pISSN 1598-298X
J Vet Clin 30(6) : 435-441 (2013)

Journal of Veterinary Clinics
www.ksvc.or.kr

Effect of the Interval from Calving to First Insemination and Days Open on the Subsequent Reproductive Performance in Dairy Cows

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(Accepted: December 20, 2013)

Abstract : This retrospective study evaluated the effects of the interval from calving to first insemination (ICFI) and days open (DO) on the reproductive performance in dairy cows. In the first analysis, data from 705 cows were grouped based on the ICFI: short (30-60 days, n = 217), medium (61-90 days, n = 309), and long (91-150 days, n = 179). The occurrence of endometritis was greater in the long group than in short and medium groups ($p < 0.05$). The occurrence of ovarian cysts increased with increasing ICFI ($p < 0.05$), while body condition score (BCS) during the 5 month postpartum period was lower with increasing ICFI ($p < 0.01$). The hazard of pregnancy by 365 days in milk (DIM) was lower (hazard ratio [HR] = 0.70, $p < 0.0001$) in the long group, but higher (HR = 1.41, $p < 0.0001$) in the short group compared with the medium group. In the second analysis, data from 436 cows were grouped based on the DO: short (30-90 days, n = 154), medium (91-180 days, n = 183), and long (181-360 days, n = 99). The occurrence of a retained placenta was greater in the long group than in the medium group ($p < 0.05$). Ovarian cysts occurred more frequently in medium and long groups than in the short group ($p = 0.08$). BCS was lower in the short group compared with medium and long groups at month 1 postpartum ($p < 0.05$). Milk yield (kg/day) was greater in the medium group compared with the short group at months 2 to 5 postpartum ($p < 0.05$). The hazard of first insemination by 150 DIM was lower in the long group than in the short group (HR = 0.73; $p < 0.02$). The hazard of pregnancy by 365 DIM was lower (HR = 0.64, $p < 0.0001$) in the long group than in the medium group, while the hazard did not differ between short and medium groups ($p > 0.05$). Moreover, the culling rate was greater in the long group than in the short group ($p < 0.05$). In conclusion, a longer ICFI and DO resulted in reduced reproductive performance in dairy cows, which was attributable to an increase in postpartum diseases, a lower BCS and a greater milk yield.

Key words **:** interval from calving to first insemination, days open, dairy cows, reproductive performance.

Introduction

Maintaining a high reproductive efficiency, that is, to attain a proper calving interval is crucial for dairy profit. Diverse herd and cow factors such as the environment, which includes climate, herd management practices and cattle physiology (e.g., milk yield, energy balance, diseases, and other factors) may associate with dairy reproductive efficiency (3,9,11,20,24). Dairy cow fertility is generally evaluated by the interval from calving to first insemination (ICFI), the pregnancy rate, and the interval from calving to conception (days open, DO) (18). To achieve a higher fertility rate, early restoration of postpartum cyclicity is critical (7,13,25), which shortens ICFI and DO. However, the timing of the first postpartum insemination might be related to the time of postpartum ovarian cyclicity, farm's heat detection efficiency, and farm's policy for the timing of the first postpartum insemination (5). Parity, calving season, postpartum endocrine status, and BCS during the early postpartum months can influence postpartum ovarian cyclicity (15,21).

Cows with a short ICFI have a lower first insemination conception rate (FICR) than cows with a long ICFI, but subsequently show an increased reproductive performance [e.g., a shorter DO where a 1-day increase in the ICFI reduced the likelihood of 0.85 to 0.86 days to become pregnant (5,26,27)]. However, another study reported that a delay in ICFI does not affect FICR. Instead, it extended DO and the economic advantage related to milk production (milk yield and contents) (1). Besides, (12) demonstrated that an extending the voluntary waiting period from 6 to 10 week extended calving interval, while it decreased the number of inseminations per conception (NIC). These results indicate that a short ICFI contributed to the shorter DO, irrespective of the FICR. With increased milk yield, on the other hand, the duration of estrus was shortened in high yielding dairy cows (19), which caused hardships for dairy producers during breeding, resulting in a decrease in fertility. Especially, due to the sharp increase in the yearly milk yield in modern dairy herds, which might affect postpartum cyclicity and FICR, the evaluation of the effect of ICFI on reproductive performance might provide valuable information on the management of high milk yield-

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ing dairy cows.

