The Association Between Reproductive Performance and Milk Yield in Chilean Holstein Cattle

P. Melendez*¹ and P. Pinedo*[†]

*College of Veterinary Medicine, University of Florida, Gainesville 32610

[†]Insecabio Ltda., Certified Recording System Organization, Los Angeles, Chile

ABSTRACT

The objective of this study was to evaluate the relationship between reproductive performance and milk yield in central-southern Chilean Holstein cattle that calved from 1990 to 2003. The analysis included 150,457 lactations obtained from a certified recording system. Reproductive indexes included in the study were calving interval (CI, d), calving to first service interval (CFSI, d), calving to conception interval (CCI, d), services per conception (SC), and conception rate at first service (CRFS). Survival analysis for the risk of pregnancy was also conducted. Models for reproductive indexes were significant and included, as independent variables, year and season of parturition, parity, length of dry period, milk and fat production standardized to 305 d, herd size, and herd. In 1990 and 2003, respectively, means $\pm$ SEM for CI were 399 ± 1.6 and 415 ± 1.1 d; for CFSI were 85 ± 0.6 and 97 ± 0.6 d; for CCI were 124 ± 1.3 d and 137 ± 1 d; and for SC were 1.6 ± 0.02 and 1.7 ± 0.01 . For every 100 kg of 305-d standardized milk yield, the CCI increased by 0.6 d and CRFS decreased by 0.9%. Association between milk yield and the risk of pregnancy was almost zero when a Cox proportional regression model was conducted (hazard ratio = 1.005; 95% confidence interval = 1.002 to 1.008). We conclude that CCI has increased over time and is related negatively to the increase in milk yield experienced by central-southern Chilean Holstein cattle during the last 15 yr. Nevertheless, risk of pregnancy was not explained by the individual level of standardized 305-d milk yield of cows studied.

Key words: fertility, milk yield, Chile, cattle

INTRODUCTION

A negative association between fertility and milk yield has been consistently reported in dairy cattle (Lucy, 2001; Washburn et al., 2002; de Vries and Risco,

2005). Fertility and milk yield are related inversely; that is, when milk yield increases, fertility decreases over time. Higher producing cows within a herd, however, are not always less fertile than lower producing cows because high milk yield does not always exacerbate negative energy balance (Lucy, 2001; Tenhagen et al., 2003). In addition, higher producing herds generally have better fertility, probably reflecting more efficacious feeding, reproductive, and herd health management programs (Nebel and McGilliard, 1993; Stevenson, 2001). Furthermore, other factors negatively affect reproductive performance of dairy herds, such as disease (Gröhn and Rajala-Schultz, 2000) and climate (de Vries and Risco, 2005). These factors may act as confounders when the pure relationship between milk yield and fertility is evaluated. The relationship between the 2 variables may be explained in several ways. Increment in milk yield may affect negatively fertility through an unfavorable genetic (Dematawewa and Berger, 1998; VanRaden et al., 2004) or phenotypic correlation, in which management and environment play a key role (Hansen, 2000), or both (negative genetic and phenotypic correlation), between the 2 variables.

Holstein genes have been introduced consistently during the last 30 yr in Chile (Elzo et al., 2004). The central-south area of Chile is a typical agricultural region, and represents 25% of the total cattle population of the country. In this geographical area, a government-certified recording system organization (Insecabio) has monitored (monthly) a population of approximately 12,000 Holstein cattle distributed in 187 herds during the last 15 yr. Based on information obtained from selected databases, few studies with small data sets have reported information about the relationship between milk yield and reproduction in Chilean dairy cattle (Mujica et al., 1995; Gonzalez et al., 1997).

Because of genetic selection and improved herd management, milk yield in Chilean dairy farms has increased over time; therefore, the current relationship between milk yield and reproductive performance has not been assessed. The objective of this study was to characterize reproductive indexes and to determine the association between reproductive and production vari-

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¹Corresponding author: melendezp@mail.vetmed.ufl.edu

ables in central-southern Chilean Holstein cattle between 1990 and 2003.

