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Evaluation of the association between the introduction of data-driven tools to support calf rearing and reduced calf mortality in dairy herds in the Netherlands

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ABSTRACT

Between 2009 and 2017, calf mortality in the Dutch dairy sector showed a slight but steady increase. The Dutch dairy industry decided to act and supported the development of several data-driven tools that were implemented from 2018 on. The tools informed farmers about their calf mortality rates and stimulated them to improve. The Trend Analysis Surveillance Component of the Dutch cattle Health Surveillance System provided the possibility to evaluate the calf mortality in Dutch dairy herds before and after implementation of these tools. The aim of this study was to evaluate the association between calf mortality and i) all actions that were taken by the Dutch dairy industry to improve the quality of calf rearing and ii) other potential management or environmental factors associated with calf mortality in Dutch dairy herds.

Census data from approximately 98 % of all Dutch dairy herds were available from July 2014 until June 2019. Four different calf mortality indicators were defined: perinatal calf mortality risk (i.e., mortality before, during, or shortly after the moment of birth up to the moment of ear-tagging), postnatal calf mortality risk (ear-tagging till 14 d), preweaned calf mortality rate (15 d-55 d) and weaned calf mortality rate (56 d-1 yr.). All data were aggregated to herd and monthly level and were analysed using Population-Averaged Generalized Estimating Equations (PA GEE models) with a Poisson distribution and log link function.

When the period before implementation of the tools (2016–2017) was compared to the period thereafter (2018–2019), all four calf mortality indicators decreased. The relative decrease varied from 3 % (postnatal calves) and 10 % (perinatal calves) up to 18 % and 30 % in preweaned and weaned calves, respectively. Registrations of veterinary treatments such as antimicrobial use, vaccinations (calf or cow) and antiparasitic treatments were associated with calf mortality. Additionally, herds with a higher level of metabolic problems in transition cows had a higher calf mortality and also extreme outside temperatures were associated with higher calf mortality.

Given that the different tools were implemented nation-wide and a control group was lacking, we could not prove that implementing the different tools caused the reduction in calf mortality. We do however, believe that all the actions and communication towards improvement of calf rearing in dairy herds led to an increased awareness among farmers towards the importance of calf rearing management and therefore a reduction in calf mortality on national level.

1. Introduction

Calves are very important for dairy herds given that they are the future replacements for the milking cows. Therefore, calves should be reared in an optimal way to maximise health, welfare and future prospective with respect to maximisation of the long-term productivity (Hultgren and Svensson, 2009; Sandgren et al., 2009; De Vries et al., 2011; Soberon et al., 2012). An important indicator of calf health is calf mortality (Ortiz-Pelaez et al., 2008; Kelly et al., 2013). Between 2009 and 2017, calf mortality in the Dutch dairy sector showed a slight but

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steady increase. Factors associated with the increase were investigated by Santman-Berends et al. (2014). They concluded that there was no clear disease-related cause for the increased mortality rates but that there appeared to be an association between calf mortality and the mindset of the farmers. Dutch farmers with high calf mortality in their herds could roughly be divided into three different groups i.e. i) farmers that were unaware of the high mortality in their herd, ii) farmers that felt powerless to change the situation and iii) farmers who were aware of the high mortality but that were reluctant to change. Based on these results, the Dutch dairy industry decided to act and supported the development of several data-driven tools that would match the mindset of the three groups of farmers.

The data-driven tools that were developed consisted of a voluntary management tool named KalfOK (Santman-Berends et al., 2018a), obligatory surveillance of calf mortality on herd-level (definitions and calculation method is presented in Santman-Berends et al., 2019) and implementation of a calf track system for veal calves. The aim of these tools was to benchmark calf rearing by a number of key indicators for performance of young stock to stimulate dairy farmers to improve young stock husbandry and to reduce calf mortality. The three tools were either implemented on a voluntary basis (KalfOK) or obligatory basis (calf mortality surveillance and the calf track system) from January 2018 on. At the end of 2018, more than 90 percent of the dairy farmers had voluntarily participated in KalfOK and all dairy farmers participated in the mandatory tools. Furthermore, the extra attention on young stock rearing and increased insight into the herds' performance also resulted in multiple other initiatives to support calf rearing at veterinary practice level and individual herd level.

The Trend Analysis Surveillance Component (TASC) of the Dutch Cattle Health Surveillance System (CHSS) (Santman-Berends et al., 2016) provided the possibility to monitor calf mortality before and after implementation of all tools to reduce calf mortality in Dutch dairy herds for the subsequent 1.5 years. The aim of this study was therefore to evaluate the association between calf mortality and i) all the actions that were taken by the Dutch dairy industry to improve the quality of calf rearing and ii) other potential management or environmental factors.

2. Material and methods

2.1. Study population and available data

For this study, anonymized census data were available from Dutch dairy herds that participate in the CHSS. In total, approximately 98 percent of the Dutch dairy farmers gave consent to use their anonymized routinely collected data for monitoring of cattle health and therefore participate in the CHSS (approximately 15,500 dairy farmers).

For these herds census data were available from seven different data sources from July 2014 until June 2019. Registrations on cattle movements, including registrations of births, purchase, slaughter, and mortality were available from the national identification and registration database (RVO, Assen, the Netherlands). Cattle mortality data were obtained from the rendering plant and included the number of rendered cattle per herd and date (Rendac, Son, the Netherlands). These data included records of collected carcasses of calves before the moment of ear-tagging including large aborted foetuses, stillborn calves and perinatal deaths in advance of tagging. Milk quality and milk production records on herd level were available for approximately 90 percent of the herds that participated in the CHSS and were provided by the Royal Dutch Cattle Syndicate (CRV, Arnhem, the Netherlands) and the milk control association Nijland (Nijland, the Netherlands). Cow-level test-day records were available for approximately 75 percent of the herds (CRV, Arnhem, the Netherlands). Herd health statuses were available from Royal GD (Deventer, the Netherlands) and Qlip laboratories (Zutphen, the Netherlands) and included the status for Bovine Viral Diarrhoea Virus (BVDV), Bovine Herpes Virus type 1 (BHV-1), salmonellosis, leptospirosis and paratuberculosis. Data of veterinary registrations on deliveries of antimicrobials, vaccines and other medicines (including the product name) were available per age category of cattle at herd level and date (MediRund, Zuivel NL, the Hague, the Netherlands). Finally, data on the regional weather conditions i.e. relative humidity and temperatures in the Netherlands on a daily basis were available from the Royal Dutch Meteorology Institute (KNMI, the Bilt, the Netherlands).