A long DO may also reduce milk yield during an extended lactation period and cause a longer dry period, resulting in obesity and metabolic disorders and/or culling after calving (22,23). Another study demonstrated that a delay of 60 days in high yielding cows has an economic advantage, which was greater for primiparous than for multiparous cows. This may be due to their persistent milk production and the higher fat and protein content of primiparous cows (1). However, the effect of DO on the reproductive performance of the next parity is presently lacking. Thus, at present, set-up for the optimal ICFI and DO for maximal productivity may be appositely required in modern dairy herds. Therefore, this retrospective study examined the effects of ICFI and DO on reproductive performance in dairy cows.

Materials and Methods

Animals and management

This study was conducted on six Holstein dairy farms located in Chungcheong Province. Cows were fed a total mixed ration and milked twice daily. The mean milk yield was approximately 10,690 kg per year per cow. They received regular reproductive health checks every 2 to 4 weeks by veterinarians at the College of Veterinary Medicine, Chungbuk University. The regular reproductive health checks included an examination of ovarian structures such as the corpus luteum, follicle, or cyst, and the uterus via transrectal palpation and ultrasonography. The voluntary waiting period from calving to the first artificial insemination (AI) was 30 days. In addition to estrous detection, a herd reproductive management program was employed for cows failing to receive AI within the 80-day postpartum interval. This included estrus synchronization using $PGF_{2\alpha}$. In addition, Ovsynch, which combined GnRH on day 0-$PGF_{2\alpha}$ on day 7-GnRH on day 9, with or without an internal drug-release device containing 1.9 g of progesterone insertion between days 0 and 7 was also included. Cows that exhibited estrus naturally or after estrus synchronization using $PGF_{2\alpha}$ were inseminated according to the am-pm rule, whereas cows treated with Ovsynch received timed AI. Pregnancy was diagnosed rectally 40-50 days after AI using both ultrasonography and manual palpation.

Data collection and study design

Data were collected from 1,141 cows (705 [156 primiparous and 549 multiparous; mean parity = 2.8 ± 0.1] in analysis 1 and 436 [all multiparous; mean parity = 3.3 ± 0.1] in analysis 2) from six dairy farms. The data included detailed information on milk production, health and reproduction. Postpartum disorders (a retained placenta; metabolic disorders such as milk fever, ketosis and abomasal displacement; endometritis; ovarian cysts) and culling were included in the data set. The body condition was scored monthly during the 5 month postpartum period based previously described procedures (6). Milk yield was collected monthly from the Korean Animal Improvement Association. In addition, parity, and dates of previous calving, insemination and conception were also included in the data set.

Analysis 1 initially evaluated the effect of ICFI on reproductive performance (e.g., FICR, NIC, hazard of pregnancy by 365 days in milk (DIM) and culling). In addition, this analysis evaluated whether postpartum disorder occurrence, BCS, and monthly milk yield were related to ICFI. In analysis 2, the effect of DO on the postpartum disorder occurrence, BCS, monthly milk yield, and reproductive performance was determined.

