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REGULAR ARTICLES

Risk factors associated with reproductive performance in small-scale dairy farms in Mexico

Luis Javier Montiel-Olguín[1,2] · Eliab Estrada-Cortés[3] · Mario Alfredo Espinosa-Martínez[2] · Miguel Mellado[4] · Josafath Omar Hernández-Vélez[5] · Guillermina Martínez-Trejo[6] · Felipe J. Ruiz-López[2] · Hector Raymundo Vera-Avila[1,2]

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Abstract

Several studies suggest that reproductive performance in small-scale dairy farms is low reducing the farms' profitability. Therefore, identifying risk factors associated with low reproductive performance is a key step to implement an improved reproductive management program. Accordingly, the aim of the present study was to identify the main risk factors affecting the reproductive performance of cows in small-scale dairy farms. Ninety-six dairy farms were incorporated into this study, and data from 1263 lactations were collected with different events as potential risk factors. Logistic regression models were used to assess the association (odds ratio, OR) and impact (population attributable fraction, PAF) between the potential risk factors and the reproductive variables. The main risk factors associated with assisted calving were male calf and primiparous cows (OR = 1.7, PAF = 0.315 and OR = 1.5, PAF = 0.131, respectively), while for retained fetal membranes (RFM) were assisted calving and abortion (OR = 4.5, PAF = 0.440 and OR = 8.1, PAF = 0.239, respectively). The main risk factors for days to first service over 70 days in milk were low body condition score at calving (BCS ≤ 2.5) and primiparous cows (OR = 2.2, PAF = 0.285 and OR = 1.4; PAF = 0.096, respectively), while for days open over 110 days in milk were low BCS at calving (BCS ≤ 2.5) and primiparous cows (OR = 1.7, PAF = 0.213 and OR = 1.4; PAF = 0.096, respectively) The main risk factor for non-pregnant cows at first service was RFM (OR = 1.7; PAF = 0.059). In conclusion, assisted calving, male calf, BCS ≤ 2.5 and RFM were the main risk factors associated with reduced reproductive performance in small-scale dairy farms in tropical and subtropical regions of Mexico.

Keywords Small-scale dairy system · Reproductive performance · Risk factors · Dairy cattle

✉ Hector Raymundo Vera-Avila
hrvera56@gmail.com

1 Present address: Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro, Av. de las Ciencias s/n, C.P. 76230 Santiago de Querétaro, Querétaro, Mexico

2 Centro Nacional de Investigación Disciplinaria en Fisiología y Mejoramiento Animal-INIFAP, km 1 Carretera a Colón, C.P. 76280 Ajuchitlán, Querétaro, Mexico

3 Campo Experimental Centro Altos de Jalisco-INIFAP, Av. Biodiversidad 2470, C.P. 47600 Tepatitlán, Jalisco, Mexico

4 Departamento de Nutrición Animal, Universidad Autónoma Agraria Antonio Narro, Calzada Antonio Narro 1923, Buenavista, C.P. 25315 Saltillo, Coahuila, Mexico

5 Campo Experimental San Martinito-INIFAP, km 56.5 Carretera Federal México-Puebla, C.P. 74100 Santa Rita Tlahuapan, Puebla, Mexico

6 Campo Experimental Valle de México-INIFAP, km 13.5 Carretera Los Reyes-Texcoco, Coatlinchán, C.P. 56250 Texcoco, Estado de México, Mexico

Introduction

Small-scale dairy systems are important because they contribute to increase food security worldwide, generate jobs in rural areas, and improve household welfare (Hemme and Otte 2010). In Mexico, milk yield of small-scale dairy farms accounts for approximately 30% of the national milk production (Barrera Camacho and Sánchez Brito 2003; Vera et al. 2009) and 23% of the total dairy cow population in Mexico (SAGARPA 2004). This milk production system in Mexico is characterized by unpaid labor of the family members, the use of medium-yielding Holstein cows, low/medium technification, medium levels of milk yield per cow, a small number of cows (García-Muñiz et al. 2007; Jiménez Jiménez et al. 2014; Camacho-Vera et al. 2017), and inefficient administration of the farm (Moreno-García et al. 2012). Also, this system is important because of social benefits (emotional satisfiers), a decreasing migration of peasants from rural areas to the cities (Zamudio et al. 2003; Espinoza-Ortega et al. 2005), and reduction of poverty in rural areas, especially if profitability is improved (Hemme and Otte 2010).