2.2. Definitions

For this study four different calf mortality indicators were distinguished according to the definitions that are generally used in the CHSS (Santman-Berends et al., 2019).

Perinatal calf mortality risk (Perinatal_CMR) was defined as the number of deceased perinatal calves per herd *h* and month *t* relative to all calves born (irrespective whether aborted, dead or alive) and was calculated according to formula 1. Deceased perinatal calves included late abortions (>6 months pregnancy), stillbirths and calves that died before the moment of ear tagging (within at maximum 3 days after birth according to Dutch legislation).

$$Perinatal\_CMR_{ht} = \frac{(\sum abortions, stillbirts, deceased\ new\ born\ calves)_{ht}}{n\ calvings_{ht}} * 100\% \quad (1)$$

Postnatal calf mortality risk (Postnatal_CMR) was defined as the number of deceased calves from the moment of ear-tagging, within three days after birth according to Dutch legislation, until 14 days (14 d) of age (the minimum age after which calves are allowed to move off-farm in the Netherlands) relative to the number of calves that were ear tagged in the same herd and time period (formula 2).

$$Postnatal\_CMR_{ht} = \frac{\text{n deceased calves}_{(ear-tagging \leq 14d)ht}}{n\ ear-tagged\ calves_{ht}} * 100\% \quad (2)$$

Preweaned calf mortality rate (preweaned_CMRA) was calculated by dividing the number of deceased calves from 15 until 55 days of age by the number of calf days at risk which resulted in the calf mortality rate per day (formula 3). The number of calf days at risk was defined as the number of calves from 15 until 55 days old that were present in herd *h* and in time period *t* corrected for the time that they were present in the herd. For example, a calf that was in the correct age category and that was present during a whole month was included for 30.4 days at risk (*DAR*) (average number of days per month). Calves that were only in the correct age category during part of time period *t* or that were moved on- or off-farm during the time period of interest were included for the number of days that they were in the correct age category and present in the herd.

$$Preweaned\_CMRA\_d_{ht} = \frac{\text{n deceased calves } 15-55\text{d}_{ht}}{DAR_{ht}} \quad (3)$$

Subsequently the preweaning calf mortality rate per day *Preweaned_CMRA_d* was multiplied by the number of days in the period *t* of interest and presented as percentage.

Weaned calf mortality rate (weaned_CMRA) was calculated similarly to the preweaned_CMRA (formula 3) and included a different age category of calves i.e. 56 days until one year of age in both the numerator and the denominator. The mortality rate was subsequently presented as percentage.

2.3. Evaluated data tools and other variables

2.3.1. Data-driven tools

The association between implementation of the different data-driven tools and mortality was evaluated by adding a categorical variable that indicated whether the tool was implemented or not. The first evaluated tool was KalfOK, a scoring system in which farmers are graded points on

Table 1
Description of the three different data-driven tools that were developed to support young stock rearing in Dutch dairy herds and the period a possible association with calf mortality could be expected.

Tool	Voluntary/ mandatory	Implementation date	Evaluation period	Comments
KalfOK	Voluntary	01-01-'18	<2018: no tools Jan 2018- Jan 2019: start period >Jan 2019: fully implemented	-Results came available 6 weeks after the end of every quarter. -During the first year the participation rate steadily increased from 0 to 90 %
Surveillance of calf mortality	Mandatory	01-01-'18	<2018: no tool Jan 2018-Jan 2019: start period >Jan 2019: fully implemented	-Results came available 4 weeks after the end of every quarter -During the first year results were not yet complete given that they were presented on an annual basis and follow-up actions were less strict
Calf track system (CTS)	Mandatory	01-04-2017	<Apr 2017: no tool Apr 2017-Jan 2018: start period >Jan 2018: fully implemented	-Results are directly available (calf appears healthy and registration is correct) -Regulations on completeness of data in CTS became stricter from Feb 2018 on.

12 different young stock rearing indicators. The sum of the scores of the individual points add to a total score between 0 and 100 points. This score is communicated to the farmer together with the value of each indicator, a bench mark and the strengths and weaknesses in the young stock management (Santman-Berends et al., 2018a). The second tool was the obligatory calf mortality surveillance, which provides the calf mortality risk for perinatal and postnatal calves ≤14 days on herd and quarterly level together with a benchmark. Farmers of herds with the five to ten percent highest mortality risk according to this tool are obliged to make a plan to improve their rearing management with their herd veterinarian. The third tool was the Calf track system (CTS) in which the trader has to check whether a calf is healthy, more than 14 days old and has complete and correct registration in the identification and registration database (Pellikaan, 2017). Only calves that meet all requirements are allowed to leave the dairy herd to the veal herd.

The participation rates in the calf mortality surveillance and the CTS increased rapidly towards 100 percent, given the mandatory nature. Participation in KalfOK was voluntary. However, we observed that over fifty percent of the dairy herds started to participate from the start, and at the end of 2018 voluntary participation rates had increased to over 90 percent of all dairy herds. For the analyses to evaluate the different tools, three periods were distinguished, i) the period before implementation of the tools, ii) the period in which the tools were just implemented and the first effects may be expected and ii) the period in which the tools were fully operational. All three tools became available for all herds at the same time. The exact start and end month of the three periods are described in Table 1. Given that KalfOK and the obligatory surveillance of calf mortality overlapped completely with regard to the moment of implementation, it was not possible to distinguish the tools in a statistical analysis and they were included as a one parameter in the statistical models.

Table 2a
Description of medicine supplies that were included in the models as potentially associated with calf mortality, with the included period and mortality indicators for which a possible association was evaluated.

Parameter	Evaluated period	Included in analyses of
Antimicrobial use respiratory in calves <56 d	3 months	-Postnatal calf mortality risk -Preweaned calf mortality rate
Antimicrobial use diarrhoea in calves <56 d	3 months	-Postnatal calf mortality risk -Preweaned calf mortality rate
Total antimicrobial use in calves 56d – 1 year*	12 months	-Weaned calves
Treatment for cryptosporidiosis*	12 months	-Postnatal calf mortality risk -Preweaned calf mortality rate
Treatment for coccidiosis*	12 months	-Preweaned calf mortality -Weaned calf mortality rate

* A 12-month period was evaluated. Because of low treatment percentages there is no added value to evaluate shorter time periods.