Statistical analysis

Postpartum disorder occurrence (a retained placenta, metabolic disorders, endometritis and ovarian cysts), FICR, and culling rate were compared using the Chi-square test in SAS (version 9.1, SAS Institute Inc., Cary, NC, USA). NIC was compared using ANOVA. BCS and milk yield during the 5 month postpartum period were compared using repeated measures of ANOVA. If there were interactions between variables, one-way ANOVA was performed to evaluate significant differences within months and/or groups. Cox's proportional hazard model with the PHREG procedure in SAS was used to analyze the hazard of first insemination by 150 DIM and the hazard of pregnancy by 365 DIM among groups. This estimated the hazard of a cow being inseminated or pregnant at a given time. The time variables used in the model were the interval in days between calving and first insemination and the interval in days between calving and pregnancy. Cows that were sold, died or remained not inseminated by 150 DIM or non-pregnant at 365 DIM were censored. The Cox models included farm, group, calving season, and postpartum disorders (a retained placenta, metabolic disorders, endometritis and ovarian cysts). Calving season was grouped as spring (March to May), summer (June to August), autumn (September to November), or winter (December to February). The proportional hazard rate was evaluated based on the interactions between explanatory variables and time and by evaluating Kaplan-Meier curves. The median and mean days to first insemination or pregnancy were determined by survival analysis from the Kaplan-Meier model using the LIFETEST procedure in SAS. A survival plot was generated using the survival module in MedCalc (version 12.7.5 for Windows, MedCalc Software, Mariakerke, Belgium).

Differences with $p < 0.05$ were considered significant and $0.05 < p < 0.1$ were designated as a tendency toward a significant difference.

Results

Analysis 1: Effect of ICFI on reproductive performance

Table 1 compares the occurrence of postpartum disorders in all groups based on ICFI. The occurrence of endometritis was greater in the long group (39.0%) than in short (29.0%) and

Table 1. Comparison of the occurrence of postpartum disorders in all three groups based on the interval from calving to first insemination

Group	Retained placenta (%)	Metabolic disorders* (%)	Endometritis (%)	Ovarian cysts (%)
Short (30-60 days) (n = 217)	22 (10.1)	5 (2.3)	63 (29.0)[a]	25 (11.5)[c]
Medium (61-90 days) (n = 309)	35 (11.3)	7 (2.3)	91 (29.4)[a]	65 (21.0)[d]
Long (91-150 days) (n = 179)	27 (15.1%)	4 (2.2)	68 (39.0)[b]	54 (30.2)[e]

*Metabolic disorders include milk fever, ketosis and abomasal displacement.
[a,b] $p = 0.06$. [c,d,e] $p < 0.05$.

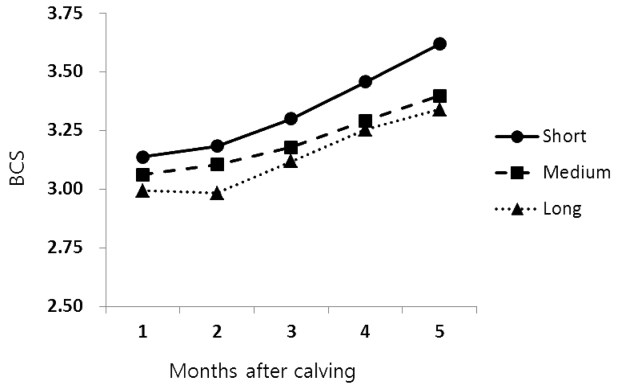

Fig 1. Comparison of BCS after calving during the 5 month period between short, medium and long groups. Group ($p = 0.009$) and month ($p < 0.0001$) effects are presented.

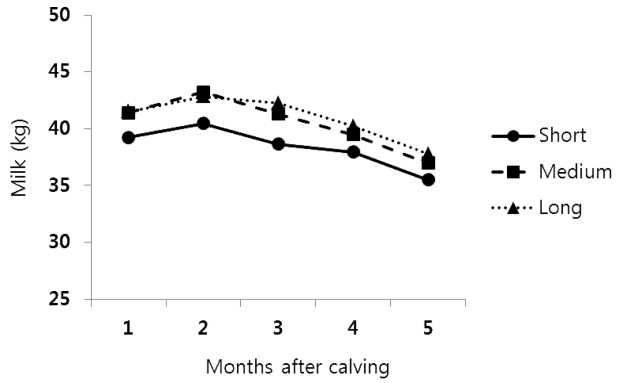

Fig 2. Comparison of milk yield during the 5 month period after calving between short, medium and long groups. Group ($p > 0.05$) and month ($p < 0.0001$) effects are presented.