MATERIALS AND METHODS

Dairy Farms and Management

The study considered dairy farms from the central-south area of Chile (VIII and IX regions; 2 of 13 political regions). The area is located between 36°00' and 38°30' south and between 71°00' west and the Pacific Ocean. Climate is temperate with winter rainfall (1,380 mm/yr) and temperatures that range from 0°C in winter to 32°C in summer (Instituto Geografico Militar, 2006).

Dairy farms included in this study consisted of Holstein cattle (90%) and crossbred Black-Pied × Holstein (10%). Housing consisted of dry lot (40%), freestalls (40%), grazing (10%), and mixed systems (10%). Feeding systems were TMR-based consisting of corn silage, alfalfa hay, and concentrates (50%), top-dressed concentrate, corn silage, and green chop/hay alfalfa (30%), grazing (10%), and mixed systems (10%).

Reproductive management consisted of AI (80%), natural service (10%), and mixed systems (10%). In herds using natural service (small herds), bulls were housed in individual pens separate from cows. Cows were hand-mated with bulls after detected estrus; therefore, date of breeding was known.

Milking frequency was 3× (35%) or 2× daily (65%) using standard commercial automated milking machines.

Study Design

The study used data obtained from a government-certified record organization (Insecabio Ltda, Los Angeles, VIII region, Chile). The study analyzed 150,457 lactations that began between 1990 and 2003, distributed in 187 herds. Inclusion criteria for the statistical analysis considered those lactations, including culled and dead cows, with a minimum of 6 monthly test days to have a more accurate projection of milk yield to 305 d. Consequently, 120,309 lactations were considered for the analysis. Data were obtained by certified technicians during monthly visits to the farms from 1990 to 2003. Information consisted of animal identification, test-day milk and fat production, reproductive records, and management records obtained during the monthly visit of the technician (e.g., true dry-off date, true calving date, and true DIM).

Outcome Variables and Statistical Analysis

Outcome variables were calving interval (CI, d), defined as the number of days occurring between 2 succes-

sive parturitions; calving to first service interval (CFSI, d), defined as the number of days between parturition and the subsequent first breeding (natural or artificial); calving to conception interval (CCI, d), defined as the number of days between parturition and the breeding (natural or artificial) that resulted in a pregnancy; services per conception (SC, units), defined as the number of breedings (natural or artificial) that a cow required to conceive during the current lactation; length of dry period, defined as the number of days between the dry-off date and the subsequent parturition; DIM, defined as the number of days between parturition and the subsequent dry-off (duration of lactation); and conception rate at first service (CRFS, %), defined as the number of first breedings that resulted in pregnancy divided by the total number of first breedings.

Explanatory independent variables were parity (1, 2, 3, or more), calving season (summer, fall, winter, spring), year of calving (1990 to 2003), milk and fat production standardized to 305 d (kg) based on an approved methodology (Keown et al., 1986), length of dry period previous to lactation of interest (d), type of herd (small, medium, and large), herd, and cow nested within herd. Cows were considered to be random in the model. Definitions of seasons were: summer = December 1 to February 28; autumn = March 1 to May 31; winter = June 1 to August 31; and spring = September 1 to November 30. Type or size of herd: small = <80 cows, medium = 80 to 150 cows, and large = >150 cows. Biologically relevant 2-way interactions were included in preliminary models, but they were removed when not significant. Because of the large sample size, CI, CFSI, CCI, SC, length of dry period, and length of lactation were evaluated by mixed model methodology, and CRFS was analyzed by logistic regression modeling through a backward elimination procedure. To account for cows that were not inseminated or diagnosed for pregnancy because of death or culling (censored), a survival analysis methodology was conducted using the entire data set ($n = 150,457$). To determine the risk of pregnancy over time, a Cox proportional regression model and survival curves by years were estimated. Data were analyzed by the mixed, logistic, and phreg procedures (SAS Institute, 2003). Variables were considered to be significant when $P \leq 0.05$.