2.3.2. Influence of transition cow problems

To evaluate whether calf mortality was associated with transition cow problems, milk recording data (CRV) was available providing information on occurrence of ketosis during the start of lactation i.e. first 60 days. On test-day level, each cow is classified as indicative for ketosis or not based on milk acetone, milk BHBA, season, fat-to-protein ratio and parity. More information on the definition of ketosis can be found in Van der Drift et al. (2012). Additionally, cow-mortality rates during the start of lactation were calculated and included as proxy for issues during calving. Both ketosis and co-mortality during the start of lactation were calculated on herd level and for three monthly periods (month t-2 until t1: for example for January 2019 the period from November 2018 until January 2019 was included). In the models we subsequently differentiated three categories for each parameter i.e. for ketosis 1) herds with no ketosis, 2) herds with <12.2 percent (median value) cows with ketosis or 3) herds with ≥12.2 percent cows with ketosis and for mortality 1) no mortality during the start of lactation, 2) mortality rate <7.1 percent (median value) during the start of lactation or 3) mortality rate ≥7.1 percent during start of lactation.

2.3.3. Medicine supplies

In the Netherlands, all medicines supplied to farmers by veterinary practices are centrally recorded in the national database MediRund (ZuivelNL). MediRund includes among others, antimicrobial usage, vaccines and other treatments such as for example antiparasitic treatments. Based on these data several parameters that were potentially associated with calf mortality were considered as independent variables. Antimicrobial usage (AMU) in the group of calves <56 days old was monitored based on the results of two parameters, AMU for respiratory treatments (AMU_{res}) and AMU for treatment of diarrhoea (AMU_{dia}). For both parameters, the daily defined doses per animal (DDDA) for a three month period was calculated (month *t*-2 until *t*1) according to the method described by Gonggrijp et al. (2016). Both parameters were eventually included as binary variables in the models i.e. AMU registered in the herd in the period of interest or not. Antimicrobial use was included as binary variable because of the skewed distribution of the DDDA, with many herds without AMU and only a few herds with substantial AMU in the period of interest. Additionally, treatments for

Table 2b
Description of vaccines that were included in the models as potentially associated with calf mortality, with the included period after vaccination in which a protective effect could be assumed and mortality indicators for which a possible association was evaluated.

Parameter	Period of treatment effect after application (start and end month)**	Included in analyses of
Vaccination against diarrhoea (administered in cows)*	+2 to +5 months	-Postnatal calf mortality risk -Preweaned calf mortality
Vaccination against respiratory infections	+2 to +8 months	-Preweaned calf mortality -Weaned calf mortality rate
Vaccination against lungworm (Dictyocaulus viviparus)	+3 to +9 months	-Weaned calf mortality rate

* Protection of calves is assumed after sufficient colostrum intake.
** The period includes the start and end month a possible protection of vaccination is assumed after the moment vaccination is administered i.e. 2–5 months means that protection is assumed to start in the second month after vaccination until 5 months after vaccination.

coccidiosis or cryptosporidiosis in the past year in the group of calves <56 days old were included as binary variables (received treatment or not). In corroboration with the co-authors IN and LvW, veterinarians and calf health experts, all registered vaccines that were supplied to Dutch dairy herds during the analysed period were classified according to the reason of application i.e. protection against respiratory issues, diarrhoea or parasites (list can be retrieved from the first author of this paper).

The medicine supply parameters were only included in the models for which they were hypothesized to be possibly associated with calf mortality and for a period during which an association with mortality could be expected. Expert opinion was used for making this decision. The description of the parameters and the models in which they were included as independent variables are presented in Tables 2a and 2b.

2.3.4. Weather conditions

Based on a previous publication, weather conditions appeared to be associated with calf mortality (Egberts et al., 2018) and we therefore decided to include the temperature-humidity index (THI) as independent variable in the study. The average THI per day was calculated according to the formula from Crescio et al. (2010) using the average daily temperature and humidity for each of the 90 2-digit postal codes (average size 380 km^2) in the Netherlands (KNMI). The THI per day was subsequently aggregated to a mean monthly level for each 2-digit postal code and classified in one of five THI-categories:

- Very cold (temperatures ≤1 percentile: THI ≤ 1.6 °C)
- Cold (temperatures >1 ≤ 5 percentile: 1.6 < THI ≤3.6 °C)
- Normal (temperatures >5 ≤ 95 percentile: 3.6 < THI ≤18.2 °C)
- Warm (temperatures >95 ≤ 99 percentile: 18.2 < THI ≤19.3 °C)
- Hot (temperatures >99 percentile: THI > 19.3 °C)

The THI was included as independent variable and the category indicating normal temperatures was included as reference category.

2.3.5. Other relevant parameters

Besides the considered variable that were already described, there are also a number of potential confounders that are always included in the trend analysis of the mortality indicators in the CHSS (Santman-Berends et al., 2016). These parameters include herd size, growth in herd size, replacement rate, location represented by province, milk production level, season, milk price, value of postnatal calves, purchase of cattle, status (free vs. non-free) for endemic diseases such as salmonellosis, leptospirosis, BVDV, BHV-1 and paratuberculosis, milking parlour (regular vs. automated milking system), an indication of whether young stock rearing is outsourced or not and a variable representing the trend in time. These variables are included as independent variables because routinely collected census data on which these variables can be calculated is available and because it is hypothesized that these variables are associated with calf mortality (on either literature or expert opinion). The continuous variables were categorised into four categories (10 % smallest, 40 % smaller, 40 % larger and 10 % largest) and the mean of the whole population was included as reference category.

2.4. Analyses

All data validation was executed using SAS® version 9.4 (SAS Institute Inc, 2019). Using descriptive analysis techniques every dataset was checked for biological implausible values such as for example cattle born before 1990, a negative amount of antibiotic supplies or a negative number of collected carcasses. Such observations only sporadically occurred (<0.1 % observations) and were removed from the dataset or corrected. The negative antimicrobial supplies and negative number of collected carcasses represented a correction on previously entered data. In these cases the previously entered data were corrected and the negative numbers were removed. Furthermore, all datasets were checked for double observations and when found, either one of the observations was preserved or the average of both observations was included (i.e. milk production records based on two bulk tanks in the herd). After the validation steps the data were aggregated to herd and monthly level as described in the previous paragraphs. Subsequently the data were combined and a final dataset for analysis was generated.