medium (29.4%) groups ($p = 0.06$). The occurrence of ovarian cysts significantly differed between the three groups ($p < 0.05$) with 11.5%, 21.0% and 30.2% for the short, medium and long groups, respectively. However, the occurrence of a

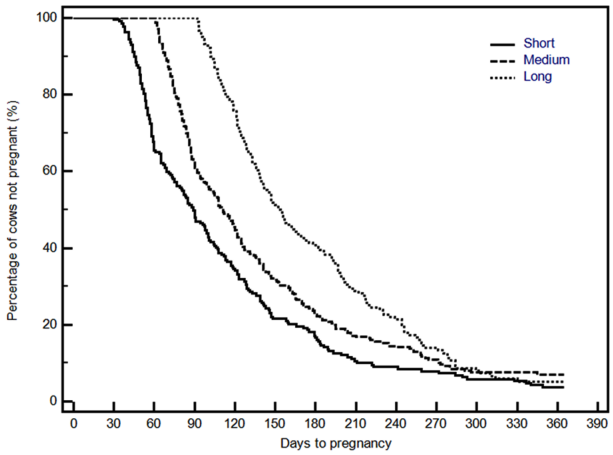

Fig 3. Survival curves for interval to pregnancy in all three groups based on the interval from calving to first insemination. The hazard of pregnancy by 365 DIM was lower (HR = 0.70; CI = 0.583-0.829; $p < 0.0001$) in the long group and higher (HR = 1.41; CI = 1.152-1.728; $p < 0.0001$) in the short group than in the medium group.

retained placenta and metabolic disorders did not differ between groups ($p > 0.05$). Fig 1 shows the changes in BCS during the 5 month postpartum period for the three groups. The mean BCS increased from months 1 through 5 postpartum ($p < 0.0001$). The BCS during the 5 month postpartum period significantly differed between the short, medium and long groups ($p = 0.009$) (Fig 1). While, milk yield did not differ between the groups ($p > 0.05$), it was affected by the month postpartum ($p < 0.0001$) (Fig 2). Table 2 and Fig 3 compare reproductive performance between the three groups. FICR (34.6% to 36.2%), NIC (2.26 to 2.34) or culling rate (3.2% to 6.1%) did not differ between the groups ($p > 0.05$). However, the hazard of pregnancy by 365 DIM was lower (hazard ratio [HR] = 0.73, $p = 0.002$) in the long group and higher (HR = 1.45, $p < 0.0001$) in the short group than in the

Table 2. Comparison of the first insemination conception rate, number of inseminations per conception and culling in all three groups based on the interval from calving to first insemination

Group	First insemination conception rate (%)	Number of inseminations per conception	Culling (%)
Short (30-60 days) (n = 217)	77 (35.5)	2.32 ± 0.1	9 (4.1)
Medium (61-90 days) (n = 309)	112 (36.2)	2.26 ± 0.1	10 (3.2)
Long (91-150 days) (n = 179)	62 (34.6)	2.34 ± 0.1	11 (6.1)

medium group. Fig 3 shows the survival curves for interval to pregnancy among the groups. The median and mean (± SE) days to pregnancy were 89 and 115.0 ± 5.6 in the short group, 111 and 141.9 ± 5.0 in the medium group, and 154 and 178.2 ± 5.6 in the long group, respectively.

