Factors influencing dairy calf and replacement heifer mortality in France

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ABSTRACT

Herd-level risk factors for dairy calf and heifer mortality in France were identified by calculating herd-level variables (including mortality risk or rate) using the National Bovine Identification Database (2005 and 2006). Eleven dairy production areas representing different livestock systems were also included. Statistical analyses were based on a probit model (mortality risk or rate = 0 or >0) and a linear model (mortality risk or rate >0) corrected by the sample bias Heckman method. The same associations were reported for 2005 and 2006. The mortality risks or rates for calves and heifers were positively associated with the proportion of purchased cows or being a Milk Control Program member and negatively associated with adhering to the Good Breeding Practices charter and having an autumn calving peak. The associations between mortality and the breeds or the production areas were positive or negative, depending on the classes of animal. Mortality and having a beef herd in addition to the dairy herd were negatively associated for noncrossed birth to 2-d-old calves, noncrossed 3-d- to 1-mo-old calves, and 3-d- to 1-mo-old heifers. Having a beef herd probably provides specific know-how related to newborn and young calf management that makes it easier to attain low mortality in pure-breed dairy calves. The proportion of males born was positively associated with mortality for the birth to 2-d-old calves (all classes) and for the 3-d- to 1-mo-old beef-crossed calves, but negatively for all classes of heifers. This indicates that heifer management was improved when the availability of newborn heifers decreased, resulting in low mortality. This lower mortality is apparent for all classes of heifers present on the farm during the year when the proportion of males was low, and demonstrates an anticipatory effect. In conclusion, this study shows that the presence of a beef herd in addition to the dairy herd within a farm is

associated with decreased dairy calf mortality. It also shows that heifer mortality decreases when the proportion of heifers born decreased. These determinants of dairy calf and heifer mortality are of great importance for farmer advisors, the dairy industry, and the political decision makers.

Key words: dairy calf mortality, France, herd-level factor, farm environment

INTRODUCTION

Calf and heifer mortality represents economic losses to the dairy industry as well as being a welfare issue (Meyer et al., 2001; Ortiz-Pelaez et al., 2008). This is all the more important in that a continuous increase in the frequency of stillbirths has been reported in many countries over the last decade (Meyer et al., 2001; Berglund et al., 2003; Steinbock et al., 2003). The mortality rates in French dairy calves and heifers, reported in a companion paper, were low to moderate, compared with other international results (Raboisson et al., 2013). In 2005 to 2006, the overall French 0- to 2-d-old and 3-d- to 1-mo-old calf mortality rates were around 6.7 and 5.7%, respectively. The heifer 3-d- to 1-mo-old, 1- to 6-mo-old, and 6-mo-old to first calving mortality rates were 4.5, 3.1, and 4.1%, respectively (Raboisson et al., 2013). The variations between mortality rates are, however, large.

Many studies have identified animal- or herd-level risk factors of dairy calf and heifer mortality, such as dystocia, sex, twin, parity of the dam, herd size, and season (Wells et al., 1996, 1997; Meyer et al., 2000; Lombard et al., 2007; Stull et al., 2008). Calf management procedures have also been associated with the risk of mortality. Among them, one of the most important risk factors of mortality (and morbidity) is failure of passive transfer of antibodies via the colostrum (Rea et al., 1996; Donovan et al., 1998; Beam et al., 2009), with effects on heifer mortality up to 8 to 10 wk of age (Tyler et al., 1998) or longer (Donovan et al., 1998). In one study in which 8.2% of the heifers died before

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16 wk of age, the baseline mortality rate was 5.0% and the mortality rate due to inadequate passive transfer was 3.2% (Tyler et al., 1999). Recent investigations have revealed associations between factors related to the farmer's behavior or working context and calf mortality. For instance, having "flexible time" appeared crucial for the management of crises and was associated with reduced calf morbidity and mortality (Vaarst and Sorensen, 2009).

Many dairy farms throughout the world have less than or around 100 cows and the farmers have to manage a wide range of tasks within the farm. Few studies dealing with the risk factors of cattle mortality have taken such constraints into account and many only focus on 1 class of animal (for instance, perinatal calf mortality; Meyer et al., 2001; Silva del Río et al., 2007; Gundelach et al., 2009; Johanson et al., 2011). However, the effects of management practices and farmer behavior can be better understood by focusing on mortality risk factors in several classes of animal simultaneously. France constitutes a good example for such studies, thanks to its broad diversity of livestock production (i.e., dairy, beef or fattening, mountains or plains, generic or specific-quality production; Rouquette and Pflimlin, 1995; Sarzeaud et al., 2008). This country offers the possibility of identifying the combinations of factors, including the farmer's know-how associated with low mortality. The first aim of the present study was to identify new herd-level factors influencing dairy calf and heifer mortality and the second aim was to determine whether some risk factors could have opposing effects on mortality, depending on the class of animal studied.