Herd characteristics and the evaluated mortality key indicators over time were described using descriptive statistics and graphical representation. Additionally, the mortality in the most recent period after implementation of the data tools i.e. July 2018 until June 2019 was descriptively compared to the mortality in the year before implementation of the data tools i.e. June 2016 until July 2017.

Multivariable population-averaged models (Population Averaged Generalised Estimated Equations) with a poisson distribution and a log link function were used for analyses in Stata® version 15 (Stata version 15, 2018). The calf mortality indicators were included as dependent variables and the potentially associated parameters were included as independent variables. The data were analysed on a herd and monthly level between July 2014 until June 2019 and the model corrected for repeated measures within herds. In population-averaged models this is done by inclusion of the marginal means of the cluster variable, in this

Table 3
Description of herd characteristics of the census study population of 15,500 Dutch dairy herds in 2019.

Herd characteristic	Mean (median)	10th and 90th percentile
Herd size		
Cows ≥2 years old	103 (90)	44 - 175
Young stock (1–2 years old)	23 (20)	4 - 44
Ear tagged calves <1 year old	31 (27)	10 - 57
Number of births in 2019	98 (85)	35 - 172
Replacement percentage*	27.5 % (26.5 %)	18 % - 38 %
Ketosis (<60 days in lactation)	10.6 % (8.3 %)	0 % - 25 %
Mortality during the start of lactation (<60 days)	3.1 % (0 %)	0 % - 10 %
Milk production (€/cow/lactation)	€ 2273 (€ 2300)	€ 1827 - €2,678
Total antimicrobial use in dairy herds (daily defined dose per animal in 2019)	2.24 (2.13)	0.56 - 3.95

* Percentage of adult cows that have been replaced compared to one year ago.

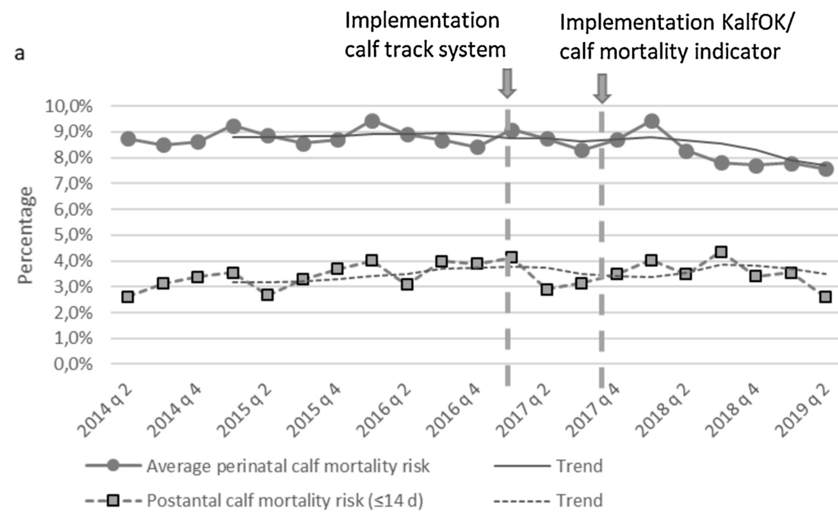

Fig. 1. The perinatal and postnatal calf mortality risk (a), and pre-weaned and weaned calf mortality rate (b) in the all Dutch dairy herds per quarter from July 2014 until June 2019.

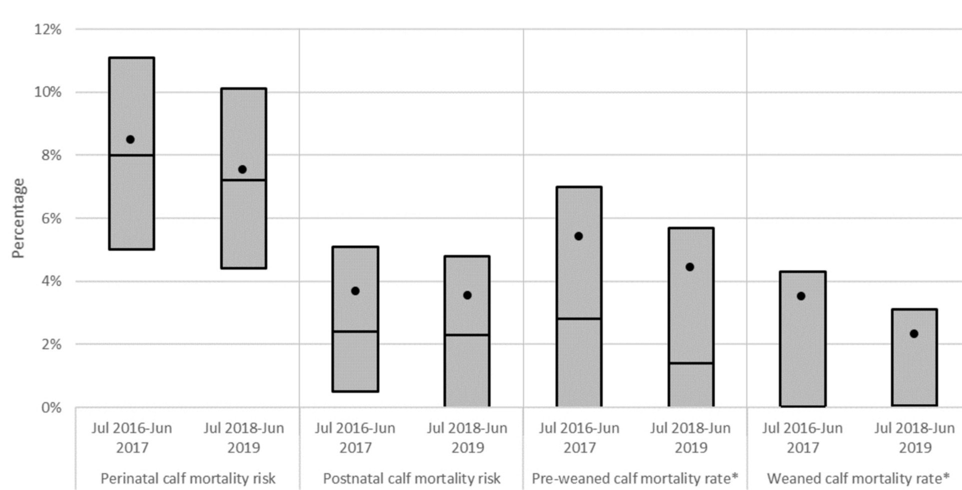

Fig. 2. The 25th, median and 75th percentile (bottom, middle and top of the box) and mean (dot) calf mortality for each of the analysed indicators before and after implementation of the data-based tools in Dutch dairy herds.
*These are mortality rates that are presented as percentages

Table 4
Selection of multivariable results of the population averaged poisson regression models to evaluate factors associated with four calf mortality indicators in approximately 13-15k Dutch dairy herds with complete data from July 2014 until June 2019. The full model results are provided in Appendix A.