RESULTS

In all the models there were no 2-way interactions ($P > 0.05$); therefore, final models considered only main effects.

Milk Yield and Fat

Standardized 305-d milk yield and fat increased ($P < 0.05$) from 1990 to 2003 in the central-southern Hol-

stein cattle of Chile (Table 1). Standardized 305-d milk and fat yield by season and parity are shown in Tables 2 and 3.

Reproductive Variables and Intervals

Calving interval, CFSI, CCI, SC, CRFS, length of dry period, and length of lactation by year, season and parity, respectively are presented in Tables 1, 2, and 3.

In Figure 1, CCI, SC, and CFSI are plotted by year. Models for CI, CFSI, CCI, and SC were significant ($P < 0.05$) and all models included as explanatory variables year and season of parturition, parity, length of dry period, standardized 305-d milk and fat yield, type of herd, and herds.

A direct association was detected between milk yield and CCI (Figure 2). For every 100-kg increase in standardized 305-d milk yield, the CCI increased ($P \leq 0.001$) by 0.6 d.

In Figure 3, standardized 305-d milk yield and CRFS from 1990 to 2003 are shown. Logistic regression for CRFS was significant ($P < 0.05$). Significant variables were standardized 305-d milk yield, parity, calving season, type of herd, and year of calving. For every 100-kg increase in standardized 305-d milk yield, the CRFS decreased ($P < 0.05$) by 0.9%.

Survival Analysis for Risk of Pregnancy

In Figure 4, survival curves for the risk of nonpregnancy by year are plotted. In Table 4, a summary of results for the Cox proportional hazard model for the risk of pregnancy is shown. Correcting for herd category, parity, and season, the risk of pregnancy decreased ($P \leq 0.05$) by 1.2% each year from 1990 to 2003. For every 1,000 kg of standardized 305-d milk yield, however, risk of pregnancy increased ($P < 0.05$) by 0.5%.

DISCUSSION

Reproductive Indexes

Results from this study showed that the reproductive performance of central-southern Chilean Holstein cattle measured by traditional indexes has decreased during the 14-yr period studied. Similar declines have been observed in other countries (Lucy, 2001). Most of the reproductive indexes analyzed in the present study, however, only considered cows that had the opportunity to be bred, without considering cows that left the farms before insemination or pregnancy diagnosis. Unfortunately, it was not feasible to obtain pregnancy rate, defined as the product of estrus-detection rate (EDR) and conception rate (CR), in the current data set. Nevertheless, through use of survival analysis, it was possi-

Table 1. Least squares means (with SEM in parentheses) of productive and reproductive variables in central-southern Holstein cattle from 1990 to 2003