MATERIALS AND METHODS

Data Sets

The characteristics of the National Bovine Identification Database have already been described in detail (Raboisson et al., 2011). Briefly, this database contains routine records for individual farms and animals. All births, deaths, purchases, and sales, as well as the date of the event, are recorded by farmers in the National Bovine Identification Database. This is mandatory and official controls are frequently carried out with potential high penalties. For this study, the animals within each farm were sorted and associated with a dairy, beef (suckler cows), or fattening (bulls, steers, or veal calves) herd. Herds with less than 6 cows per year were excluded. All data were geolocated at the municipal level. There are 3,600 municipalities in France, with a mean area of 15 km². Other data sets used were the farms registered as adhering to the Good Breeding Practices charter (a voluntary program that includes constraints

on management, feeding, breeding, and welfare), herds in the Milk Control Program (registration of milk production and milk composition plus herd management recommendations), and herds in dairy production areas, as previously described (Raboisson et al., 2011).

Variables

Mortality Risk and Rate. The mortality risks and rates were calculated annually (2005 and 2006), for each group of animals within each herd. The 0- to 2-d mortality risk was the number of deaths occurring between birth and 2 d of age divided by the number of calves born (males and females). This value was calculated for the pure dairy breed (noncrossed) and the beef-crossed dairy calves. The numerators for the male and female 3-d- to 1-mo-old calf, the 3-d- to 1-mo-old heifer, the 1- to 6-mo-old heifer, and the 6-mo-old to first-calving heifer mortality rates were the number of deaths occurring during the period. The denominators were the number of male and female calf-months, heifer-months, heifer-5 mo, and heifer-years, respectively. Heifer-5 mo equaled 1 if the heifer stayed for 5 mo and 0.5 if it stayed for 2.5 mo. For the 3-d- to 1-mo-old calf mortality, distinctions were also made between pure breed and beef-crossed dairy calves.

Herd-Level and Contextual Factors. Most of the herd-level factors used in the present study have already been described in detail (Raboisson et al., 2011). Variables included the annual number of cow-years, the predominant breed of the herd (>75% of the dairy cows in the herd), the average calving interval and the farm type (specialized in dairy production, dairy and beef production, or dairy and fattening production on the same farm). The variable "purchase of cows from other farms" was defined as the number of purchased cows divided by the number of cow-years, transformed into a categorical factor (no purchase, low purchase, or high purchase), low and high purchase being defined as the 75% quartile of the purchase percentage (i.e., 27 and 19% for 2005 and 2006, respectively). The annual proportion of primiparous cows was the number of first-calving cows divided by the overall number of calvings in the year. The culling rate was the number of dairy cows sold, death excluded, divided by the number of cow-years, irrespective of the in-milk or dry status, or of the reasons for removal. The variable "autumn calving peak" was defined as the calving peak (>35% of the annual calvings occurred during 3 mo) between July and November. It was designed to make use of the inclination of farmers to produce milk during the best-paid period of the year. Being a Milk Control Program member or adhering to the Good Breeding Practices charter was defined once for the 2-yr period.

Table 1. Descriptive statistics for continuous variables in 2005 and 2006

Variable	Year	Minimum	Maximum	Mean	SD	Median
Number of cow-years ¹	2005	5.1	404.2	37.7	20.3	34.4
	2006	5.1	421.1	38.7	20.7	35.2
First-calving cow proportion, %	2005	0.0	100	28.6	12.7	30.0
	2006	0.0	100	28.0	12.9	29.4
Percentage of beef-crossed calves, %	2005	0.0	100	23.4	30.6	8.8
	2006	0.0	100	22.8	30.1	7.8
Percentage of males born, %	2005	5.6	94.7	50.9	10.6	50.9
	2006	5.3	95.8	51.0	10.5	51.1

¹The number of cow-years equaled the sum of all the days and all the cows divided by 365.

Two other herd-level variables were included in the present study. The percentage of beef-crossed calves was defined as the number of beef-crossed calves born from dairy cows divided by the overall number of calves born from dairy cows. The percentages of males in relation to all calves born from dairy cows were calculated annually.

The 2 contextual factors, notably the cattle density (in livestock unit/km²) and the inhabitant density (no./km²), have been described previously (Raboisson et al., 2011). The 11 dairy production areas of France (Raboisson et al., 2011) approximately overlap the French livestock systems (Rouquette and Pflimlin, 1995; Sarzeaud et al., 2008).

