first service conception rate and the cumulative incidence of pregnancy by 150 days after calving are lower in cows calving during the warmer seasons (May to September) than in cows calving during the colder seasons (October to April) (5). In addition, several studies have shown that the probability of conception following the first insemination is lower during summer than during the other seasons (4,40). Badinga *et al.* (4) showed that the conception rate of lactating cows is much lower when the maximum air temperature on the day after insemination exceeds 30ºC. In addition, a temperature-humidity index of 73 is the most likely threshold for the influence of heat stress on conception rate, and the 3-week period preceding the day of insemination is when cows are most sensitive to heat stress (33).

Heat stress during the breeding period impairs fertility because of hormonal imbalances and abnormal follicular development, impaired oocyte quality and embryo development, and embryonic and fetal death (29,31). Heat stress may also lead to infertility through a direct effect of hyperthermia on the reproductive axis and/or an indirect effect on appetite and feed intake, worsening energy balance (11). Spring was the worst season for calving with regard to reproductive outcomes (resumption of postpartum cyclicity, hazards of insemination by 150 days and pregnancy by 210 days after calving, and probability of conception at the first insemination) in the present study. Thus, application of a reproductive program, such as Ovsynch, during early lactation, might compensate for the lower fertility in spring-calving cows. This was demonstrated by a previous study (10) in which a program of estrus synchronization and fixed time insemination were shown to improve the fertility of cows suffering from heat stress. At the same time, cooling facilities, such as sprinklers and shades, could be provided to reduce losses due to heat stress (23,34).

In summary, our data show that spring calving is worst, and autumn calving is best, with regard to postpartum health and reproductive performance, whereas milk yield is higher in spring-calving cows than in summer-calving cows. Persistent heat stress during the spring and summer months, and higher milk yield during early lactation, in spring-calving cows likely cause this poor postpartum health and reproductive outcomes. Therefore, we suggest the use of vigorous cooling systems, better nutrition, and the use of active reproductive programs to improve health and reproductive performance in spring-calving dairy cows.

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