Item ¹	Year													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
MY 305, kg	5,979 ^a (24.6)	6,055 ^b (24.8)	6,476 ^c (24.8)	6,572 ^d (22.5)	6,912 ^e (21.8)	7,135 ^f (20.9)	7,219 ^g (21.0)	7,320 ^h (22.6)	7,527 ⁱ (21.9)	7,665 ^j (22.1)	7,970 ^k (22.6)	7,968 ^l (21.4)	7,704 ^m (22.8)	7,626 ⁿ (23.1)
Fat 305, kg	200.4 ^a (0.78)	187.5 ^b (0.75)	205.5 ^c (0.79)	205.6 ^d (0.79)	225.9 ^e (0.77)	248.4 ^f (0.74)	247.1 ^g (0.73)	249.0 ^h (0.75)	245.8 ⁱ (0.69)	257.3 ^j (0.72)	274.3 ^k (0.76)	259.0 ^l (0.70)	264.7 ^m (0.76)	253.2 ⁿ (0.80)
DIM	333.2 ^a (1.22)	333.7 ^a (1.16)	335.5 ^a (1.08)	339.3 ^b (1.05)	340.9 ^{bc} (0.94)	346.5 ^d (0.92)	347.8 ^{de} (0.86)	354.5 ^f (0.87)	345.8 ^g (0.78)	347.3 ^h (0.81)	350.2 ⁱ (0.84)	353.9 ^j (0.82)	352.0 ^{jk} (0.88)	353.8 ^{kl} (0.87)
DDP, d	81.0 ^a (1.42)	72.6 ^b (0.71)	76.5 ^c (0.84)	77.5 ^c (0.91)	74.3 ^b (0.61)	75.3 ^c (0.75)	74.6 ^c (0.65)	78.5 ^d (0.78)	81.9 ^e (0.92)	77.3 ^c (0.72)	71.0 ^e (0.54)	70.6 ^e (0.54)	70.1 ^e (0.55)	71.5 ^e (0.60)
CI, d	399 ^{ab} (1.60)	398 ^a (1.37)	401 ^a (1.36)	402 ^b (1.26)	400 ^c (1.09)	400 ^c (1.04)	405 ^d (0.99)	411 ^e (1.04)	416 ^f (1.07)	412 ^e (1.03)	407 ^d (0.96)	411 ^e (1.02)	412 ^e (1.05)	415 ^e (1.09)
CCI, d	124.2 ^a (1.29)	124.0 ^a (1.23)	124.5 ^a (1.14)	125.9 ^a (1.06)	127.2 ^b (0.99)	131.8 ^c (0.98)	135.3 ^d (0.92)	141.6 ^e (0.95)	131.6 ^c (0.82)	133.4 ^d (0.86)	133.3 ^d (0.87)	138.9 ^e (0.87)	135.3 ^d (0.91)	137.4 ^e (0.95)
CFSI, d	85.4 ^a (0.64)	87.9 ^b (0.69)	88.6 ^b (0.66)	90.6 ^c (0.60)	91.7 ^c (0.59)	92.4 ^d (0.56)	91.7 ^c (0.50)	93.4 ^d (0.52)	90.8 ^c (0.45)	93.0 ^d (0.50)	92.8 ^d (0.52)	96.8 ^e (0.53)	95.4 ^e (0.55)	96.8 ^e (0.58)
SC, no.	1.60 ^a (0.02)	1.65 ^{bc} (0.02)	1.68 ^b (0.02)	1.61 ^{ac} (0.01)	1.60 ^c (0.01)	1.61 ^{bc} (0.01)	1.60 ^{bc} (0.01)	1.72 ^d (0.01)	1.83 ^e (0.01)	1.76 ^f (0.01)	1.70 ^d (0.01)	1.70 ^d (0.01)	1.71 ^d (0.01)	1.72 ^d (0.01)
CRFS, %	54.0 ^a (0.02)	55.3 ^a (0.02)	55.7 ^a (0.02)	57.1 ^b (0.01)	56.6 ^b (0.01)	53.4 ^a (0.01)	50.8 ^c (0.01)	47.7 ^d (0.01)	50.3 ^c (0.01)	51.3 ^c (0.01)	50.5 ^c (0.01)	48.9 ^d (0.01)	50.6 ^c (0.01)	50.4 ^c (0.01)

^{a-n}Values within row bearing different superscript letters differ ($P \leq 0.05$).

¹MY 305 = Milk yield standardized to 305 d; Fat 305 = fat standardized to 305 d; DDP = days of dry period; CI = calving interval; CCI = calving to conception interval; CFSI = calving to first service interval; SC = services to conception; and CRFS = conception rate at first service.

Table 2. Least squares means (with SEM in parentheses) of productive and reproductive variables in central-southern Holstein Chilean cattle by calving season between 1990 and 2003