Parameter	Description	Perinatal calf mortality		Postnatal calf mortality		Preweaned calf mortality		Weaned calf mortality	
		IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*
KalfOK/ Calf mortality indicator									
Before implementation	<2018	Ref.		Ref.		Ref.		Ref.	
Start implementation	Jan '18-Jan '19	0.94	0.91 - 0.97	0.97 ns	0.94 - 1.01	0.85	0.80 - 0.90	0.83	0.79 - 0.87
Full implementation	>Jan '19	0.84	0.81 - 0.87	0.75	0.71 - 0.79	0.70	0.65 - 0.75	0.67	0.62 - 0.72
Calf track system									
Before implementation	<Apr '17	Ref.		Ref.		Ref.			
Start implementation	Apr '17-Jan '18	1.00 ns	0.98 - 1.02	0.77	0.73 - 0.80	0.80	0.75 - 0.84	X	
Full implementation	>Jan '18	0.95	0.92 - 0.98	0.81	0.76 - 0.86	0.82	0.75 - 0.89	X	
Vaccination (relative to no vaccination)									
Against diarrhoea (dams)	17 % herds	X		0.91	0.88 - 0.93	1.07	1.03 - 1.11	X	
Against respiratory infections (calves)	14 % herds	X		X		0.90	0.87 - 0.94	1.03 ns	0.99 - 1.07
Against lungworm infections (calves)	2 % herds	X		X		X		0.86	0.79 - 0.94
Antimicrobial use (relative to no use)									
For diarrhoea (past 3 mo.)	9 %	X		1.46	1.42 - 1.51	1.36	1.31 - 1.42	X	
For respiratory infections (past 3 mo.)	14 %	X		1.13	1.10 - 1.16	1.26	1.22 - 1.30	X	
Total use in calves 56d-1yr (past year)	30 %	X		X		X		1.31	1.26 - 1.35
Treatments (relative to no treatment)									
For coccidiosis	32 % herds	X		X		0.86	0.83 - 0.89	1.00 ns	0.96 - 1.03
For cryptosporidiosis	38 % herds	X		1.25	1.22 - 1.28	1.26	1.22 - 1.30	X	
Ketosis during the first 60d of lactation									
0 %	27 % herds	Ref.		Ref.		Ref.			
>0 and <12.1 % of cows	36 % herds	1.07	1.05 - 1.08	1.05	1.03 - 1.08	1.07	1.04 - 1.11	X	
≥12.1 % of cows	36 % herds	1.05	1.03 - 1.06	1.05	1.02 - 1.09	1.02 ns	0.99 - 1.06	X	
Mortality during the start of lactation (<60d in lactation)									
0 %	57 % herds	Reference							
>0 and <7.1 % of cows	22 % herds	1.16	1.15 - 1.18	X		X		X	
≥7.1 % of cows	21 % herds	1.26	1.24 - 1.27	X		X		X	
Temperature humidity index (24h-period)									
Normal	≥3.6°C<18.2°C	Reference		Reference		Reference		Reference	
Very cold	<1.6°C	1.09	1.05 - 1.13	1.01 ns	0.96 - 1.07	1.14	1.06 - 1.23	1.14	1.04 - 1.26
Cold	≥1.6°C<3.6°C	1.05	1.03 - 1.06	1.07	1.04 - 1.10	1.17	1.12 - 1.22	1.16	1.10 - 1.23
Warm	≥18.2°C<19.3°C	1.02	1.00–1.04	1.18	1.14 - 1.22	0.98 ns	0.92 - 1.04	0.99 ns	0.93 - 1.06
Hot	≥19.3°C	1.09	1.05 - 1.13	1.44	1.36 - 1.52	1.23	1.11 - 1.35	1.04 ns	0.92 - 1.17
Purchase of cattle in the past 12 months									
No	49 %	Reference		Reference		Reference		Reference	
Sporadic (1/2 cattle/year)	9 %	0.98 ns	0.96 - 1.00	1.00 ns	0.96 - 1.04	0.91	0.87 - 0.95	0.91	0.87 - 0.96
Yes (>2 cattle/year)	42 %	0.95	0.93 - 0.96	0.92	0.90 - 0.95	0.82	0.79 - 0.85	0.77	0.75 - 0.80
Herd health status									
BHV-1-free (vs. non-free)	39 %	0.97	0.95 - 0.99	0.98 ns	0.95 - 1.01	0.95 ns	0.92 - 0.99	0.91	0.87 - 0.94
BVD-free (vs. non-free)	45 %	0.98	0.96 - 0.99	0.96 ns	0.93 - 0.99	0.90	0.87 - 0.93	0.86	0.83 - 0.89
Salmonella-unsuspected (vs. indication of infection)	93 %	0.97 ns	0.95 - 1.00	0.88	0.84 - 0.91	0.79	0.76 - 0.83	0.85	0.81 - 0.90
Paratuberculosis unsuspected (vs. indication of an infection)	80 %	0.99 ns	0.97 - 1.00	0.91	0.88 - 0.94	0.89	0.85 - 0.93	0.87	0.84 - 0.91

ns = not significant at $P < 0.01$.
X: not included in the model.
* 95 CI: 95 % confidence interval.

study 'herd'. Such models do not include specific effects of each cluster, but instead include the average across the population of clusters (Dohoo et al., 2003). The large numbers of observations in our data increases the probability of type I errors and therefore a conservative *P*-value below 0.01 was used to indicate significance. Model fit was evaluated using the quasi-likelihood under the independent model criterion (QIC) (Pan, 2001; Cui, 2007) and the amount of variance explained by the model (R^2).

3. Results

3.1. Descriptive results

The average herd size of all Dutch dairy herds that were included in this study was 103 (median 90) cows (≥2 years old) in 2019. In that year the average number of calves born in each dairy herd was 98 (Table 3). More descriptive results of these herds can be found in Table 3.

The average perinatal calf mortality risk showed a seasonal trend with highest risk in the first quarter of each year i.e. the winter months (Fig. 1). This seasonal trend was also observed for the other three calf mortality indicators. Up to the implementation of the data tools in 2017 or 2018, perinatal and weaned calf mortality showed a slight increase whereas the postnatal and pre-weaned calf mortality were clearly increasing (Fig. 1).

When the period before implementation of the data-driven tools and increased focus on young stock rearing was compared to the period thereafter, a reduction was observed in all four calf mortality indicators (Fig. 2). Between July 2018 and June 2019, the mean perinatal calf mortality risk in the whole population of approximately 15,500 dairy herds was 7.6 percent (median 7.2 %) compared to 8.5 percent (median 8.0 %) between July 2016 and June 2017. This equals an eleven percent reduction in perinatal calf mortality risk. The mean postnatal calf mortality risk between July 2018 and June 2019 was comparable to the risk in this age category in the period between July 2016 and June 2017 (respectively 3.5 % versus 3.6 %, median values were respectively 2.3 % and 2.4 %). A reduction in calf mortality rates of 18 percent and 29 percent, was observed for respectively the groups of preweaned and weaned calves (Fig. 2). The preweaned calf mortality reduced from on average of 5.4 percent (median 2.8 %) from July 2016 until June 2017 to 4.4 percent (median 1.4 %) from July 2018 until June 2019. The weaned calf mortality reduced from on average 3.4 percent to 2.4 percent (median 0 % in both years) in the two evaluated periods. Besides a reduction in average calf mortality, we observed that there were more herds without mortality in the different age groups of calves and fewer herds with high mortality between July 2018 and June 2019 as compared to July 2016 until June 2017. The latter is shown by the reduction in 75th percentile values (Fig. 2).