High reproductive performance is a determinant factor for profitability in dairy herds (Gröhn and Rajala-Schultz 2000; Inchaisri et al. 2010). Several studies suggest that cows in small-scale dairy farms in Mexico have poor reproductive performance, which in turn reduces the competitiveness of the farms (Ojeda Carrasco et al. 2012; Vázquez-Selem et al. 2016; Silva Salas et al. 2017). In this regard, an average of 135 days open (DO), range 110–180 days in small-scale dairy farms, has been reported (Guevara et al. 2006; Abrego 2011; Vázquez-Selem et al. 2016). However, the optimal average DO for this type of production system has been suggested to be less than 110 days (Vera et al. 2009). Moreover, the prevalence of dystocia was reported to be between 4.9 and 26.8% (Villaseñor et al. 2011; Silva Salas et al. 2017), when it should not exceed 6% (Mee 2008). This information indicates that reproductive performance in small-scale dairy farms in Mexico is deficient and exists great variability, representing an area of opportunity to improve competitiveness.

A fundamental step to initiate a program to improve reproductive performance in dairy operations is to identify the main risk factors that compromise the fertility of cows. Several studies in different countries and dairy production systems have identified risk factors associated with the diminished reproductive performance of cows (López-Gatius et al. 2005; Santos et al. 2009; Keshavarzi et al. 2017). Nevertheless, characteristics of farms used in these studies, such as size, production level, and level of technification, differ from the conditions prevailing in the small-scale dairy system (Martínez-García et al. 2015). Hence, extrapolating information between systems to take management decisions is inappropriate. Therefore, the aim of this study was to identify the risk factors with greater impact on the reproductive performance of cows in the small-scale dairy system in tropical and subtropical zones of Mexico. Our working hypothesis was that reproductive performance is deficient in these systems existing diverse risk factors associated with this low reproductive output.

Materials and methods

Location

A prospective cohort study was conducted in seven Mexican states which have a significant presence of small-scale dairy farms: Jalisco (20° 51′ N, semi-warm sub-humid), Coahuila (25° 25′ N, semi-dry), Estado de Mexico (19° 28′ N, temperate sub-humid), Puebla (18° 52′ N, temperate sub-humid), Tlaxcala (19° 19′ N, temperate sub-humid), Guanajuato (20° 31′ N, semi-dry sub-humid), and Queretaro (20° 43′ N, semi-dry).

Farm selection and data collection

Ninety-six dairy farms were included (1263 complete lactations) based on four criteria: (1) exclusively family labor, (2) herd size between 10 and 100 milking cows, (3) milk production as the main activity, and (4) low to intermediate machine milking level (manual milking or few individual milking machines and without milk cooling systems). Farms included in the present study meet the characteristics of small-scale dairy herds in Mexico described elsewhere (SAGARPA 2004; Vera et al. 2009; Camacho-Vera et al. 2017). The average number of cows and daily milk production per cow were 38.1 ± 4.0 cows and 17.3 ± 0.6 kg/day, respectively. The estimated culling rate and percentage of the Holstein breed in farms were 27.1% and 92.6%, respectively. Reproductive events such as calving dates, occurrence of abortion, services, calf sex, body condition score (BCS) at calving, occurrence of assisted calving, retained fetal membranes (RFM), and pregnancy diagnosis at 50 days after service were recorded for 18 months.

Performance indicators, events of interest, and potential risk factors associated with reproductive performance

The following reproductive variables were calculated: days to first estrous, days to first service, days open, first service conception rate, abortion rate, assisted calving (high and low assistance combined), RFM (animals with retained placenta > 12 h), and services per conception. When applicable, the quartile distribution of the reproductive variables was determined. In accordance with the biological and zootechnical criteria, there were excluded records that had less than 30 days to first service and over 278 days in milk (1% higher) and days open less than 30 and over 459 (1% higher). Assisted calving, RFM, days to first service over 70 days in milk (DFS > 70), days open over 110 days in milk (DO > 110), and non-pregnancy at first service (NG1S) were considered as events of interest or indicators of reproductive failure. The limit values for DFS (> 70 days) and DO (> 110 days) were established according to what has been suggested optimum values for the small-scale dairy system in Mexico (Vera et al. 2009).

