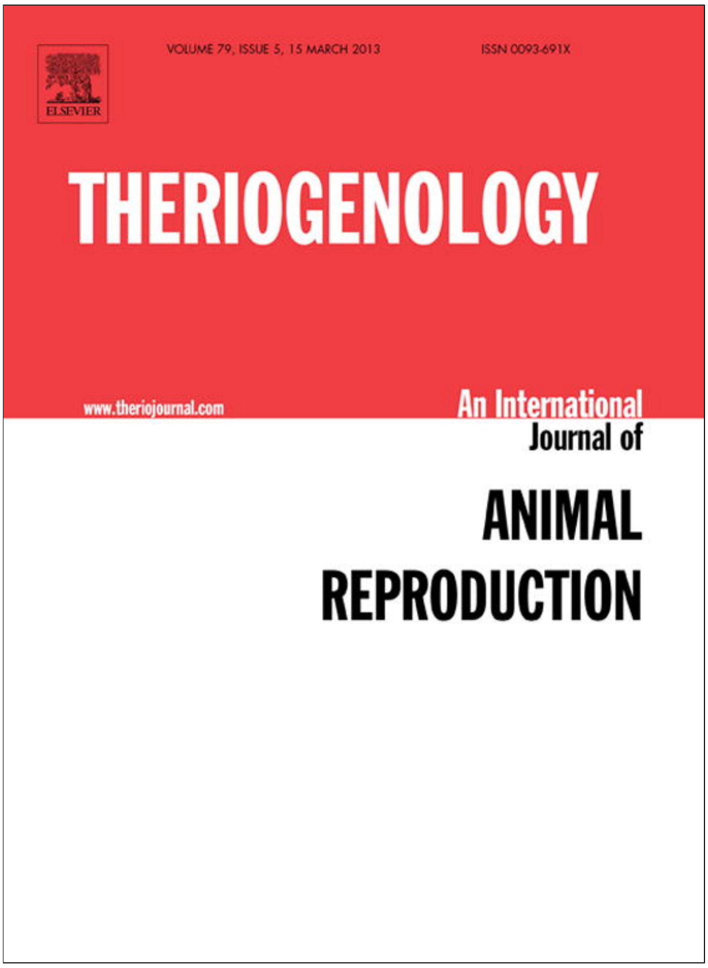
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Some factors affecting the number of days open in Argentinean dairy herds

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ABSTRACT

The objective of this study was to estimate the relative contribution of factors affecting how quickly cattle become pregnant in Argentine dairy herds. Data from 76,401 cows from 249 dairy herds were analyzed. A hazard model was used to explore days open (DO). The factors considered were milk yield, lactation number, calving season, and breeding technique (i.e., type of service: artificial insemination [AI], or combined service). Cows with lower milk yield had 1.09 to 1.38 higher likelihood to become pregnant than those with higher milk yield ($P < 0.0001$). The number of DO increased linearly with an increasing number of lactations ($P < 0.0001$). Cows calving in fall-winter had a shorter interval to conception than those calving in summer. The hazard rate for combined service was 1.27; therefore, cows with combined service were more likely to become pregnant during the observation period than those bred by AI. The difference in DO between cows of high versus low milk yield was smaller when dairies used AI as the main breeding technique than when they used combined service. Furthermore, dairies using mainly combined service had lower milk yield (5693.7 L) than those using mainly AI (7684.4 L). Although lactation number and calving season contributed to explain the number of DO, the influence of production level, the type of service, and the interaction between them was also associated with reproductive efficiency in Argentine dairy herds.

1. Introduction

The world's economic situation requires efficient management practices to increase profitability of dairy operations. However, reproductive performance has been progressively declining, mainly because of a decrease in fertility in the modern dairy cow [1–3] and inefficient estrus detection in most management systems [4,5]. High milk production is associated with low plasma concentrations of steroid hormones (because of increased liver metabolism), which results in poor expression of estrus, ovulation of an altered (aged) oocyte, and increased embryonic losses [5,6]. Although numerous studies have associated an apparent decrease in fertility in dairy herds with the significant increase in milk production during the past 50 years [2,7–9], others have questioned this relationship and suggested that several other management factors (e.g., nutrition and housing) should also be considered [10].

Timely and consistent monitoring with accurate measurements of productive and reproductive indicators is crucial to make good management decisions aimed at reducing unproductive days and improve sustainability of dairy herds [11]. Although management practices in commercial dairy herds vary throughout the world, the main reproductive objective is for cows to become pregnant in a timely manner after calving [4,12].