Analysis 2: Effect of DO on reproductive performance

Table 3 compares the occurrence of postpartum disorders in all groups based on DO. The occurrence of a retained placenta was greater in the long group (20.2%) than in the medium group (10.9%) ($p < 0.05$), while that of the short group (15.6%) was the same as that of the medium and long groups ($p > 0.05$). The occurrence of ovarian cysts was greater in medium (26.2%) and long (28.3%) groups than in the short (18.2%) group ($p = 0.08$). Fig 4 shows the changes in BCS during the 5 month postpartum period among the three groups. The mean BCS increased from months 1 through 5 postpartum ($p < 0.0001$). A group by month interaction ($p = 0.0012$) among the groups was observed; BCS was lower in the short group (3.01 ± 0.1) than in medium (3.14 ± 0.1) and long (3.16 ± 0.1) groups at month 1 postpartum ($p = 0.04$). Furthermore, one-way ANOVA analysis of the BCS for the 5 month postpartum period in each group revealed that recovery of the BCS was more delayed in the long group. Fig 5 shows the changes in milk yield during the 5 month postpartum period among the three groups. Milk yield was affected by the month postpartum ($p < 0.0001$). A group by month interaction ($p = 0.048$) was observed among groups. Milk yield was greater for cows in the medium group (47.3 ± 1.1 and 45.3 ± 0.9 kg) than for cows in the short group (43.3 ± 1.1 and 41.6 ± 0.9 kg) at months 2 and 3 postpartum ($p < 0.05$), and was also greater in medium (42.6 ± 0.8 and 42.2 ± 0.6 kg) and long (43.1 ± 1.2 and 40.7 ± 1.1 kg) groups than in the short group (39.3 ± 0.9 and 37.4 ± 1.0 kg) at months 4 and 5 postpartum ($p < 0.01$). Figs 6 and 7, and Table 4 show a comparison of reproductive performance among the three groups.

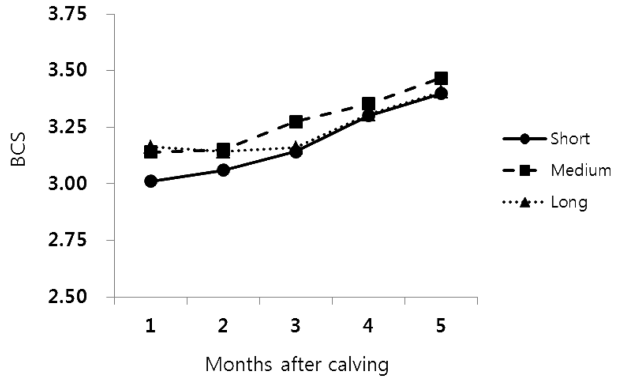

Fig 4. Comparison of BCS during the 5 month period after calving between short, medium and long groups. Group ($p > 0.05$), month ($p < 0.0001$) and group by month ($p = 0.0012$) effects are presented.

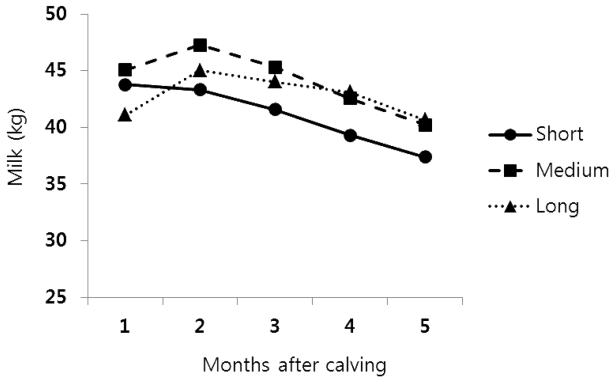

Fig 5. Comparison of milk yield during the 5 month period after calving between short, medium and long groups. Group ($p = 0.068$), month ($p < 0.0001$) and group by month ($p = 0.048$) effects are presented.