Assisted parturition, RFM, first lactation or first calving, abortion, twin calving, male calf, low BCS (BCS ≤ 2.5) or high BCS at calving (BCS ≥ 3.25), and early days to first service (DFS ≤ 60d) were included as explanatory risk factors. The limits for low and high DFS and BCS were established according to the quartile distribution for the variables from the database (Bijttebier et al. 2017); first quartile limit for DFS (60 days), and first and third quartile limit for BCS (2.5 and 3.25).

Statistical analysis

All analyses were performed using SAS version 9.3 (SAS Institute Inc. Cary, NC, USA). The strategy to identify the risk factors with greater impact on reproductive variables was by identifying the degree of association between events of interest and selected factors, using multivariate logistic regression models (PROC LOGISTIC), following the methodology of Potter et al. (2010). First, univariate logistic regression models were used to identify the factors which were used to build multivariate models; only variables significant at $P \leq 0.35$ were retained for subsequent analyses. To prevent collinearity, simple correlation coefficients and χ^2 tests were obtained between pairs of retained factors (PROC FREQ/CHISQ); when the correlation coefficient's confidence interval for a pair of factors did not include 0 and the P value for χ^2 was < 0.05, that pair was not used in the same multivariate model. To meet the parsimony principle of multivariate models, a backward stepwise elimination procedure using PROC LOGISTIC of SAS for non-significant factors and their second-order interactions ($P > 0.1$) was used (Potter et al. 2010). Once the multivariate models were constructed, the odds ratios (OR), risk ratios (RR), and population attributable fraction (PAF) were calculated using the following formulas:

$\mathrm{RR} = \mathrm{OR}/((1 - \mathrm{P0}) + (\mathrm{P0} \times \mathrm{OR}))$ (Zhang and Yu 1998).

$\mathrm{PAF} = (\mathrm{RR} - 1)/(\mathrm{Pe}\ (\mathrm{RR} - 1) + 1)$ (Potter et al. 2010)

The factors with the highest PAF were considered the main risk factors affecting the reproductive variables.

Results

Performance indicators, events of interest, and potential risk factors associated with reproductive variables

Performance indicators

The average days to first observed estrous, days to first service, and days open are presented in Table 1. The first service conception rate was 48.7%, and the services per conception were 1.97. The prevalence of abortion, assisted calving, and retained fetal membranes were 8.2, 14.1, and 13.5%, respectively.

Events of interest

Assisted calving and RFM were considered as possible indicators of reproductive failure, as well as DFS > 70, DO > 110, and NP1S, whose proportions were 60.4, 45.3, and 51.3%, respectively.

Potential risk factors

In addition to assisted calving and RFM, first lactation or first calving, twin calving, male calf, low body condition at calving (BCS ≤ 2.5), and high body condition at calving (BCS ≥ 3.25) were also considered as potential risk factors whose prevalence were 25.6, 1.2, 50.7, 33.0, and 31.1%, respectively.

Factors associated with low reproductive performance

Table 2 shows the significance level and odds ratios from the univariate analysis. Based on these results and collinearity analyses, multivariate models were designed for each event of interest (Table 3). The significant factors ($P < 0.10$) and corresponding estimations for OR, RR, and PAF for each model of each reproductive variable are shown in Table 4. For assisted calving, the factors that significantly affected ($P < 0.10$) this trait were male calves, first calving, and the interaction between first calving and BCS ≥ 3.25 (Fig. 1a). The significant factors ($P < 0.10$) for RFM were assisted calving, first calving, the occurrence of abortion, BCS ≥ 3.25, BCS ≤ 2.5, twin calving, and male calf. The significant factors ($P < 0.10$) for DFS > 70 were assisted calving, BCS ≤ 2.5, first calving, and BCS ≥ 3.25. For DO > 110, the significant factors ($P < 0.10$) were assisted calving, BCS ≥ 3.25, first calving, retained fetal membranes, and BCS ≤ 2.5. For NP1S, the significant factors ($P < 0.10$) were male calf, retained fetal membranes, first calving, BCS ≤ 2.5, the interaction between male calf and RFM present in model 1 (Fig. 1b), and the interaction between RFM and BCS ≤ 2.5 present in model 3 (Fig. 1c).