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Indicators of reproductive performance used in dairy herds have been developed and expanded through numerous studies of associations between management variables and reproductive efficiency [reviewed in 12]. In Argentina, one of the main milk producing countries in Latin America, metrics such as days open (DO), calving interval, days to first breeding (DFB), number of breedings per lactation (NB), 21-day pregnancy rate (21-d PR), and the annual mean 21-d PR (i.e., mean pregnancy rate of the 17 cycles, 21 days long, in one calendar year) are used to monitor reproductive performance. It should be noted that DO is a biased estimate for evaluating reproductive performance, because it typically includes only calving to conception information for cows that have actually achieved and maintained pregnancy. Animals that are culled as nonpregnant because of a failure to conceive, failure to maintain a pregnancy (aborted), or never having the opportunity to conceive because of culling before the breeding period do not contribute information to calculate DO. A better alternative is estimating DO from survival curves for time to pregnancy considering all cows. Survival analysis is a statistical method that not only considers individual animals that do not experience the event or are lost to follow-up, but it also includes those that did experience the event [10]. This approach uses individual-level data from the entire population to produce a better reflection of herd reproductive performance.

The 21-d PR is currently considered a reliable parameter of overall reproductive performance because it has less lag than many other metrics and indicates the percentage of eligible cows that become pregnant every 21-day period, allowing for more timely detection of changes in reproductive performance [13]. However, the 21-d PR is not readily available in many data sets; thus, other measurements (e.g., DO) might be useful to make management decisions or other estimations. For example, VanRaden et al. [14] used a nonlinear formula to convert DO to pregnancy rate for genetic evaluations. It has been suggested that milk production should be considered before making breeding management decisions (i.e., culling or keeping a given cow in the herd for an additional interval [13,15]). Therefore, it might be useful to estimate how long a nonpregnant cow with a specific level of milk production can be kept in the herd without affecting economic returns [16].

The objectives of this study were to: (1) examine individual lactation records collected from Argentine dairy herds and to evaluate the relationship between calving-to-conception time and adjusted number of DO in relation to milk yield (MY) and other factors, such as lactation number (Lact#), calving season (CS), and type of service (TS); and (2) describe the values of DFB and NB.

2. Materials and methods

2.1. Data

The data used in this study consisted of 76,401 cows from 249 dairies located in the central-southern region of the province of Santa Fe and the eastern-southern region of the province of Córdoba, Argentina, collected during a 1-year period (one lactation per cow in 2008). All dairy farms involved in the study used Dairy Comp 305 herd-management software and usually reported their data to a central recording office (Dairy Tech SRL, Rosario, Argentina). Farms were managed with the traditional system used in Argentina, which consists of grazing (mainly alfalfa, 40%–60% of the diet), plus supplementation with corn grain and corn silage. The data were subjected to extensive screening and depuration to prepare the final data set used for analysis. Thus, lactations that had some missing data, e.g., calving date or MY, were removed. Lactations with less than 25 days or lactations of 125 L or less of cumulative production in 25 days in milk (DIM; 25 days $\times$ 5 L per day $=$ 125 L) were also excluded.

Milk yield was expressed as 305 mature equivalent (305ME; [17]) to standardize records from different lactations in number and duration. Lactations were categorized at three levels (low, medium, and high MY), in agreement with the value of 305ME by using the percentiles 33 (P33), and 66 (P66) of yield distribution within each herd. Lactations with values of 305ME lower than the P33 were classified as low MY, lactations with 305ME values between P33 and P66 were classified as medium MY, and finally, lactations with 305ME values higher than P66 were classified as high MY. With regard to the CS, animals that calved in December, January, and February were considered as calving in the summer; those calving in March, April, and May were considered as calving in the fall, those calving in June, July, and August were regarded as calving in winter, and finally those calving in September, October, and November were assigned to spring calving. All cows calved in 2008 and were followed through 300 days in lactation or until they were culled or confirmed pregnant. The main type of breeding used in the farm (i.e., type of service) were defined as: artificial insemination (AI), when 80% or more of the breedings recorded were from AI; or combined, when AI was used in less than 80% of the breedings recorded.

2.2. Statistical analyses

An exploratory analysis by MY levels was performed for the variables DFB and NB. Both variables were expressed in median instead of mean, because their distributions were skewed to the right. Survival curves with Kaplan–Meier method [18] for each MY level were obtained for comparison of time to event (DO) at a given proportion of pregnant cows. The log rank test [19] was used to test the equality of the survival functions among MY levels. High log rank values are associated with low P values (probability that the curves were different by chance). In this study, $P < 0.05$ was used to indicate statistical significant differences between survival curves.