Statistical Analysis

Data were analyzed using R (version 2.10.1; R Foundation for Statistical Computing, Vienna, Austria). The models used have been described in detail elsewhere (Raboisson et al., 2011). First, the probability of having at least 1 death was analyzed by probit regression. Second, the mortality risk or rate was subjected to a linear regression using the Heckman correction and the results of the previous probit regression. The models were applied to the different classes of animal separately for 2005 and 2006. For each model, those variables which were not significant were removed and the results from the final multifactorial models are reported.

The results of the probit regression were expressed as odds ratios. For linear regression modeling, they were expressed as the percentages change when the quantitative variables were changed by 1 unit or compared with a reference class for the categorical variables (UCLA, 2012).

All possible 2-factor interactions with all the main effects were included (one by one) in the model. Depending on the coefficient of the interaction and on the Akaike information criterion of the model, the interaction, even if significant, could be removed from the model and interpreted as a significant interaction without any biological importance.

RESULTS

The descriptive statistics for the mortality risks or rates per class of animal and the odds ratios of mortality per breed, sex, and dairy production areas have been described in a companion paper (Raboisson et al., 2013). The descriptive statistics for the variables used in the models are reported in Tables 1 and 2.

The same associations ($P < 0.01$) and very similar coefficients were obtained for 2005 and 2006 and only the final multifactorial models for 2005 are reported (Tables 3 to 6). The culling rate, the average calving interval, and the 2 contextual variables (municipal cattle and inhabitant densities) were not significantly associated with the mortality risk or rate in any of the models. These variables were, therefore, removed from the models. Most of the significant interactions were considered as non-biologically relevant. Their associations with mortality were very weak.

For the great majority of variables and for all models, the same associations between the variables and mortality (whether positive or negative) were reported for the probit (having at least 1 death) and linear models (mortality risk or rate, if >0). Some variables were deleted from the probit or linear models, when nonsignificant.

Whatever the class of animal considered, the models showed the same associations between mortality and the herd size (positive), purchasing dairy cows (positive), having a calving peak in autumn (negative), being a Milk Control Program member (positive), and adhering to the Good Breeding Practices charter (negative; Tables 3 to 6). Nevertheless, there were 2 exceptions. One was the negative association between being a Milk Control Program member and heifer mortality between 6 mo of age and the first calving. The second was the negative association between adhering to the Good Breeding Practices charter and the 0-d- to 2-d-old calf mortality.

Having a beef or fattening herd in addition to the dairy herd was associated with decreased mortality for the noncrossed 0- to 2-d-old and the noncrossed 2-d- to

Table 2. Descriptive statistics for categorical variables in 2005 and 2006

Variable	Number of farms	
	2005	2006
Predominant breed		
Holstein	57,496	55,041
Montbéliarde	16,034	15,408
Normande	9,024	8,470
No predominant	16,170	15,402
Other breeds	2,721	2,633
Farm type		
Dairy	48,220	45,507
Dairy and beef	17,625	17,313
Dairy and fattening	35,624	34,144
Purchased cow proportion		
No purchase	75,585	71,571
Low purchase	23,386	21,157
High purchase	2,474	4,226
Milk Control Program member		
No	38,941	36,196
Yes	62,504	60,758
Good Breeding Practices member		
No	39,090	35,353
Yes	62,355	61,601
Autumn calving peak		
No	79,116	76,090
Yes	22,329	20,864
Dairy production area		
1 (Grand-Ouest)	31,662	30,263
2 (Normandie)	14,400	13,701
3 (Nord)	9,348	8,899
4 (Est)	8,130	7,828
5 (Centre)	1,697	1,597
6 (Poitou)	2,905	2,755
7 (Massif Central)	8,628	8,320
8 (Rhône-Alpes)	7,617	7,204
9 (Sud-Ouest)	9,442	9,010
10 (Franche-Comté)	5,226	5,077
11 (Savoie)	2,390	2,316

1-mo-old calves (Tables 3 and 4), as well as for the 2-d- to 1-mo-old heifers (except for fattening; Table 5). The association was yet positive for the beef-crossed 0- to 2-d-old and the beef-crossed 2-d- to 1-mo-old calves (Tables 3 and 5) and for heifers >1 mo of age (Table 6). The proportion of primiparous cows was positively associated with the mortalities of 0- to 2-d-old (Table 3) and beef-crossed 3-d- to 1-mo-old calves (Table 4), whereas a negative association was reported for non-crossed 3-d- to 1-mo-old calves (Table 4) and heifers (Tables 5 and 6). When significant, the percentage of beef-crossed calves was negatively associated with mortality risk or rate for all classes of animal, except for beef-crossed calves (Tables 3 to 6). The percentage of males born was positively associated with the mortality of 0- to 2-d-old calves (all classes) and noncrossed 3-d- to 1-mo-old calves, whereas no association was found for beef-crossed 3-d- to 1-mo-old calves (Tables 3 and 4). A negative association with mortality was reported for all classes of heifers (Tables 5 and 6). The associations between the dairy production areas or breeds and

the mortality per class of animal are described in detail in Tables 3 to 6 and summarized in Table 7.