Discussion

To our knowledge, this is the first study that determines the risk factors for reproductive variables that is carried out in the small-scale dairy system in tropical and subtropical zones of Mexico, with a wide and diverse sample in terms of geographical location. Recent studies have reported a low reproductive performance of cows exploited in these systems (Ojeda Carrasco et al. 2012; Vázquez-Selem et al. 2016; Silva Salas et al. 2017). However, our results indicate that days to first estrous are prolonged, but days to first service, days open, and first service conception rate were slightly beyond the optimal range suggested for this type of dairy production system in Mexico (Vera et al. 2009). Furthermore, the rates of assisted calving,

Table 1 Days to first observed estrous, days to first service, and days open in the small-scale dairy farms in tropical and subtropical zones of Mexico ($n = 1263$ lactations)

	Mean ± SE	Minimum	Quartile 1	Median	Quartile 3	Maximum
DFE	79.9 ± 1.2	16	50	69	99	278
DFS	88.6 ± 1.2	30	59	78	108	278
DO	117.7 ± 1.8	30	70	101	150	350

DFE days to first observed estrous, *DFS* days to first service, *DO* days open, *SE* standard error

RFM, and occurrence of abortions are moderately high compared with the optimum values proposed for this system (Vera et al. 2009). Our results show that the reproductive performance of cows kept in this system is slightly suboptimum. Nevertheless, culled cows were not included in the present study; it is important to mention that culled cows might decrease the reproductive performance, and frequently, their contribution is not considered for some indicators (for instance calving interval variable, unless it is estimated from days open), possibly being the case for the present study. Also, it is noteworthy to mention that the size of the farms included in our study would partially explain the differences found in the reproductive performance compared with other reports. Farms included in this study do not include "traspatio" production (herds with < 10 cows) which is a small population of farms that belong to the small-scale dairy system in Mexico (SAGARPA 2004; Abrego Castillo 2011).

The factors associated with assisted calving were male calves, first calving, and the interaction between parity and high BCS at calving. The small-scale dairy system in Mexico is characterized for using mainly Holstein cows (Núñez et al. 2009). Holstein male calves are heavier and taller at birth than female calves which increases the probability of calving difficulty (Kertz et al. 1997; Johanson and Berger 2003). In addition, the importance of male calf as a risk factor for dystocic parturitions is supported by its high prevalence (50%). In fact, our results indicate that 31.5% of assisted calving can be attributed to the delivery of male calves. On the other hand, it has been reported that primiparous cows have higher risk for assisted calving than multiparous cows (Steinbock et al. 2003; Berry et al. 2007) and that there is no association between BCS at calving and assisted calving (Gearhart et al. 1990; Berry et al. 2007). Nevertheless, the abovementioned studies did not evaluate if an interaction between these factors existed. Our results indicate that the interaction between first calving and high BCS at calving (≥ 3.25) is important (Fig. 1a). In this regard, it was only observed that the differences in assisted calving between primiparous and multiparous cows when BCS at calving was < 3.25. A possible explanation is that primiparous cows with a high BCS (≥ 3.25) could have a higher weight and size which would reduce the risk for assisted calving (Thompson et al. 1983; Erb et al. 1985).