3.2. Multivariable results

A selection of the model results, which were of particular interest and described in material and methods are presented in Table 4. The full model results can be found in Appendix A. A significant association was found between the periods in which the data-driven tools in support of young stock rearing were implemented and all four calf mortality indicators. The period in which KalfOK and the calf mortality indicator were fully implemented was associated with a 1.2–1.5 times lower mortality (IRR = 0.84 to 0.67) relative to the period before implementation (Table 4). Implementation of the Calf track system was associated with a 1.05–1.2 times lower mortality (IRR = 0.81-0.95). Vaccinating dams to prevent diarrhoea in their new-born calves, was associated with a lower postnatal calf mortality (IRR = 0.91), but a higher mortality rate in preweaned calves (IRR = 1.07). Vaccination of calves for respiratory infections was associated with a significantly lower preweaned calf mortality rate (Table 4). Supplies of antimicrobials were associated with a higher calf mortality incidence rate in all four indicators as was treatment against cryptosporidiosis. Herds with more health issues during the transition period of cows were associated with higher calf mortality. Occurrence of mortality in transition cows during the first 60 days in lactation was associated with a significantly higher perinatal calf mortality. Having cows with ketosis during the start of lactation was associated with higher mortality in perinatal, postnatal and preweaned calves (Table 4). Other factors that were associated with higher mortality rates included extreme warm or cold temperatures, purchase, low production levels, autumn, high replacement percentages and larger herd sizes. A free or unsuspected herd status for infectious diseases such as BHV-1, BVDV, salmonellosis or paratuberculosis was associated with significantly lower mortality in all four analysed calf mortality indicators (Table 4).

4. Discussion

The aim of this study was to evaluate the association between calf mortality in Dutch dairy herds and i) the efforts of the cattle industry to improve the quality of calf rearing and ii) other potential management and environmental factors.

Descriptively, a decreased mortality was observed in perinatal, preweaned and weaned calves. The mortality risk in postnatal calves however, was similar when the periods before and after implementation of the data-driven tools were compared. The fact that the mortality in this age group of calves (from moment of ear tagging until 14 days of age) was not reduced could be because there might have been a change in the moment of ear-tagging or in the decision whether or not to ear-tag a stillborn calf. A rule in the Calf track system is that calves are only allowed to leave the dairy herd for the veal industry, at least 14 days after ear-tagging and the accompanying registration in the identification and registration system. Given that farmers want to sell the bull calves and part of the heifer calves as soon as possible, they may ear-tag these calves earlier than before this regulation in the calf track system existed. Given that the probability for calves to die decreases with increasing age, and that ear-tagged calves may have become a bit younger, one would expect an increase in postnatal calf mortality. However, we observed that the postnatal calf mortality remained stable. Another possibility is that stillborn calves may receive an ear-tag more often given the national BVDV control programme that was implemented in 2018. In this programme, ear-tag testing is applied in part of the herds to detect persistent BVD carriers. By testing stillborn calves for BVD virus farmers can get an indication whether or not the virus is present in their herd and whether follow-up actions are required. Previously, these stillborn calves were included in perinatal calf mortality. By ear-tagging them, they are included in the mortality risk of postnatal calves. This change could also have resulted in an increase in postnatal calf mortality that was not seen. To study whether all efforts to improve the standard of young stock husbandry and to reduce calf mortality paid off, multivariable models were used. The period in which the tools were implemented was associated with a decrease in mortality. Given the observational study design, we could however not prove that the implementation of the data-driven tools resulted in this decrease. All Dutch dairy herds were exposed to the tools given that it was mandatory to participate in two out of three tools that were implemented i.e. the calf mortality indicator and the calf track system. This resulted in lack of a control group that could have provided more insight in the added value of implementing the tools. Participation in KalfOK was voluntary and during the study period five to ten percent of the herds did not participate in this programme. In theory, we could have used these herds as a control group. However, no herd-level data was available whether or not herds participated and what the starting date of participation was. One could further question the true value of this small control group. The herds that decided not to participate in the KalfOK programme are not random herds and will not be representative for the population of Dutch dairy herds. Nevertheless, given the timing of the introduction of the data-driven tools and the subsequent change in trend of the calf mortality indicators, we believe that the implementation of the data-driven tools has supported the reduction in calf mortality. Notwithstanding, we can however not conclude that the change in trend was solely associated with the implementation of the data-driven tools. Providing information alone does not improve young stock mortality. Awareness of the situation and possibilities to improve management can result in changed behaviour. From our previous study (Santman-Berends et al., 2014) we concluded that a proportion of the farmers had a lack of knowledge about the level of calf mortality in their herds relative to other herds. Information about the calf mortality levels in their herds relative to a benchmark could possibly initiate a change in mindset, resulting in changed behaviour i.e. management practices that would help to reduce calf mortality. Development and implementation of the data-driven tools provided this information and subsequently resulted in multiple initiatives to improve. For example, a blueprint for good calf management was introduced (Blueprint Calf Rearing project group, 2018) and the Dutch veterinary board developed guidelines to develop a plan to improve young stock rearing management (KNMvD, 2018) that could be used by the farmer and the herd veterinarian when the calf mortality indicator detected a high calf mortality in the herd. Additionally, many initiatives tailored to the needs of individual farmers were initiated by veterinary practices and feed suppliers and environmental factors such as extreme temperatures were considered more often. Another change was that a phosphate regulation was introduced in the beginning of 2017. On average, this resulted in a decrease in the number of replacement calves in dairy herds. A smaller number of calves may be associated with a lower infection pressure and may also have helped to reduce morbidity and subsequent mortality in Dutch dairy herds. In conclusion, the incidence rate ratios of the data-driven tools provide the association of implementation of the combination of all initiated actions rather than implementation of the tools alone.