A Cox proportional hazard model was fitted using PROC PHREG in SAS (SAS Institute, Cary, NC) [20,21] to estimate the relative contribution of factors affecting how quickly cows became pregnant. The explanatory variables included in the model were: MY levels, number of lactation, calving season, type of service, and the interaction effect between MY level and type of service. The goodness of fit test based on the likelihood-ratio statistic through PROC LIFEREG was used to prove the assumption that hazards were proportional.

Table 1
Mean ± SEM of milk production and median ± standard error of DFB, and NB by MY level, #Lact, CS, TS, and the interaction between MY and TS for 76,401 cows in 249 Argentine dairy herds.

Item	Number of records (%)	MY 305ME	NB	DFB
MY level				
Low	25,257 (33.0)	5505.5 ± 9.7	1 ± 0.010	64 ± 0.23
Medium	25,306 (33.2)	7552.5 ± 10.0	2 ± 0.012	65 ± 0.21
High	25,838 (33.8)	9283.6 ± 12.7	2 ± 0.013	68 ± 0.22
#Lact				
First	21,067 (27.6)	7369.9 ± 18.2	2 ± 0.012	67 ± 0.25
Second	19,097 (24.9)	7607.4 ± 16.8	2 ± 0.014	65 ± 0.25
Third	14,724 (19.3)	7950.8 ± 17.2	2 ± 0.016	65 ± 0.28
Fourth or greater	21,513 (28.2)	6914.6 ± 14.5	2 ± 0.014	65 ± 0.25
CS				
Summer	14,081 (18.4)	7033.5 ± 18.2	2 ± 0.018	70 ± 0.33
Autumn	25,494 (33.4)	7461.9 ± 14.5	2 ± 0.013	66 ± 0.22
Winter	22,593 (29.6)	7887.6 ± 16.3	2 ± 0.012	63 ± 0.23
Spring	14,233 (18.6)	7206.2 ± 18.4	1 ± 0.011	66 ± 0.33
TS				
Combined	8565 (11.2)	5693.7 ± 18.2	1 ± 0.017	63 ± 0.47
AI	67,836 (88.8)	7684.4 ± 8.8	2 ± 0.007	66 ± 0.13
Interaction MY by TS				
High by natural		7057.0 ± 27.3	2 ± 0.035	67 ± 0.87
High by AI		9564.6 ± 12.7	2 ± 0.013	68 ± 0.22
Low by natural		4300.8 ± 21.1	1 ± 0.025	60 ± 0.79
Low by AI		5657.6 ± 10.2	1 ± 0.011	64 ± 0.24

Abbreviations: #Lact, number of lactations; 305ME, 305 mature equivalent; AI, artificial insemination; CS, calving season; DFB, days to first breeding; MY, milk yield; NB, number of breedings per lactation; TS, type of service.

For the analysis of DO, cows entered the “at risk set” after calving during 2008. Then, each cow was followed through 300 days after calving, so they were at risk to become pregnant until 300 days after calving. Therefore, a cow that did conceive and did not have a recorded abortion before 300 days after calving was regarded as uncensored. Data were censored when the cow did not conceive or was culled or died within 300 days after calving. Other specific censured cases were cows that became pregnant, but then aborted and did not become pregnant again within 300 days after calving. Thus, the variable DO was measured as the number of days from calving to censorship or to a successful breeding confirmed by transrectal palpation and without a subsequent abortion during the observational period. A stepwise procedure was used to select the most significant factors affecting DO, and variables with $P > 0.05$ were excluded from the multivariate model.

3. Results and discussion

The data evaluated in this study included 76,401 cows from 249 dairy herds observed during 300 days after calving (all cows calved in 2008). The mean number of cows in a dairy herd in the region was 307. The number of cows involved in the present study represented 4.21% of the total number of dairy cows in Argentina (1,814,841) [22].

The number of lactation records, classified according to levels of MY, lactation number, calving season, and type of service for all cows are shown in Table 1. The mean MY of the lactation records (standardized in 305ME) was 9283 L for high MY cows and 5505 L for low MY cows (Table 1). The annual mean MY reported for all cows in the United States was approximately 9300 L, and it was 7461 L in the present study [23].