Variable ¹	Season			
	Summer	Autumn	Winter	Spring
MY 305, kg	7,683 ^a (18)	7,881 ^a (17)	7,977 ^b (17)	7,818 ^a (18)
Fat 305, kg	258.0 ^a (0.60)	261.2 ^b (0.60)	264.3 ^b (0.60)	260.5 ^a (0.60)
CI, d	407.2 ^a (0.60)	407.6 ^a (0.57)	408.5 ^a (0.55)	408.6 ^a (0.34)
CCI, d	127.2 ^a (0.50)	127.0 ^a (0.60)	128.8 ^a (0.60)	130.3 ^b (0.60)
CFSI, d	85.3 ^a (0.30)	86.0 ^b (0.30)	87.5 ^c (0.30)	89.1 ^d (0.30)
SC, no.	1.74 ^a (0.01)	1.74 ^a (0.01)	1.74 ^a (0.01)	1.73 ^a (0.01)
CRFS, %	51.0 ^a	51.3 ^a	52.8 ^b	52.4 ^b
DIM	337.2 ^a (0.60)	335.1 ^a (0.60)	335.7 ^a (0.50)	338.6 ^a (0.50)
DDP, d	70.6 ^a (0.40)	73.2 ^b (0.40)	74.6 ^b (0.30)	75.1 ^b (0.40)

^{a-d}Values within row bearing different superscript letters differ ($P \leq 0.05$).

¹MY 305 = Milk yield standardized to 305 d; Fat 305 = fat standardized to 305 d; CI = calving interval; CCI = calving to conception interval; CFSI = calving to first service interval; SC = services to conception; CRFS = conception rate at first service; and DDP = days of dry period.

ble to include cows that were not bred ($n = 19,811$), giving more precise information about reproductive performance of the central-southern Chilean Holstein cattle.

Calving interval in central-southern Chilean dairy cattle increased from 399 d (13.1 mo) in 1990 to 415 d (13.6 mo) in 2003. Extended calving intervals negatively influence the productive life, because the cow has fewer lactations during the same period of herd life compared with cows with shorter calving intervals (Hare et al., 2006). The most important determinant of CI is the CCI because gestation length is considered to be less variable than time to conception. In addition, CCI is accounted for the voluntary waiting period (VWP), EDR, failure to return to cyclicity, CR, and abortion rate of the herd (Risco et al., 1998). Mean herd CI in US Holstein cattle has increased from 12.8 to 13.3 mo, whereas individual CI for cows has increased from 12.9 to 13.4 mo between 1991 and 2002 (USDA, 2002). In a recent study, using more than 1 million lactation records of Holstein cattle, the CI was estimated to be 13.3 mo, with an annual increase of 0.90 to 1.07 d/yr (Hare et al., 2006). This information is similar and consistent with the values for the Chilean Holstein population reported in the present study between 1990 and 2003.

The increase in CI was mainly due to a prolonged calving to conception interval (from 124.2 d in 1990 to

Table 3. Least squares means of productive and reproductive variables in central-southern Holstein Chilean cattle by parity between 1990 and 2003

Variable ¹	PARITY		
	1	2	3 or more
MY 305, kg	6,810 ^a (14)	7,760 ^b (14)	7,898 ^c (11)
Fat 305, kg	254.0 ^a (0.50)	258.3 ^b (0.50)	262.5 ^c (0.40)
CI, d	—	413.7 ^a (0.51)	404.8 ^b (0.34)
CCI, d	128.2 ^a (0.50)	129.8 ^a (0.40)	127.3 ^a (0.50)
CFSI, d	80.3 ^a (0.50)	88.5 ^b (0.50)	85.9 ^c (0.50)
SC, no.	1.70 ^a (0.01)	1.71 ^a (0.01)	1.75 ^a (0.01)
CRFS, %	33.3 ^a	52.7 ^b	51.3 ^b
DIM	316.2 ^a (0.40)	339.7 ^b (0.50)	333.6 ^b (0.40)
DDP, d	—	70.6 ^a (0.40)	76.0 ^b (0.40)

^{a-c}Values within row bearing different superscript letters differ ($P \leq 0.05$).

¹MY 305 = Milk yield standardized to 305 d; Fat 305 = fat standardized to 305 d; CI = calving interval; CCI = calving to conception interval; CFSI = calving to first service interval; SC = services to conception; CRFS = conception rate at first service; and DDP = days of dry period.

137.4 d in 2003), which is ultimately related to decreased CR, poorer EDR, or delayed cyclicity (Risco et al., 1998). Estrus-detection rate is difficult to estimate on dairy farms and was not evaluated in the present study.