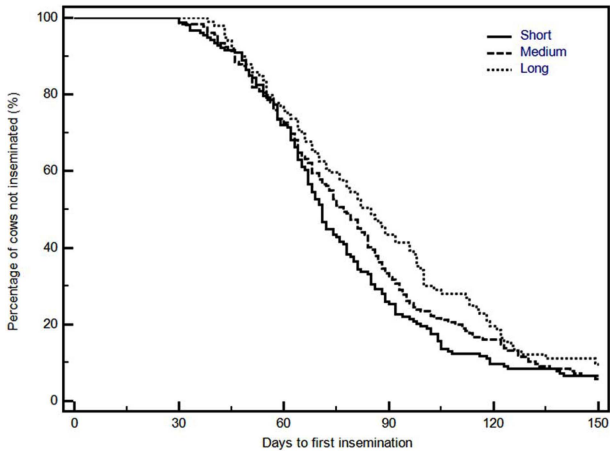

Fig 6. Survival curves for the interval to first postpartum insemination in all three groups based on the days open. The hazard of first insemination by 150 days DIM did not differ between short and medium groups ($p > 0.05$). On the other hand, the hazard was lower in the long group than in the short group (HR = 0.73; CI = 0.563-0.941; $p = 0.016$).

Table 3. Comparison of the occurrence of postpartum disorders in all three groups based on days open

Group	Retained placenta (%)	Metabolic disorders* (%)	Endometritis (%)	Ovarian cysts (%)
Short (30-90 days) (n = 154)	24 (15.6)[ab]	6 (3.9)	58 (37.7)	28 (18.2)[c]
Medium (91-180 days) (n = 183)	20 (10.9)[a]	4 (2.2)	58 (31.7)	48 (26.2)[d]
Long (181-360 days) (n = 99)	20 (20.2%)[b]	1 (1.0)	34 (34.3)	28 (28.3)[d]

*Metabolic disorders include milk fever, ketosis and abomasal displacement.
[a,b] $p < 0.05$. [c,d] $p = 0.08$.

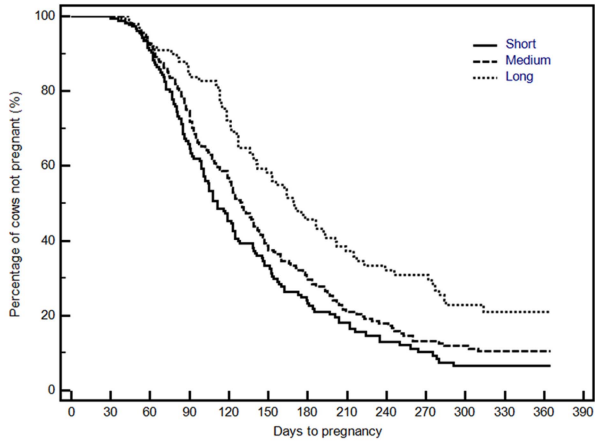

Fig 7. Survival curves for interval to pregnancy in all three groups based on the days open. The hazard of pregnancy by 365 DIM did not differ between short and medium groups ($p > 0.05$). On the other hand, the hazard was lower in the long group than in short (HR = 0.53; CI = 0.402-0.689; $p < 0.0001$) and medium groups (HR = 0.64; CI = 0.501-0.826; $p < 0.0001$).

The hazard of first insemination by 150 DIM did not differ between short and medium groups ($p > 0.05$), while the hazard was lower in the long group than in the short group (HR = 0.77; $p = 0.05$). Fig 6 shows the survival curves for the interval to first postpartum insemination among groups. The median and mean days to first insemination were 71 and 77.7 ± 2.4 in the short group, 77 and 82.2 ± 2.3 in the medium group, and 85 and 88.4 ± 3.3 in the long group. FICR was greater in short (35.7%) and medium (35.0%) groups than in the long group (20.2%, $p < 0.01$), while the NIC was lower in the short group (2.03) than in the long group (2.56, $p < 0.05$). The culling rate was higher in the long group (14.1%) than in the short (5.8%) group ($p < 0.05$). The hazard of pregnancy by 365 DIM was lower in the long group than in the short group (HR = 0.54; $p < 0.0001$). Fig 7 shows the survival curves for the interval to pregnancy among the three groups. The median and mean days to pregnancy were 111 and 139.8 ± 7.0 in the short group, 130 and 156.5 ± 7.0 in the medium group, and 170 and 199.0 ± 11.1 in the long group.