DISCUSSION

Database, Statistical Methods, and Previously Reported Associations

The data in the National Bovine Identification Database are very accurate (Raboisson et al., 2011, 2013). The age classes used in the present study are in accordance with previous studies (Donovan et al., 1998; Meyer et al., 2001; Gulliksen et al., 2009; Johanson et al., 2011), even though the classes were often broader in the other studies.

The observed positive association between the proportion of primiparous cows and mortality in 0- to 2-d-old calves or in 3-d- to 1-mo-old beef-crossed calves is in accordance with previous results (Meyer et al., 2001). This might be due to the higher probability of dystocia for primiparous cows (Meyer et al., 2000; Bicalho et

Table 3. Mortality of noncrossed and beef-crossed 0- to 2-d-old dairy calves¹

Item	Noncrossed 0- to 2-d-old dairy calves		Beef-crossed 0- to 2-d-old dairy calves	
	Odds ratio of having ≥ 1 death ²	Mortality risk (mortality change ³), %	Odds ratio of having ≥ 1 death ²	Mortality risk (mortality change ³), %
Number of cow-years ⁴	1.20 (1.20–1.21)	1.0***	1.14 (1.06–1.22)	1.5***
Predominant breed				
Holstein	Reference	Reference	Reference	Reference
Montbéliarde	0.91 (0.88–0.95)	–6.2***	0.91 (0.87–0.95)	–4.8***
Normande	0.85 (0.82–0.89)	–4.5***	0.94 (0.86–1.01)	–1.7*
No predominant	0.86 (0.84–0.89)	–4.1***	0.95 (0.89–1.01)	–2.1***
Other breeds	0.78 (0.73–0.83)	–7.6***	0.85 (0.77–0.93)	–7.1***
Farm type				
Dairy	Reference	Reference	Removed	Reference
Dairy and beef	0.84 (0.82–0.86)	–3.1***		3.7***
Dairy and fattening	0.95 (0.93–0.97)	–0.3		3.8***
Purchased cow proportion				
No purchase	Removed	Reference	Removed	Reference
Low purchase		1.6***		1.3***
High purchase		2.1***		2.6**
First-calving cow proportion, ⁵ %	1.07 (1.06–1.07)	1.5***	1.09 (1.07–1.10)	2.2***
Percentage of beef-crossed calves, ⁵ %	0.89 (0.88–0.90)	Removed	1.10 (1.09–1.11)	Removed
Percentage of males born, ⁵ %	1.04 (1.03–1.04)	1.0***	1.10 (1.09–1.11)	1.3**
Autumn calving peak				
No	Removed	Reference	Removed	Removed
Yes		–0.6***		
Milk Control Program member				
No	Reference	Reference	Reference	Reference
Yes	1.80 (1.76–1.84)	9.7***	1.49 (1.44–1.53)	12.2***
Good Breeding Practices member				
No	Reference	Reference	Reference	Reference
Yes	1.17 (1.14–1.19)	1.1***	1.16 (1.12–1.20)	3.3***
Dairy production area				
1 (Grand-Ouest)	Reference	Reference	Reference	Reference
2 (Normandie)	1.15 (1.10–1.18)	4.2***	1.26 (1.19–1.32)	11.6***
3 (Nord)	0.65 (0.62–0.67)	–3.6***	0.85 (0.79–0.92)	1.5*
4 (Est)	0.86 (0.82–0.89)	0.2	1.03 (0.95–1.12)	7.3***
5 (Centre)	0.87 (0.79–0.93)	–2.2***	0.89 (0.80–0.99)	–3.7**
6 (Poitou)	0.65 (0.62–0.69)	–3.7***	0.72 (0.67–0.77)	–10.2
7 (Massif Central)	0.74 (0.71–0.77)	–4.4*	0.87 (0.83–0.91)	–7.3***
8 (Rhône-Alpes)	0.71 (0.68–0.74)	–3.4*	0.83 (0.78–0.87)	–6.5***
9 (Sud-Ouest)	0.66 (0.64–0.69)	–6.1*	0.72 (0.69–0.75)	–12.1***
10 (Franche-Comté)	0.95 (0.89–1.01)	0.7	0.99 (0.89–1.10)	4.3***
11 (Savoie)	0.62 (0.57–0.66)	–12.1***	0.70 (0.63–0.77)	–16.7***
Adjusted R ²		0.27		0.23

¹Reference = for the considered variable, class used as reference; removed = the variable was removed from the model because it was not significant.