Conception rate at first service decreased slightly from 54% in 1990 to 50% in 2003, confirming the tendency of depressed conception over time, which partially explains the inflated CCI and the CI. Supporting our findings, a previous study conducted in Chile also estimated a decreased CRFS over time (from 63.1% in 1980 to 50% in 1990; Gonzalez et al., 1997). More recent values of CRFS reported in the US Holstein population are between 30 and 40% (Butler, 1998; Pursley et al., 1998) and CRFS reported by the present study (50% in 2003) is more similar to that of Holstein cattle in the United States in 1950 (Lucy, 2001). The tendency of declining CRFS over time is consistently reported in the United States (Butler, 1998; VanRaden et al., 2004; Hare et al., 2006) and other countries such as Ireland (Roche et al., 2000), the UK (Wall et al., 2003), Australia (McMillan et al., 1996), and Spain (Gonzalez-Recio et al., 2004).

First-lactation cows had lower CRFS (33.3%) than cows in their second and third or more lactations (52.7 and 51.3%, respectively). These results are in contrast to reports conducted in the United States and Europe,

Figure 1. Reproductive indexes in central-southern Chilean Holstein cattle between 1990 and 2003. CCI = days from calving to conception; SC = services per conception; CFSI = days from calving to first service interval.

Figure 2. Standardized 305-d milk yield 305 d (kg; -----) and calving to conception interval (d; —) in central-southern Chilean Holstein cattle between 1990 and 2003.

Figure 3. Standardized 305-d milk yield 305 d (kg; -----) and conception rate at first service (%; —) in central-southern Chilean Holstein cattle between 1990 and 2003.

in which first-lactation cows have similar or better fertility compared with multiple-lactation cows (Weigel, 2004; Windig et al., 2005). This might be explained because first-lactation cows were first bred 5 to 10 d

earlier ($P \leq 0.05$) than multiple-lactation cows. Nevertheless, fertility was balanced afterward between lactation groups, because CCI did not differ between them (Table 3).

Figure 4. Survival curves for the risk of nonpregnancy in central-southern Chilean Holstein cattle ($n = 150,457$) by year.

Table 4. Cox proportional regression model for the risk of pregnancy in central-southern Holstein Chilean cattle (n = 150,457)

Variable	Hazard ratio	95% HR CI ¹	P
Years 1990 to 2003	0.988	0.98 to 0.99	<0.0001
Standardized 305-d milk yield 3 (for each 1,000 kg)	1.005	1.002 to 1.008	0.0012

¹95% Hazard ratio confidence interval.

Actual CCI in the Chilean cattle population was around 137 d and slightly greater in cows calving in spring than in cows calving in other seasons. This result indicated that the effect of calving season on fertility is minimal in temperate Mediterranean climates such as the studied Chilean region and California (Oseni et al., 2003) compared with subtropical climates such as Florida and Georgia, in which CCI increased dramatically in cows calving during spring (de Vries and Risco, 2005). Because CRFS was approximately 50% and SC was 1.75, the only explanation for the value of CCI obtained in the present study is the longer CFSI (89 d). This interval may be accounted for by a longer VWP, poorer EDR, greater rate of cows having prolonged anestrus, or a combination of these factors. On average, VWP in Chilean cattle is not >60 d. In addition, Chilean dairy herds rarely use ovulation synchronization protocols or timed AI. Consequently, detection of estrus is extremely important in managing reproduction of Chilean herds. Based on these conclusions, further studies to estimate EDR or determine the dynamic of postpartum reproductive cyclicity on Chilean Holstein cattle is warranted.

Reproduction and Milk Yield

Standardized 305-d milk yield increased from 1990 to 2003 in central-southern Chilean Holstein cattle. This is consistent with studies reporting genetics trends as a consequence of use of US Holstein genetics (Elzo et al., 2004). Actual standardized 305-d milk yields (about 7,500 kg) in our study are comparable with cattle from those herds with the lowest averages in the United States and similar to Holstein cattle from Florida and Georgia in 2002 (de Vries and Risco, 2005). Besides genetic improvement, trends for increased milk yield can be explained by introduction of new technologies and improved management, such as nutrition and herd health.