In previous reports, several risk factors have been associated with RFM (Markusfeld et al. 1997; Hossein-Zadeh and Ardalan 2011). The main risk factors associated with RFM in the present study were assisted calving, abortion, male calf, low BCS at calving, and twin calving. Although twin calving was significantly associated with retained fetal membranes (OR = 2.6), its low prevalence (1.2%) makes this risk factor less relevant (PAF = 0.017). Low BCS at calving has also been identified as a risk factor for RFM (Markusfeld et al. 1997). Even though low BCS at calving (≤ 2.5) was a risk factor with a high prevalence in the present study (33%), we found a low level of association with retained fetal membranes (OR = 1.3),

Table 2 *P* values and odds ratios (OR) for potential risk factors considering different reproductive variables of interest; univariate analysis

Potential risk factors	Assisted calving (P; OR)	RFM (P; OR)	DFS > 70 (P; OR)	DO > 110 (P; OR)	NP1S (P; OR)
Assisted calving	–	< 0.001; 4.50	0.033; 1.54	0.114; 1.35	0.428; NC
RFM	–	–	0.987; NC	0.001; 2.09	0.004; 1.69
First calving	0.044; 1.52	0.143; 0.77	0.021; 1.43	0.040; 1.36	0.094; 0.81
Abortion	0.537; NC	< 0.001; 8.04	0.603; NC	0.307; 2.43	0.293; 1.91
Twin calving	0.218; 2.32	0.022; 2.46	0.626; NC	0.535; NC	0.693; NC
Male calf	0.001; 1.92	0.035; 1.56	0.439; NC	0.472; NC	0.105; 0.84
BCS ≥ 3.25	0.171; 1.32	< 0.001; 1.88	< 0.001; 0.48	< 0.001; 0.42	0.527; NC
BCS ≤ 2.5	0.101; 0.72	< 0.001; 0.57	< 0.001; 2.09	< 0.001; 1.73	0.070; 0.81
DFS ≤ 60 d	–	–	–	–	0.194; 1.17

RFM retained fetal membranes, *DFS > 70* days to first service over 70 days in milk, *DO > 110* days open over 110 days in milk, *NP1S* non-pregnant at first service, *BCS ≥ 3.25* high body condition at calving, *BCS ≤ 2.5* low body condition at calving, *DFS ≤ 60d* early days to first service, *NC* indicates no OR calculated for not being significant

Table 3 Non-collinear potential risk factors for events of interest included in multivariate models

Events of interest	Model	Potential risk factors
Assisted calving	1	Male calf + first calving + BCS ≥ 3.25
	2	Male calf + first calving + BCS ≤ 2.5
	3	Male calf + twin calving
RFM	1	Assisted calving
	2	Abortion + first calving + BCS ≥ 3.25
	3	Abortion + BCS ≤ 2.5
	4	Male calf + twin calving + BCS ≥ 3.25
DFS > 70 days	1	Assisted calving + BCS ≤ 2.5
	2	First calving + BCS ≥ 3.25
DO > 110	1	Assisted calving + BCS ≥ 3.25
	2	Male calf + first calving + RFM
	3	Male calf + BCS ≤ 2.5
NP1S	1	Male calf + RFM + DFS ≤ 60d
	2	Male calf + first calving + abortion
	3	Male calf + RFM + BCS ≤ 2.5

RFM retained fetal membranes, *DFS > 70* days to first service over 70 days in milk, *DO > 110* days open over 110 days in milk, *NP1S* non-pregnant at first service, *BCS ≥ 3.25* high body condition at calving, *BCS ≤ 2.5* low body condition at calving, *DFS ≤ 60d* early days to first service

making this factor less important compared with others. According to PAF values, the main risk factors associated with RFM were assisted calving and abortion which also had a relatively high prevalence (16.6 and 5.9%, respectively). On the other hand, first calving and high BCS at calving ≥ 3.25 had negative PAF values. A negative PAF value could indicate that there is a "protective effect" against the occurrence of RFM. Our results agree with the previous studies that show that primiparous cows have less risk of RFM and that a high BCS at calving reduces the prevalence of this condition (Markusfeld et al. 1997; Rajala and Gröhn 1998; Hossein-Zadeh and Ardalan 2011).