Of all lactation records, 27% were from first lactation cows (Table 1). The mean MY (standardized in 305ME) of the first lactations (7369 L) was lower than that in the second and third lactations, as reported [24–27]. Sixty-three percent of the calvings occurred during fall and winter, and only 18.6% were during the spring and 18.4% during the summer (Table 1). With respect to the type of service used, 88.8% of the lactation records with confirmed pregnancy diagnosis were from farms that used mainly AI, and 11.2% were from farms that used mainly the combined breeding system (Table 1). The NB and the DFB was one and two breedings and 64 and 68 days in cows with low MY and those with high MY, respectively (Table 1).

3.1. Survival analysis by milk yield

Survival curves for DO according to MY levels are shown (Fig. 1). The three survival curves, indicating the proportion of animals open after calving over time, were significant ($P < 0.0001$). Once again, it should be noted that the high MY cows were associated with highest values of DO. At 100 DIM, 39% of the low MY cows were pregnant, and 30% of the high MY cows were pregnant at the same time. Furthermore, the median DO was 124 day for low MY cows, 129 days for medium MY cows, and 148 days for high MY cows. There was a delay of 24 days to achieve the same proportion of pregnant cows in high MY cows compared with low MY cows. Although some cows with lactations in the different MY groups received their first service at different times (i.e., less than 40 days for lactations in the low MY groups and more than 40 days in high MY cows; Fig. 1), it is unlikely that this factor significantly influenced DO, because the median DFB were 64 and 68 days for low MY and high MY cows, respectively. Therefore, for this particular data set, high-producing cows had more DO than lower producing cows.

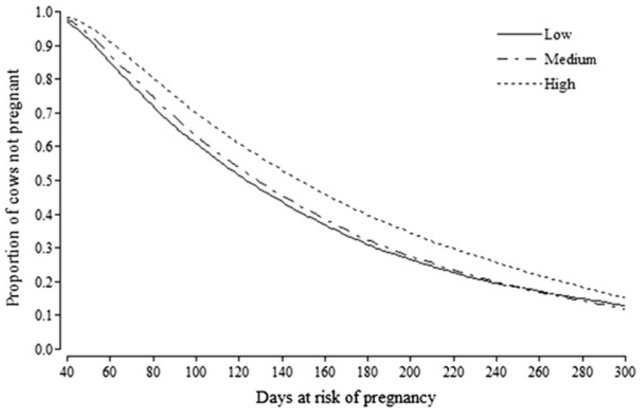

Fig. 1. Kaplan–Meier survival curves for time to pregnancy (days open) for cows with different levels of milk yield for 76,401 cows in 249 Argentine dairy herds.

Table 3
Hazard ratios and 95% CI of risk to get pregnant within MY level, #Lact, CS, and TS for 76,401 cows in 249 Argentine dairy herds.

Contributing factor	HR	95% CI HR	P value
MY (low vs. high)	1.38	1.33–1.42	<0.0001
MY (low vs. medium)	1.09	1.05–1.12	<0.0001
MY (medium vs. high)	1.26	1.23–1.30	<0.0001
#Lact (1 vs. 4)	1.29	1.26–1.32	<0.0001
#Lact (2 vs. 4)	1.27	1.24–1.30	<0.0001
#Lact (3 vs. 4)	1.17	1.17–1.23	<0.0001
#Lact (1 vs. 2)	1.01	0.99–1.03	0.2389
#Lact (1 vs. 3)	1.07	1.04–1.09	<0.0001
CS (winter vs. summer)	1.04	1.01–1.06	0.0061
CS (autumn vs. summer)	1.06	1.04–1.09	<0.0001
CS (spring vs. summer)	1.07	1.04–1.10	<0.0001
TS (combined vs. AI)	1.27	1.14–1.21	<0.0001

Abbreviations: #Lact, number of lactations; AI, artificial insemination; CI, confidence interval; CS, calving season; HR, hazard ratio; MY, milk yield; TS, type of service.

Eicker et al. [15] reported that the median DO for cows with a confirmed pregnancy diagnosis and the number of days required for a cow to become pregnant increased linearly with the accumulated milk production by 60 DIM. There was a 12-day difference in DO between very high and very low MY lactations. This difference was obviously lower than the 24-day difference between low and high MY cows in the present study. However, it is noteworthy that the differential MY between the very low and very high MY lactations studied by Eicker et al. [15] was 1000 L, whereas this difference was 3.7 times higher in our study (i.e., 3778 L). Therefore, production data in the current study was more variable than in the population studied by Eicker et al. [15]. There are huge variations among Argentine dairies in terms of management practices, genetics, feeding, housing, and reproduction. Possibly, the nature of the Argentine management systems, which is a mix between a pasture-based New Zealand-type system and the all total mixed ration, intensive North American-type management system, might be an important contributing factor to this variation.