A major objective of this study was to characterize reproductive performance of Chilean cattle and to examine the relationship between reproduction and milk yield. This is the first large-scale study (>50,000 lactations) conducted in Chile reporting this kind of associa-

tion. Results of the present study show a negative association between milk yield and some reproductive indexes. In the statistical model for CCI, this index was significantly associated with the standardized 305-d milk yield. For every 100-kg increase in standardized 305-d milk yield, the CCI increased by 0.6 d. This association was corrected for calving season, parity, herd size, and herd. The negative association between milk yield and fertility is commonly reported in US Holstein cattle (Washburn et al., 2002; Rajala-Schultz and Frazer, 2003; de Vries and Risco, 2005). This cannot be considered as a cause-and-effect relationship, but rather partly explained by the antagonistic genetic correlation between milk yield and fertility (Dematawewa and Berger, 1998; Hansen, 2000). In addition, other factors exist that are involved with reproductive performance, such as diseases, that this study was not able to identify. Periparturient diseases are important factors that affect fertility of dairy cattle (Gröhn and Rajala-Shultz, 2000). Other factors that change over time, such as herd size, feeding strategies, and housing, might affect overall reproductive management and performance. Although models were adjusted for herd size in the present study, increases in herd size over time might have affected the efficiency of detecting estrus. One limitation of the present analysis is that the reported negative association between milk yield and CCI was determined in cows that all eventually became pregnant. This is a serious bias that is acknowledged when traditional reproductive indexes, such as CI and CCI, are used to estimate reproductive efficiency of dairy farms. A more powerful statistical methodology such as survival analysis accounts for cows that were present in the farm, but left the herd before breeding, and gives more accurate information about reproductive efficiency of dairy herds. These cows not bred (culled, sick, or dead) contribute to herd reproductive performance when fertility is evaluated. As a result, in the present study, survival curves for the risk of nonpregnancy were different among years, especially when comparing lactations that started in 1990 and 2003. In 1990, 50% of the cows were pregnant by 111 DIM, whereas in 2003, 50% of the cows were pregnant by 137 d. In addition, older cows were less likely to become pregnant than younger

cows, which is consistent with studies conducted in the United States and Europe (Weigel, 2004; Windig et al., 2005). In addition, the association between individual standardized 305-d milk yield and risk of pregnancy was not negative to any further extent. That is, for an extra 1,000 kg of standardized 305-d milk yield, the risk of pregnancy increased by 0.5%. This result is in agreement with the findings of Gröhn and Rajala-Schultz (2000), who also used survival analysis and found a hazard ratio between pregnancy and milk yield close to 1.0. The meaning of this hazard ratio is that the relationship between milk yield and risk of pregnancy is essentially nonexistent when correcting for herd size, parity, season, and year of calving. High milk yield is not always consistent with negative energy balance. Therefore, high-producing cows are not those having the lowest BCS within a herd (Lucy, 2001) and they are not at risk for infertility when compared with low-producing cows (Lucy et al., 1992). Although the relationship reported in the present study (hazard ratio = 1.01) may not be of biological significance, it introduces contradictory evidence when culled cows are considered as part of the analysis of reproductive efficiency of dairy herds. In the analysis of the association between milk yield and CCI, the conclusion that fertility is suppressed as milk yield increases may be incorrect. This is because culling decisions in a herd are extremely important factors that may account for this complex and multifactorial relationship (Gröhn and Rajala-Schultz, 2000).

CONCLUSIONS

Standardized 305-d milk yield and calving to conception interval have increased during the last 15 yr in central-southern Chilean Holstein cattle. For every 100-kg increase in 305-d milk yield, the CCI increased by 0.6 d and CRFS decreased by 0.9%. When culled cows were included in the statistical analysis (Cox-proportional regression model), however, the association between milk yield and risk of pregnancy over time was almost nonexistent.

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