In our study, calf mortality in herds that were assumed to be protected by vaccination was compared to herds that were not protected by vaccination i.e. herds that did not vaccinate or herds that did apply vaccination but outside the period in which protection could be expected. Vaccination was associated with a higher preweaned calf mortality risk which can be explained by the fact that farmers often start vaccination after problems occur. When we conducted an analysis on a subset of vaccinating herds and compared calf mortality after vaccination with mortality in the year prior to vaccination, vaccination was always associated with a reduction in calf mortality (results not shown). However, vaccination is very often part of a strategy to improve young stock rearing and reduce calf mortality. In this study, only centrally registered data were available and only supplies of medicines and vaccinations could be included as proxy of such an improvement strategy. Our results therefore provide an indication of the association between mortality and implementing an improvement strategy for young stock husbandry rather than application of vaccination alone. According to the available data we only had records on the date on which medicines (both vaccinations and antibiotics) were supplied by the veterinarian. Given that vaccinations in the Netherlands are only allowed to be administered by veterinarians, the supply date is equal to the date of actual use. For antimicrobials, the farmer is sometimes allowed to administer the antimicrobials him or herself, which may have resulted in some bias. Nevertheless, given that antimicrobials can only be supplied for curative purposes, we believe that the date of supply and the date of use are highly correlated. It may be that some antimicrobials are kept for later treatment, but this phenomenon is randomly distributed over all herds and is therefore not assumed to have a major effect on the study results.

Also other herd and environmental factors were found to be associated with calf mortality. Extreme outside temperatures were associated with higher mortality rates. This finding was supported by Egberts et al. (2019) who found an association between mortality and extreme temperatures and the results of Hyde et al. (2020) who found that the temperature in the month of birth played an important role in neonatal on-farm mortality rates. When we analysed mortality in veal calf herds we did not observe an effect of extreme outside temperatures on calf mortality, probably due to the mechanical ventilation systems and better isolation of the barn in veal herds (results not shown). Such results indicate that mortality related to extreme temperature could be avoided by tailored management. Larger herd sizes were associated with higher calf mortality rates in postnatal, preweaned and weaned calves. These findings are in accordance with previous findings of Reimus et al. (2020) who also found higher mortality in larger herds. A possible reason for higher mortality in larger herds is a higher infection pressure, but herd size is also a known proxy for factors that were not included in this study such as time spend per calf per day, amount of foreign labour, number of visitors, etc. A noteworthy finding was that herds with more transition cow problems had higher mortality rates in calves. This may indicate that dry-cow management also plays a role in preventing calf mortality but it may also be that that the finding is a result of the general management that results in increased transition problems and increased mortality. Therefore, this finding warrants further research. To our knowledge there is no literature that studied the association between transition problems in cows and calf mortality, although other studies did find that general herd problems such as presence of pathogenic infections or higher mortality rates in other age groups were a risk factor for calf mortality (Reimus et al., 2020; Mock et al., 2020; Santman-Berends et al., 2018b).

In this study, we presented calf mortality figures in Dutch dairy herds according to the definitions agreed upon in the Netherlands. In a review conducted by Cuttance and Laven (2019) the average perinatal calf mortality was estimated to be 6.2 percent and is lower than the 7.6 percent perinatal calf mortality that we observed between July 2018 and June 2019. The definition used in their study only included the deaths of full term calves either during parturition or shortly thereafter. In our definition, late term abortions (>6 months of pregnancy) are also included which generally account for approximately 20 percent of the perinatal calf mortality. Given this knowledge it may be that the Dutch perinatal calf mortality rate is comparable to the average that was estimated in Cuttance and Laven (2019). Comparison between the Dutch mortality risk and rates and those found in other countries is complicated because of differences in definitions, different age categories and differences in calculation methods (Compton et al., 2017). Ideally, the definitions and calculation methods would be similar between countries as recommended by Fetrow et al. (2006). However, definitions and age categories that are distinguished when calculating calf mortality are often related to data availability and the aim for which the figures are calculated. Therefore, one has to be very careful when comparing mortality figures between countries.

This study showed that increased awareness of calf health and calf mortality provided by data-driven tools and all subsequent actions of Dutch dairy farmers, resulted in a nation-wide decrease in calf mortality rates.

5. Conclusion

This study indicates that the implementation of data-driven tools in support of young stock rearing and the increased effort of farmers to optimize young stock rearing practices likely have resulted in a reduction in calf mortality in the Netherlands since 2018. The data-driven tools provide insight and guidance for the individual farmer and the herd veterinarian and can be used as basis for discussion on possibilities to improve young stock management. This study describes that use of data can have an impact on cattle health by providing more insight into the key performance indicators which created awareness towards the importance of calf rearing management.

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Appendix A

See Table A1

Table A1
Full results of the population averaged poisson regression models to evaluate factors associated with calf mortality in 13-15k Dutch dairy herds with complete data from July 2014 until June 2019. Non-significantly associated parameters ($P < 0.01$) are presented with “ns”.

Parameter	Description	Perinatal calf mortality		Postnatal calf mortality		Preweaned calf mortality		Weaned calf mortality	
		IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*
KalfOK/ Calf mortality indicator									
Before implementation	<2018	Reference		Reference		Reference		Reference	
Start implementation	Jan ’18-Jan ’19	0.94	0.91 - 0.97	0.97 ns	0.94 - 1.01	0.85	0.80 - 0.90	0.83	0.79 - 0.87
Full implementation	>Jan ’19	0.84	0.81 - 0.87	0.75	0.71 - 0.79	0.70	0.65 - 0.75	0.67	0.62 -0.72
Calf track system									
Before implementation	<Apr ’17	Reference		Reference		Reference			
Start implementation	Apr ’17-Jan ’18	1.00 ns	0.98 - 1.02	0.77	0.73 - 0.80	0.80	0.75 -0.84	X	
Full implementation	>Jan ’18	0.95	0.92 - 0.98	0.81	0.76 - 0.86	0.82	0.75 -0.89	X	
Vaccination (relative to no vaccination)									
Against diarrhoea (dams)	17 % herds	X		0.91	0.88 - 0.93	1.07	1.03 - 1.11	X	
Against respiratory infections (calves)	14 % herds	X		X		0.90	0.87 - 0.94	1.03 ns	0.99 - 1.07
Against parasitic infections (calves)	2 % herds	X		X		X		0.86	0.79 - 0.94
Antimicrobial use (relative to no use)									
For diarrhoea (past 3 mo.)	9 %	X		1.46	1.42 - 1.51	1.36	1.31 - 1.42	X	
For respiratory infections (past 3 mo.)	14 %	X		1.13	1.10 - 1.16	1.26	1.22 - 1.30	X	
Total use in calves 56d-1yr (past year)	30 %	X		X		X		1.31	1.26 - 1.35
Treatments (relative to no treatment)									
For coccidiosis	32 % herds	X		X		0.86	0.83 - 0.89	1.00 ns	0.96 - 1.03
For cryptosporidiosis	38 % herds	X		1.25	1.22 - 1.28	1.26	1.22 - 1.30	X	
Ketosis issues during the start of lactation (<60d in lactation)									
0 %	27 % herds	Reference		Reference		Reference			
>0 and <12.1 % of cows	36 % herds	1.07	1.05 - 1.08	1.05	1.03 - 1.08	1.07	1.04 - 1.11	X	
≥12.1 % of cows	36 % herds	1.05	1.03 - 1.06	1.05	1.02 - 1.09	1.02 ns	0.99 - 1.06	X	
Mortality during the start of lactation (<60d in lactation)									
0 %	57 % herds	Reference							
>0 and <7.1 % of cows	22 % herds	1.16	1.15 - 1.18	X		X		X	
≥7.1 % of cows	21 % herds	1.26	1.24 - 1.27	X		X		X	
Temperature humidity index (24h-period)									
Normal	≥3.6°C<18.2°C	Reference		Reference		Reference		Reference	
Very cold	<1.6°C	1.09	1.05 - 1.13	1.01 ns	0.96 - 1.07	1.14	1.06 - 1.23	1.14	1.04 - 1.26
Cold	≥1.6°C<3.6°C	1.05	1.03 - 1.06	1.07	1.04 - 1.10	1.17	1.12 - 1.22	1.16	1.10 - 1.23
Warm	≥18.2°C<19.3°C	1.02	1.00–1.04	1.18	1.14 - 1.22	0.98	0.92 - 1.04	0.99	0.93 - 1.06
Hot	≥19.3°C	1.09	1.05 - 1.13	1.44	1.36 - 1.52	1.23	1.11 - 1.35	1.04 ns	0.92 - 1.17
Herd size									