Discussion

Our retrospective analyses showed that reproductive performance in dairy cows was reduced by a longer ICFI and DO, which was attributable to an increase in disease occurrence, a slower postpartum BCS recovery, and a greater milk yield.

In the first analysis, cows with later insemination after calving had a greater occurrence of endometritis and ovarian cysts than cows with earlier insemination, which is consistent with previous studies (8,16,17). However, our observation that other postpartum diseases, such as a retained placenta and metabolic diseases did not associate with ICFI is discordant with previous reports (9,27), which might be due to differences between our study and other studies with respect to herd health management practices, and the timing and methods for the diagnosis of different diseases. Significant differences in BCS between the three groups during the 5 month postpartum period indicate that a higher BCS is associated with earlier energy balance recovery during early lactation. This may initiate postpartum cyclicity and ICFI, in agreement with other studies (3,14). Monthly milk yield did not influence ICFI, as shown by other studies (4,10). Some reproductive parameters (e.g., FICR, NIC and culling rate) did not differ between the groups, while DO increased with increasing ICFI. A previous study showed that FICR was lower and NIC was higher in cows with first insemination before 60 days than in cows with first insemination after 60 days postpartum, while DO was shorter in cows that had first insemination before 60 days than in cows with first insemination after 60 days postpartum (5). Similarly, another report demonstrated that cows with first insemination at a later lactation (up to 100 DIM) had a higher FICR, a longer DO and a greater culling rate than cows with first insemination at an earlier lactation (27). Differences in the outcomes of the reproductive parameters (e.g., FICR and NIC) between our study and those of other studies might be related to the recovery of the reproductive organs after calving. Culling is dependent on the owners' breeding policy, which is influenced by cow productivity, the number of the replacement heifers, and other complex factors. Considering all of these results, a shorter ICFI may be favorable for the reproductive management of dairy cows. On the basis of our data, first postpartum insemination within 90 days is recommended. In addition, important risk factors for a delayed ICFI (e.g., increased occurrence of postpartum diseases such as endometritis and ovarian cysts, and lower BCS during early lactation) should be addressed to improve reproductive performance.

In the second analysis, cows with later pregnancy after calving had a greater occurrence or tendency to have a retained placenta and ovarian cysts than cows with earlier pregnancy, while there was no difference in the occurrence of

Table 4. Comparison of the first insemination conception rate, number of insemination per conception and culling in all three groups based on days open

Group	First insemination conception rate (%)	Number of insemination per conception	Culling (%)
Short (30-90 days) (n = 154)	55 (35.7)[a]	2.03 ± 0.1[c]	9 (5.8)[c]
Medium (91-180 days) (n = 183)	64 (35.0)[a]	2.32 ± 0.1[cd]	20 (10.9)[cd]
Long (181-360 days) (n = 99)	20 (20.2)[b]	2.56 ± 0.1[d]	14 (14.1)[d]

[a,b] $p < 0.01$. [c,d] $p < 0.05$.

metabolic disorders and endometritis between the groups. Cows with extended DO become obese during the dry period, which may result in a severe negative energy balance and metabolic disorders after calving (2,23). Prepartum obesity resulting from longer lactation and/or dry period, and a decrease in dry matter intake after calving increased peripartum (a retained placenta) and postpartum disease (ovarian cysts) in this study. Postpartum recovery of BCS in the long group was rather slow during early lactation, while milk yield was greater in the medium group than in the short group. Our data indicate that the medium group, that is, cows that became pregnant between 91 to 180 days postpartum had higher milk yield and better BCS recovery than cows that became pregnant at earlier or later days. More importantly, all reproductive outcomes such as the hazard of first insemination by 150 DIM, NIC, hazard of pregnancy by 365 DIM, and culling rate were poorer in the long group than in the short group, while there was no difference with respect to these outcomes between short and medium groups. These results strongly indicate that extended DO may severely affect reproductive performance, which may be attributable to peri- and postpartum diseases and the slower recovery of postpartum BCS.