²The 95% CI is given in parentheses.

³The results were expressed in mortality change (%). For instance, having a beef herd in addition to a dairy herd (farm type = dairy and beef) was associated with a mortality risk change of –3.1% for the noncrossed 0- to 2-d-old dairy calves, and with a mortality risk change of +3.7% for the beef-crossed 0- to 2-d-old dairy calves, compared with not having a beef herd in addition to a dairy herd (farm type = dairy; reference class).

⁴For an increase in herd size of 10 cow-years; the number of cow-years equaled the sum of all the days and all the cows divided by 365.

⁵For an increase of 10%.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

al., 2007; Lombard et al., 2007; Linden et al., 2009). In contrast, the negative association between heifer mortality and the proportion of primiparous cows could be related to differences in the replacement policy between herds. Herds with low heifer mortality were more likely to have a high proportion of primiparous cows.

Herd size and the purchasing of dairy cows were positively associated with calf and heifer mortality for all classes of animal, in accordance with previous results

(Wells et al., 1997; Gulliksen et al., 2009). The observed associations between mortality and being a member of the Milk Control Program (positive), adhering to the Good Breeding Practices charter (negative), and having a calving peak in autumn (negative) have already been reported for dairy cows in France (Raboisson et al., 2011). The positive association between adherence to the Good Breeding Practices charter and the 0- to 2-d-old calf mortality remains unexplained.

Table 4. Mortality of noncrossed and beef-crossed 3-d- to 1-mo-old dairy calves¹

Item	Noncrossed 3-d- to 1-mo-old dairy calves		Beef-crossed 3-d- to 1-mo-old dairy calves	
	Odds ratio of having ≥ 1 death ²	Mortality rate (mortality change ³), %	Odds ratio of having ≥ 1 death ²	Mortality rate (mortality change ³), %
Number of cow-years ⁴	1.21 (1.20–1.22)	0.5***	1.16 (1.14–1.18)	1.7***
Predominant breed				
Holstein	Reference	Reference	Reference	Reference
Montbéliarde	1.07 (1.04–1.11)	–1.9***	0.95 (0.90–1.01)	–6.2***
Normande	1.05 (1.01–1.08)	–0.2	0.84 (0.74–0.94)	–5.7***
No predominant	1.07 (1.04–1.09)	1.6***	1.03 (0.98–1.08)	0.2
Other breeds	0.85 (0.80–0.90)	–3.7***	0.87 (0.77–0.98)	–9.5***
Farm type				
Dairy	Removed	Reference	Reference	Reference
Dairy and beef		–3.3***	1.06 (1.01–1.10)	2.5***
Dairy and fattening		–2.5***	1.12 (1.07–1.17)	2.1***
Purchased cow proportion				
No purchase	Reference	Reference	Removed	Reference
Low purchase	1.14 (1.11–1.16)	6.6***		1.6***
High purchase	1.06 (0.98–1.13)	6.2***		4.5***
First-calving cow proportion, ⁵ %	Removed	–1.2***	1.07 (1.05–1.08)	1.5***
Percentage of beef-crossed calves, ⁵ %	0.89 (0.89–0.89)	Removed	1.10 (1.09–1.11)	Removed
Percentage of males born, ⁵ %	Removed	1.0***	Removed	Removed
Autumn calving peak				
No	Reference	Reference	Removed	Removed
Yes	0.95 (0.93–0.96)	–2.5***		
Milk Control Program member				
No	Reference	Reference	Reference	Reference
Yes	1.21 (1.20–1.22)	1.6***	1.29 (1.24–1.35)	5.7***
Good Breeding Practices member				
No	Reference	Reference	Reference	Reference
Yes	0.97 (0.95–0.99)	–4.3***	0.99 (0.96–1.03)	–2.9***
Dairy production area				
1 (Grand-Ouest)	Reference	Reference	Reference	Reference
2 (Normandie)	1.21 (1.18–1.25)	6.4***	1.36 (1.24–1.48)	17.3***
3 (Nord)	1.08 (1.04–1.11)	4.7***	1.27 (1.13–1.43)	14.0***
4 (Est)	1.15 (1.11–1.19)	3.9***	1.18 (1.04–1.34)	10.1**
5 (Centre)	0.99 (0.92–1.06)	1.6	0.90 (0.77–1.05)	–3.2
6 (Poitou)	0.87 (0.82–0.92)	–3.6***	0.88 (0.81–0.96)	–7.4***
7 (Massif Central)	0.98 (0.95–1.01)	–0.7	0.93 (0.88–0.99)	–11.5***
8 (Rhône-Alpes)	0.97 (0.93–1.02)	–1.3**	0.94 (0.88–1.01)	–9.5***
9 (Sud-Ouest)	1.03 (0.99–1.06)	1.1	0.98 (0.93–1.03)	–5.9***
10 (Franche-Comté)	1.05 (0.99–1.10)	1.7***	1.21 (1.04–1.40)	8.1***
11 (Savoie)	1.27 (1.18–1.35)	8.3***	1.71 (1.50–1.95)	14.1***
Adjusted R ²		0.24		0.17