Days to first service when estrous is not synchronized are an indicator of reproductive performance that allows indirect monitoring of the postpartum anestrous interval and the efficiency of estrous detection. Additionally, days open are a global indicator that also allows for monitoring fertility. Our results show that the main risk factor for DFS > 70 and DO > 110 was low BCS at calving (≤ 2.5). Around 30 and 20% of DPS > 70 and DAB > 110, respectively, are attributable to low BCS at calving. Post-calving negative energy balance (NEB) plays a significant role in the postpartum anestrous interval, thereby playing a role in days to first service and days open (Butler and Smith 1989; Bishop and Pfeiffer 2008). This phenomenon has been widely studied in high-yielding cows in which the increased energy expenditure associated to high milk production cannot be compensated with increased feed intake and requires the mobilization of body energy reserves (Butler and Smith 1989; Chalmeh et al. 2015). In cows with low BCS at calving, the NEB is greater which lead to a delayed onset of postpartum ovarian cyclicity (Villa-Godoy et al. 1988; Markusfeld et al. 1997). It seems that the NEB in cows in the small-scale dairy system is low due to the low-intermediate production levels of milk; nevertheless, the nutrient supplies in these systems are limited (Val-Arreola et al. 2004; García-Muñiz et al. 2007). Therefore, cows with low BCS at calving and low energy intake, even if they produce moderate levels of milk, could have a delay in their postpartum ovarian cyclicity increasing the days to first service and days open (Villa-Godoy et al. 1988). In this regard, it was observed that high BCS at calving had a "protective effect" on DFS > 70 and DO > 110 (negative PAF). Together, these results suggest that BCS at calving plays a significant role in the reproductive performance of cows even when milk production levels are low to moderate as in the small-scale dairy system (Val-Arreola et al. 2004; Kawonga et al. 2012).

The effect that low BCS at calving had on DFS > 70 and DO > 110 contrasts with what we observed for NP1S. According to our results, low BCS at calving would have a protective effect against not to be pregnant at first service (PAF = − 0.085). In other words, cows with low body energy reserves at calving have a higher probability to get pregnant at first service; however, the interaction between this factor and RFM was significant for the first service conception rate. Our results indicate that, in the absence of RFM, there is no difference in first service conception rate between cows with different BCS at calving. However, in cows with RFM, the proportion of cows with low BCS that did not get pregnant at first service decreased. A possible explanation is that cows with low body energy reserves at calving and RFM present estrous later. Because these cows receive the first postpartum service later in lactation, could be that these cows present an increment in their BCS, which increases the probability of becoming pregnant. Nevertheless, we consider that more studies are needed regarding the association between BCS at calving and BCS at first service and fertility, to better understand this phenomenon.

On the other hand, our results show that first calving improves first service conception rate (PAF = − 0.056). Primiparous cows are known to have a lower risk of having RFM (Rajala and Gröhn 1998; Hossein-Zadeh and Ardalan 2011). Also, RFM is one of the main risk factors affecting the first service conception rate. We hypothesize that first calving improves the first service conception rate by the lower risk of cows having RFM. This result is consistent with other studies, but the reasons why primiparous cows are less prone to RFM are not well known. It has been suggested that the administration of antioxidants before calving reduces the prevalence of RFM (Bourne et al. 2007). Furthermore, antioxidant endogenous mechanisms are known to be altered when RFM occur (Kankofer 2001; Endler et al. 2016). In addition, it has been

Table 4 Results of multivariate logistic regression models for events of interest that indicate reproductive failure