In conclusion, our results demonstrate that ICFI within 90 days postpartum and DO within 180 days postpartum resulted in better reproductive performance, and that a longer ICFI and DO decreases reproductive performance, which may be attributable to an increase in disease occurrence, a slower postpartum BCS recovery, and a greater milk yield. Therefore, farm managers and veterinarians need to be mindful of nutritional management and need to check for ICFI and DO in order to maintain proper reproductive performance of their dairy cows.

Acknowledgments

This work was supported by the research grant of Chungbuk National University in 2013.

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젖소에서 분만 후 첫 수정 간격 및 임신 간격이 이후의 번식능력에 미치는 영향

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요 약 : 본 연구는 젖소에서 분만 후 첫 수정 간격 및 임신 간격이 이후의 번식능력에 미치는 영향에 대하여 조사하였다. 첫 번째 분석에서는, 705두의 젖소 자료를 첫 수정 간격에 따라 짧은 간격(30-60일, n = 217), 중간 간격(61-90일, n = 309) 및 긴 간격(91-150일, n = 179) 군으로 구분하였다. 자궁내막염의 발생은 짧은 간격 및 중간 간격 군에 비해 긴 간격 군에서 증가되었다($p < 0.05$). 첫 수정 간격이 증가함에 난소낭종의 발생은 증가한($p < 0.05$) 반면, 분만 후 5 개월 간의 BCS는 반대로 낮았다($p < 0.01$). 분만 후 365일까지의 임신율은 중간 간격 군에 비하여 긴 간격 군에서는 낮았으나(hazard ratio[HR] = 0.70, $p < 0.0001$), 짧은 간격 군에서는 높았다(HR = 1.41, $p < 0.0001$). 두 번째 분석에서는, 436두의 젖소 자료를 임신 간격(공태 기간)에 따라 짧은 간격(30-90일, n = 154), 중간 간격(91-180일, n = 183) 및 긴 간격(181-360일, n = 99) 군으로 구분하였다. 후산정체 발생율은 중간 간격 군에 비해 긴 간격 군에서 높았으나($p < 0.05$), 난소낭종의 발생은 짧은 간격 군에 비해 중간 간격 및 긴 간격 군에서 증가하는 경향이 있었다($p = 0.08$). BCS는 분만 후 1개월에 중간 간격 및 긴 간격 군에 비해 짧은 간격 군에서 낮았다($p < 0.05$). 산유량은 분만 후 2개월에서 5개월까지 짧은 간격 군에 비해 중간 간격 군에서 증가하였다($p < 0.05$). 분만 후 150일까지 첫 수정율은 짧은 간격 군에 비해 긴 간격 군이 낮았다(HR = 0.73, $p < 0.02$). 분만 후 365일까지의 임신율은 중간 간격 군에 비하여 긴 간격 군에서는 낮았으나(HR = 0.64, $p < 0.0001$), 짧은 간격 군과 중간 간격 군에서는 차이가 없었다($p > 0.05$). 더욱이, 도태율은 짧은 간격 군에 비해 긴 간격 군에서 증가하였다($p < 0.05$). 결론적으로, 젖소에서 첫 수정 간격 및 임신 간격의 연장은 이후 번식능력의 감소를 초래하였으며, 이것은 산후 질병의 증가, BCS 감소 및 많은 산유량에 기인하였다.

주요어 : 첫 수정 간격, 임신 간격, 젖소, 번식 능력.