¹Reference = for the considered variable, class used as reference; removed = the variable was removed from the model because it was not significant.

²The 95% CI is given in parentheses.

³The results were expressed in mortality change (%). For instance, having a beef herd in addition to a dairy herd (farm type = dairy and beef) was associated with a mortality rate change of –3.3%, for the noncrossed 3-d- to 1-mo-old dairy calves, compared with not having a beef herd in addition to a dairy herd (farm type = dairy; reference class).

⁴For an increase in herd size of 10 cow-years; the number of cow-years equaled the sum of all the days and all the cows divided by 365.

⁵For an increase of 10%.

** $P < 0.01$; *** $P < 0.001$.

New Findings

The present results show that the mortality of noncrossed 0- to 2-d-old and of noncrossed 2-d- to 1-mo-old dairy calves is negatively associated with having a beef herd in addition to the dairy herd within the farm. The direction of the relationship remains unknown. This negative association might indicate that dairy farmers with low calf mortality are more likely to have a beef herd in addition to their dairy herd compared with

those with high calf mortality. It might also indicate that having a beef herd is associated with better technical management of dairy calves (reduced mortality). Whatever the direction of the relationship, the only logical mechanism we found is that farmers with a beef herd in addition to a dairy herd are technically more competent in young calf management (including calving) than farmers specialized in dairy production. This is highly suggested by the frequency of difficult calving and the greater need for nursing in French beef breeds

Table 5. Mortality of 3-d- to 1-mo-old dairy heifers¹

Item	3-d- to 1-mo-old dairy heifers	
	Odds ratio of having ≥ 1 death ²	Mortality rate (mortality change ³), %
Number of cow-years ⁴	1.17 (1.16–1.18)	1.7***
Predominant breed		
Holstein	Reference	Reference
Montbéliarde	1.07 (1.02–1.12)	0.9*
Normande	1.09 (1.05–1.13)	2.8***
No predominant	1.06 (1.03–1.09)	3.3***
Other breeds	0.86 (0.80–0.93)	–4.2***
Farm type		
Dairy	Reference	Reference
Dairy and beef	0.96 (0.93–0.99)	–1.1***
Dairy and fattening	1.04 (1.01–1.06)	2.1***
Purchased cow proportion		
No purchase	Reference	Reference
Low purchase	1.16 (1.13–1.19)	7.2***
High purchase	1.09 (1.01–1.18)	6.9*
First-calving cow proportion, ⁵ %	Removed	–1.0***
Percentage of beef-crossed calves, ⁵ %	0.89 (0.87–0.90)	–1.7***
Percentage of males born, ⁵ %	0.89 (0.89–0.89)	–1.0**
Autumn calving peak		
No	Reference	Reference
Yes	0.92 (0.90–0.94)	–3.7***
Milk Control Program member		
No	Reference	Reference
Yes	1.10 (1.07–1.13)	1.1***
Good Breeding Practices member		
No	Reference	Reference
Yes	0.94 (0.92–0.96)	–4.8***
Dairy production area		
1 (Grand-Ouest)	Reference	Reference
2 (Normandie)	1.20 (1.16–1.24)	8.9***
3 (Nord)	1.08 (1.04–1.12)	5.7***
4 (Est)	1.13 (1.14–1.22)	7.8***
5 (Centre)	1.05 (0.97–1.13)	2.2
6 (Poitou)	0.94 (0.88–1.01)	–2.1
7 (Massif Central)	1.06 (1.01–1.11)	2.4**
8 (Rhône-Alpes)	1.01 (0.95–1.05)	0.9
9 (Sud-Ouest)	1.07 (1.02–1.12)	4.4***
10 (Franche-Comté)	1.12 (1.05–1.18)	3.6***
11 (Savoie)	1.40 (1.29–1.51)	15.1***
Adjusted R ²		0.20

¹Reference = for the considered variable, class used as reference; removed = the variable was removed from the model because it was not significant.

²The 95% CI is given in parentheses.