3.2. Hazard models

The proportional hazard regression model explained the DO in terms of MY level, number of lactation, calving season, type of service, and the interaction between MY level and type of service ($P < 0.0001$). Coefficient estimates are depicted in Table 2 and hazard ratios (HR), in Table 3.

Coefficient estimates for high MY and the other MY levels decreased linearly as the level of MY increased ($P < 0.0001$; Table 2). The HR for low MY compared with high MY cows was 1.38 (95% confidence interval, 1.33–1.42), indicating that cows with low MY had 1.38 higher likelihood of becoming pregnant during the observation period ($P < 0.0001$; Table 3). These results do not agree with those reported by Bello et al. [28], who evaluated the relationship between milk production and reproductive performance on first-lactation dairy cows in Michigan. They concluded that the relationship was heterogeneous across herds, to the point that in some herds they were unable to find an antagonistic relationship between the two traits. Differences between that report and the present study are that the management system used in Michigan differs from the mixed (grazing plus corn silage plus corn grain) management system used in Argentina, and that the number of DO in the present study was calculated for the whole animal population (i.e., primiparous and multiparous cows). Primiparous and multiparous cows might behave differently. When DO were evaluated considering lactation number by production levels, in primiparous cows the absolute difference in the median DO between high MY and low MY was 23 days (140 vs. 117 days), and in multiparous

Table 2
Hazard model parameter estimates[a] for MY level, #Lact, CS, TS, and the interaction between MY and TS for 76,401 cows in 249 Argentine dairy herds.

Term	Estimate	Standard error	Lower 95% CI	Upper 95% CI	LRT	P value
MY (low)	0.1347	0.0096	0.1157	0.1536	417	<0.001
MY (medium)	0.0504	0.0093	0.0321	0.0686		
#Lact (1)	0.0845	0.0073	0.0700	0.0989	555	<0.001
#Lact (2)	0.0704	0.0075	0.0556	0.0852		
#Lact (3)	0.0146	0.0083	−0.0017	0.0310		
CS (winter)	−0.0045	0.0074	−0.0191	0.0101	28	<0.001
CS (autumn)	0.0193	0.0070	0.0055	0.0330		
CS (spring)	0.0261	0.0093	0.0077	0.0445		
TS (combined)	0.1185	0.0066	0.1053	0.1316	296	<0.001
MY by TS (low by combined)	−0.0066	0.0148	−0.0358	0.0224	30	<0.001
MY by TS (medium by combined)	0.0281	0.0147	−0.0008	0.0570		

Abbreviations: #Lact, number of lactations; CI, confidence interval; CS, calving season; LRT, likelihood ratio test for factor significance; MY, milk yield; TS, type of service.
[a] Dependent variable: days open (DO), event (0 pregnant), censoring (1 open cow).

cows this difference was 25 days (152 vs. 127 days), respectively. We inferred that differences in reproductive performance might be more pronounced in multiparous than in primiparous cows, especially in the grazing with supplementation management system used in Argentina.

Type of service was another factor with a great effect on the time at which cows became pregnant. The difference between the coefficients for AI compared with combined service was significant ($P < 0.0001$); therefore, cows in herds that used both AI and natural service had a higher risk of pregnancy (Table 2). The HR for combined service was 1.27; therefore, cows in herds that used both AI and natural service were more likely to become pregnant during the observation period than those bred by AI only (Table 3). Other studies have compared reproductive performance between AI and natural service. Pregnancy rates obtained from dairy herd records of cows bred by AI or natural service were not different [29,30], but pregnancy rate was more variable among herds using natural service than among those using AI [30]. In another study from north central Florida, there was no difference between AI and natural service [31]. By contrast, in a study conducted in California, cows became pregnant at a faster rate when they were bred by AI than when they were exposed to bulls [32]. Because reproductive efficiency in herds using only AI is dependent on estrus detection [13], the superior reproductive performance in herds that used the combined service might also indicate that estrus detection is poor in many dairies of the population studied. In fact, it was previously reported that the mean estrus detection efficiency in dairy herds in the same region was 42% [16].