Events of interest	Model	Risk factors	Comparison (risk factor vs reference)	*P* value	OR	95% CI (OR)	RR	95% CI (RR)	Pe	PAF
Assisted calving	1	Calf sex	Male vs female	0.006	1.74	1.17–2.57	1.38	1.10–1.65	0.507	0.315
		Parity	1 vs ≥ 2	0.043	1.52	1.01–2.28	1.14	1.01–1.24	0.274	0.131
RFM	1	Assisted calving	Yes vs no	< 0.001	4.50	3.33–6.08	1.47	1.41–1.53	0.166	0.440
	2	Parity	1 vs ≥ 2	0.038	0.70	0.50–0.98	0.92	0.84–1.00	0.256	− 0.079
		Abortion	Abortion vs calving	< 0.001	8.06	5.49–11.82	1.24	1.22–1.26	0.059	0.239
		BCS ≥ 3.25	High vs remaining	0.001	0.56	0.40–0.78	0.84	0.74–0.94	0.311	− 0.164
	3	Abortion	Abortion vs calving	< 0.001	8.36	5.71–12.25	1.24	1.23–1.26	0.059	0.240
		BCS ≤ 2.5	Low vs remaining	0.058	1.31	0.99–1.72	1.09	1.00–1.18	0.330	0.089
	4	Twin calving	Twin vs simple	0.044	2.62	1.03–6.66	1.02	1.00–1.02	0.012	0.017
		Calf sex	Male vs female	0.034	1.36	1.02–1.81	1.19	1.01–1.36	0.528	0.170
		BCS ≥ 3.25	High vs remaining	0.005	0.62	0.45–0.86	0.77	0.78–0.97	0.314	− 0.127
DFS > 70	1	Assisted calving	Yes vs no	0.015	1.65	1.10–2.46	1.07	1.02–1.11	0.141	0.067
		BCS ≤ 2.5	Low vs remaining	< 0.001	2.21	1.66–2.94	1.32	1.21–1.41	0.374	0.285
	2	Parity	1 vs ≥ 2	0.025	1.43	1.05–1.94	1.10	1.01–1.17	0.274	0.096
		BCS ≥ 3.25	High vs remaining	< 0.001	0.45	0.33–0.61	0.80	0.71–0.89	0.260	− 0.211
DO > 110	1	Assisted calving	Yes vs no	0.062	1.43	0.98–2.09	1.05	1.00–1.09	0.141	0.050
		BCS ≥ 3.25	High vs remaining	< 0.001	0.42	0.30–0.57	0.38	0.41–0.68	0.260	− 0.534
	2	Parity	1 vs ≥ 2	0.022	1.42	1.05–1.90	1.10	1.02–1.17	0.274	0.096
		RFM	Yes vs no	< 0.001	2.41	1.55–3.72	1.10	1.06–1.13	0.113	0.097
	3	BCS ≤ 2.5	Low vs remaining	< 0.001	1.73	1.33–2.26	1.23	1.12–1.33	0.374	0.213
NP1S	1	Calf sex	Male vs female	0.080	0.82	0.66–1.02	0.91	0.80–1.01	0.505	− 0.100
		RFM	Yes vs no	0.004	1.71	1.19–2.45	1.06	1.02–1.09	0.109	0.058
	2	Parity	1 vs ≥ 2	0.094	0.81	0.63–1.04	0.76	0.87–1.01	0.260	− 0.056
	3	Calf sex	Male vs female	0.095	0.83	0.67–1.03	0.91	0.80–1.02	0.505	− 0.095
		RFM	Yes vs no	0.003	1.73	1.20–2.48	1.06	1.02–1.09	0.109	0.059
		BCS ≤ 2.5	Low vs remaining	0.045	0.79	0.63–0.99	0.92	0.83–1.00	0.362	− 0.085

RFM retained fetal membranes, *DFS > 70* days to first service over 70 days in milk, *DO > 110* days open over 110 days in milk, *NP1S* non-pregnant cows at first service, *BCS ≥ 3.25* high body condition at calving, *BCS ≤ 2.5* low body condition at calving, *PAF* population attributable fraction, *OR* odd ratios, *RR* risk ratios, *Pe* proportion of cows exposed to risk factor

observed that younger animals have a better response to oxidative stress (Dai et al. 2014), and this could account for the lower prevalence of RFM in primiparous cows.

According to our results, male calf possesses a protective effect against NP1S. This finding seems contradictory; however, there was a significant interaction between male calf and RFM. The negative effect that male calf has over NP1S is only observed in the presence of RFM. The number of non-pregnant cows with RFM and male calf are much higher than those having female calves (18% difference). This result suggests that there is a synergistic effect of these two factors on NP1S, highlighting the relevance of both risk factors.