³The results were expressed in mortality change (%). For instance, having a beef herd in addition to a dairy herd (farm type = dairy and beef) was associated with a mortality rate change of –1.1%, compared with not having a beef herd in addition to a dairy herd (farm type = dairy; reference class).

⁴For an increase in herd size of 10 cow-years; the number of cow-years equaled the sum of all the days and all the cows divided by 365.

⁵For an increase of 10%.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

(Charolais, Limousine, and Blonde d'Aquitaine). As a partial conclusion, the presence of a beef herd is associated with decreased dairy calf mortality, probably through better technical skills and know-how in new-born calf management.

The increased mortality of dairy beef-crossed calves on farms with a beef herd cannot be explained without further research. Mortality in heifers >1 mo old (Table

6) as well as in cows (Raboisson et al., 2011) is also positively associated with having a beef or a fattening herd in addition to the dairy herd. Maybe having 2 herds leads to difficulties in farm management (dispersal of daily activities). The fact that mortality and having a beef herd were positively or negatively associated, depending on the category of animal, is in accordance with the lower risk of calf mortality noted in areas with

Table 6. Mortality of dairy heifers from 1-mo-old to the first calving¹

Item	1- to 6-mo-old dairy heifers		6-mo-old to first-calving dairy heifers	
	Odds ratio of having ≥ 1 death ²	Mortality rate (mortality change ³), %	Odds ratio of having ≥ 1 death ²	Mortality rate (mortality change ³), %
Number of cow-years ⁴	1.15 (1.15–1.16)	2.5***	1.15 (1.14–1.16)	2.0***
Predominant breed				
Holstein	Reference	Reference	Reference	Reference
Montbéliarde	1.02 (0.97–1.06)	0.8	0.94 (0.89–1.01)	–2.6
Normande	1.06 (1.02–1.10)	4.4***	1.15 (1.10–1.20)	7.8***
No predominant	1.06 (1.02–1.09)	3.7***	1.09 (1.06–1.13)	5.8***
Other breeds	0.97 (0.90–1.06)	–1.1	0.94 (0.87–1.03)	–2.8
Farm type				
Dairy	Reference	Reference	Reference	Reference
Dairy and beef	1.04 (1.01–1.07)	2.6***	1.09 (1.06–1.13)	3.3***
Dairy and fattening	1.05 (1.02–1.07)	2.7***	1.07 (1.05–1.11)	2.4***
Purchased cow proportion				
No purchase	Reference	Reference	Reference	Reference
Low purchase	1.26 (1.23–1.30)	7.4***	1.15 (1.12–1.18)	6.4***
High purchase	1.20 (1.18–1.22)	7.0***	1.20 (1.18–1.22)	6.0***
First-calving cow proportion, ⁵ %	Removed	–1.5***	Removed	–5.2***
Percentage of beef-crossed calves, ⁵ %	0.90 (0.89–0.91)	–1.3***	0.90 (0.89–0.91)	–0.7***
Percentage of males born, ⁵ %	0.90 (0.89–0.91)	–2.5***	0.90 (0.89–0.91)	–0.5**
Autumn calving peak				
No	Reference	Reference	Removed	Reference
Yes	0.91 (0.89–0.93)	–3.6***		–2.4***
Milk Control Program member				
No	Reference	Reference	Reference	Reference
Yes	1.05 (1.03–1.08)	0.8***	0.94 (0.92–0.97)	–5.1***
Good Breeding Practices member				
No	Reference	Reference	Reference	Reference
Yes	0.91 (0.89–0.94)	–5.8***	0.88 (0.89–0.91)	–8.6***
Dairy production area				
1 (Grand-Ouest)	Reference	Reference	Reference	Reference
2 (Normandie)	1.05 (1.01–1.08)	3.2***	1.26 (1.22–1.30)	9.7***
3 (Nord)	0.95 (0.90–1.01)	–0.0	1.15 (1.11–1.19)	5.5***
4 (Est)	0.96 (0.91–1.02)	–0.6	1.19 (1.15–1.24)	6.2***
5 (Centre)	0.90 (0.84–0.98)	–4.2***	0.96 (0.89–1.05)	–2.5
6 (Poitou)	0.87 (0.82–0.93)	–5.3***	1.02 (0.95–1.08)	–0.0
7 (Massif Central)	0.98 (0.93–1.04)	–1.1	1.19 (1.13–1.25)	5.1***
8 (Rhône-Alpes)	1.02 (0.96–1.09)	1.4*	1.19 (1.14–1.25)	6.2***
9 (Sud-Ouest)	0.91 (0.87–0.96)	–3.7*	1.05 (1.01–1.09)	1.8***
10 (Franche-Comté)	0.88 (0.82–0.93)	–8.2***	1.22 (1.14–1.29)	3.6***
11 (Savoie)	0.87 (0.80–0.95)	–3.7***	1.09 (1.01–1.20)	–0.7
Adjusted R ²		0.27		0.28

¹Reference = for the considered variable, class used as reference; removed = the variable was removed from the model because it was not significant.