Kaplan–Maier survival curves for DO were constructed as a function of the main MY levels used in combined service (Fig. 2a) and AI (Fig. 2b). The Kaplan–Meier survival curves demonstrated that time to pregnancy was faster for cows exposed to combined service than to AI, for all MY levels. There was a 15-day difference in median DO between combined service and AI. This difference could also be associated with a difference in MY of 1991 L between the natural service and AI lactations (Table 1). The difference in time to pregnancy between MY levels was smaller in those using AI (Fig. 2b) than in those using combined service. Would therefore we assume that the benefit of using AI was reflected mainly in the milk production indicators, and that the use of AI was less detrimental in the reproductive performance of high-producing cows than in low producing ones in Argentina. Likewise, an unbiased evaluation of the benefit of AI was hampered by the confounding effects of the type of service with the production level. As previously mentioned, most high MY cows were associated with AI as the main type of service used (Table 1). The beneficial effects of using AI in high-producing cows, especially fixed-time AI in high-producing herds where estrus detection is inefficient, were reported previously [33–36].

Coefficient estimates for the variable number of lactation were positive and highly significant ($P < 0.00001$), decreasing linearly as the number of lactations increased (Table 2). Therefore, first lactation cows were expected to have fewer DO than older cows. The HR was 1.29 (95% confidence interval, 1.26–1.32) for Lact# 1 versus Lact# 4,

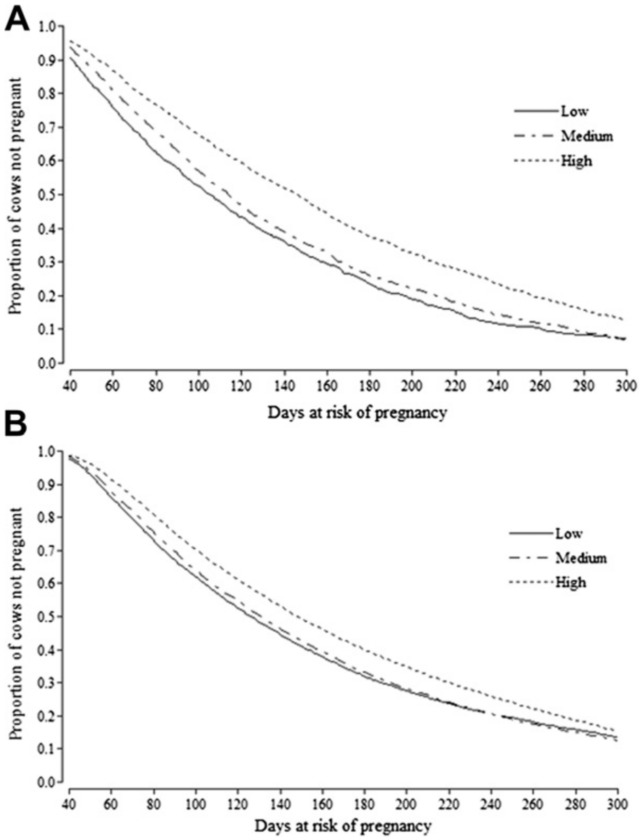

Fig. 2. Kaplan–Meier survival curves for time to pregnancy (days open) for the three levels of milk yield by type of service for combined (A), and artificial insemination (B) for 76,401 cows in 249 Argentine dairy herds.

1.27 for Lact# 2 versus Lact# 4, and 1.17 for Lact# 3 versus Lact# 4. The negative effect of Lact# on DO has been reported previously [24–27].

Calving season affects the risk of pregnancy, as reported [37,38]. In the present study, cows calving during the colder seasons (fall and winter) had fewer DO than those calving in summer. The HR was 1.04 times higher for cows calving in winter and 1.06 times higher for those calving in fall than for cows calving in summer (Table 3). The present results confirmed the assumption that cows that begin their lactations under heat stress are more likely to have reduced reproductive performance than those calving under more favorable conditions [23,39]. The estimation of DO has also been found to be affected by the month of calving [40] and the negative effect of increased ambient temperature was more critical in the southern than in the northern regions of the United States [3,41,42].

3.3. Conclusions

Though lactation number and calving season were contributing factors to explain the number of days open, the influence of MY level, the type of service, and the interaction between them were also determinant factors influencing reproductive efficiency. Although combined service resulted in fewer days open, the interaction between type of service and MY had lower variation in the number of days open between the levels of milk production in cows bred by AI than those bred by combined service. Furthermore, the use of combined service was always associated with lower milk production. An estimation of the economic consequences of using various types of breeding in relation to milk production in Argentine dairy herds warrants further investigation.

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