In the present study, common risk factors affecting the reproductive performance were detected (male calf, BCS ≤ 2.5, RFM, and assisted calving). Despite the detection of these risk factors on reproductive variables, it remains to be seen their impact on profitability. In the small-scale dairy system, production levels, lactation curves, and operation costs differ from the ones present in the intensive production systems (Val-Arreola et al. 2004; Jiménez Jiménez et al. 2014). Hence, a study estimating the impact of these risk factors on profitability in this system could generate additional information to optimize decisions related to dairy cow reproductive management. Moreover, there are several management strategies that could be implemented to reduce the prevalence of some of the detected risk factors. For example, the use of sexed semen has been suggested to reduce the prevalence of the male calf (Potter et al. 2010). Additionally, improving nutritional management or designing of strategic energy supplementation during postpartum could counteract the negative effects of BCS ≤ 2.5 on reproductive performance (Roche 2006).

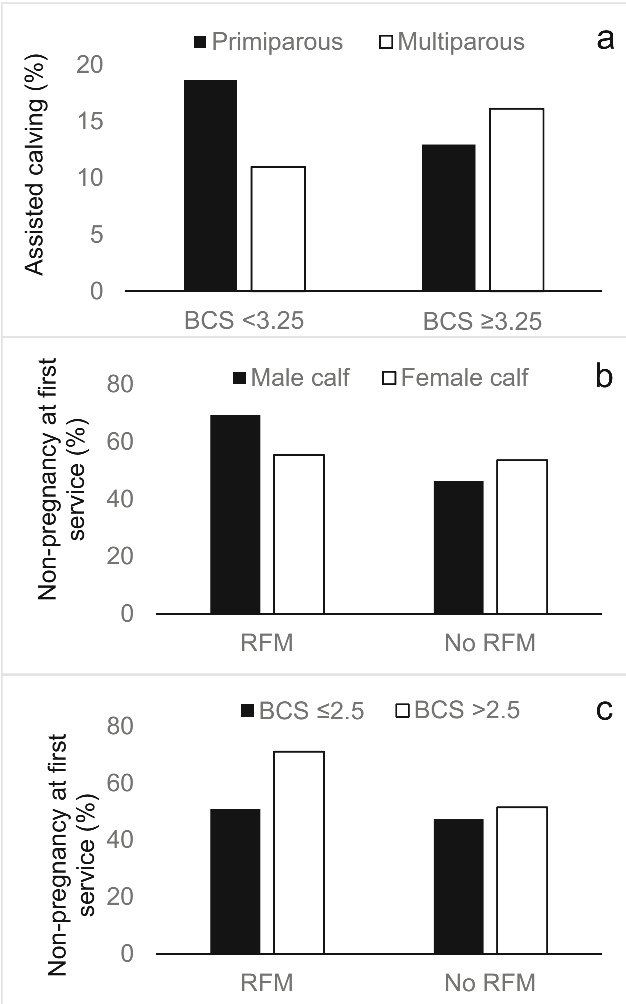

Fig. 1 Significant interactions in multivariate models. **a** Assisted calving; model 1, parity X BCS ≥ 3.25 ($P = 0.094$). **b** Non-pregnancy at first service; model 1, calf sex X retained fetal membranes ($P = 0.017$). **c** Non-pregnancy at first service; model 3, BCS ≤ 2.5 X retained fetal membranes ($P = 0.027$)

In conclusion, the reproductive performance of small-scale dairy herds in tropical and subtropical zones of Mexico is moderately suboptimum. The main risk factors associated with low reproductive performance were assisted calving, male calves, low BCS at calving (≤ 2.5), and RFM. It is necessary for further studies to determine the impact on these factors on milk yield and profitability of the farms. Furthermore, in the present study, risk factors at the individual level were determined; therefore, risk factors at the herd level (artificial insemination vs natural breeding, grazing vs total confinement, herd size, and prevalence of infectious reproductive disease) remain to be tested. Together, this information would allow designing integral strategies to improve the profitability of small-scale dairy system in tropical and subtropical zones of Mexico.

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Compliance with ethical standards

Statement of animal rights Managements applied to animals throughout the study were according to the protocols indicated in the Mexican Official Norm NOM-051-ZOO-1995 and Mexican Federal Law of Animal Health (DOF 25-07-2007).

Conflict of interest The authors declare that they have no conflict of interest.

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