²The 95% CI is given in parentheses.

³The results were expressed in mortality change (%). For instance, having a beef herd in addition to a dairy herd (farm type = dairy and beef) was associated with a mortality rate change of +2.6 and +3.3%, for 1- to 6-mo-old dairy heifers and 6-mo-old to first-calving dairy heifers, respectively, compared with not having a beef herd in addition to a dairy herd (farm type = dairy; reference class).

⁴For an increase in herd size of 10 cow-years; the number of cow-years equaled the sum of all the days and all the cows divided by 365.

⁵For an increase of 10%.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

a history of beef production [for instance, areas 7 (Massif Central) and 8 (Rhône-Alpes); Sarzeaud et al., 2008]. It is also in accordance with the lowest heifer mortality reported for area 1 (Grand-Ouest), with dairy production as the main production (Table 7).

The second main finding in the present study was the negative association between the proportion of males born and the mortality of heifers for all heifer classes of age. This association was positive for the other categories

of animals (Tables 3 to 6). Testing this association is not irrational, as suggested by the standard deviations of the proportion of males born (Table 1). Importantly, the decrease in mortality with the increase in the proportion of males born was observed not only for young heifers but also, for a given year, for older heifers up to the first calving (i.e., born in the previous year). The decrease in heifer mortality with an increase in the proportion of males born cannot be distinguished here

Table 7. Associations between mortality of breeds and French areas¹

Item	0- to 2-d-old calves		3-d- to 1-mo-old calves		Heifers		
	Noncrossed	Beef-crossed	Noncrossed	Beef-crossed	3-d- to 1-mo-old	1- to 6-mo-old	6-mo-old to first calving
Predominant breed							
Holstein				Reference			
Montbéliarde	–	–	/	–	+	NS	NS
Normande	–	–	+	–	+	+	+
No predominant	–	–	+	NS	+	+	+
Other breeds	–	–	–	–	–	NS	NS
Dairy production area							
1 (Grand-Ouest)				Reference			
2 (Normandie)	+	+	+	+	+	+	+
3 (Nord)	–	/	+	+	+	NS	+
4 (Est)	–	+	+	+	+	NS	+
5 (Centre)	–	–	+	NS	NS	–	NS
6 (Poitou)	–	–	–	–	NS	–	NS
7 (Massif Central)	–	–	NS	–	+	NS	+
8 (Rhône-Alpes)	–	–	–	–	NS	+	+
9 (Sud-Ouest)	–	–	NS	–	+	–	+
10 (Franche-Comté)	NS	+	+	+	+	–	+
11 (Savoie)	–	–	+	+	+	–	+

¹Results are a summary of associations between mortality and breed or dairy production area detailed in Tables 3 to 6. Results refer to the variable reference class (Holstein or area 1). + = positive significant association in 2005 and 2006; – = negative significant association in 2005 and 2006; / = significant positive or negative association, depending on the year.

from the increase in heifer mortality with the increase in the proportion of females born. But the fact that older heifers were also affected by the proportion of males born in a given year shows that an increase in the proportion of males born (or decrease in proportion of females born) is associated with changes in heifer management, whatever their age class considered. Farmers cannot control the male:female ratio, except in the few herds using sexed gametes. It demonstrates an adaptation of farmers' management of heifers when the heifer birth proportion changes. The fact that heifer mortality increases with the proportion of females born also demonstrates that farmers do not systematically implement the management practices leading to low calf and heifer mortality even though they have the technical capacities to achieve low mortality. They only implement the necessary measures under certain conditions. To our knowledge, the association between heifer mortality (all classes of age) and the proportion of females to males born for a given year has not been demonstrated so far.

The main limit of the present work is that the evaluation of farmer characteristics (know-how for difficult calving or nursing) was indirect and based on data set variables. It is likely that questionnaires and surveys would have provided more precise data, but using such methods would have reduced the number of observations and the diversity of situations involved and would have increased the subjectivity of the results. In contrast, with the present method, the risk factors could be compared between different populations (newborn

calves, calves, heifers, and cows) under the same field conditions.

CONCLUSIONS

The present study shows first that the presence of a beef herd in addition to a dairy herd within a farm is associated with decreased dairy calf mortality. It also demonstrates that farmers achieve low heifer mortality when the proportion of heifers born decreases. These determinants of dairy calf and heifer mortality are of great importance for farmer advisors, the dairy industry, and political decision makers.

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