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Table A1 (*continued*)

Parameter	Description	Perinatal calf mortality		Postnatal calf mortality		Preweaned calf mortality		Weaned calf mortality	
		IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*
Dutch average		Reference		Reference		Reference		Reference	
10 % smallest herds	<43	1.00 ^{ns}	0.97 - 1.03	0.80	0.75 - 0.86	0.86	0.79 - 0.94	0.85	0.78 - 0.92
40 % smaller herds	≥43 < 90	1.01 ^{ns}	1.00–1.03	1.06	1.03 - 1.09	0.97	0.94 - 1.01	0.87	0.84 - 0.91
40 % larger herds	≥90 < 172	1.01 ^{ns}	1.00–1.03	1.13	1.10 - 1.17	1.07	1.04 - 1.11	1.03 ^{ns}	0.99 - 1.07
10 % largest herds	≥172	0.98 ^{ns}	0.96 - 1.00	1.03 ^{ns}	0.99 - 1.07	1.11	1.06 - 1.16	1.31	1.26 - 1.37
Milk production level (presented in € cow/ lactation)									
Dutch average		Reference		Reference		Reference		Reference	
10 % lowest production	<€1792	1.12 ^{ns}	0.95 - 1.31	1.47	1.35 - 1.60	2.09	1.90 - 2.30	1.58	1.48 - 1.69
40 % lower production	≥€1792 < €2253	1.08 ^{ns}	0.92 - 1.27	1.09	1.06 - 1.12	1.12	1.08 - 1.15	1.01 ^{ns}	0.98 - 1.05
40 % higher production	≥€2253 < €2612	1.04 ^{ns}	0.88 - 1.21	0.95	0.92 - 0.97	0.89	0.86 - 0.92	0.79	0.77 - 0.82
10 % highest production	≥€2612	1.00 ^{ns}	0.85 - 1.17	0.81	0.78 - 0.84	0.69	0.66 - 0.72	0.70	0.67 - 0.74
Unknown	11 % of observations	0.80 ^{ns}	0.42 - 1.51	1.00 ^{ns}	1.00–1.00	1.00 ^{ns}	1.00–1.00	1.12	1.06 - 1.19
Season									
Dutch average		Reference		Reference		Reference		Reference	
Winter	Jan-Mar	0.99	0.98 - 1.00	1.09	1.07 - 1.11	1.25	1.22 - 1.28	1.01 ^{ns}	0.98 - 1.04
Spring	Apr-Jun	0.92	0.91 - 0.93	0.86	0.84 - 0.88	0.81	0.78 - 0.84	0.94	0.91 - 0.97
Summer	Jul-Sep	1.05	1.04 - 1.06	1.03	1.01 - 1.04	0.90	0.88 - 0.92	0.98	0.96 - 1.00
Autumn	Oct-Dec	1.05	1.04 - 1.06	1.03	1.01 - 1.05	1.10	1.07 - 1.13	1.07	1.04 - 1.10
Replacement percentage cows>2 years/year									
Dutch average		Reference		Reference		Reference		Reference	
10 % lowest	<17 %	0.96	0.95 - 0.98	0.87	0.84 - 0.90	0.88	0.84 - 0.93	0.81	0.77 - 0.85
40 % lower	≥17 %<26 %	1.01 ^{ns}	1.00–1.02	0.97	0.95 - 0.99	0.96	0.94 - 0.98	0.89	0.87 - 0.91
40 % higher	≥26 %<36 %	1.02	1.01 - 1.03	1.06	1.04 - 1.08	1.03	1.01 - 1.06	1.07	1.05 - 1.10
10 % highest	≥36 %	1.01 ^{ns}	0.99 - 1.03	1.12	1.08 - 1.16	1.14	1.09 - 1.19	1.29	1.23 - 1.35
Growth in herd size									
Dutch average		Reference		Reference		Reference		Reference	
10 % lowest	<-10 %	0.97	0.96 - 0.99	1.01 ^{ns}	0.98 - 1.04	1.01 ^{ns}	0.97 - 1.05	0.99	0.96 - 1.03
40 % lower	≥-10 %<0 %	1.00 ^{ns}	0.99 - 1.01	0.96	0.94 - 0.97	0.94	0.92 - 0.97	0.93	0.91 - 0.95
40 % higher	≥0 %<13 %	1.01	1.00–1.02	0.98	0.96 - 1.00	0.97	0.95 - 0.99	0.97	0.95 - 0.99
10 % highest	≥13 %	1.02 ^{ns}	1.00–1.03	1.06	1.03 - 1.08	1.08	1.04 - 1.12	1.12	1.08 - 1.16
Purchase of cattle in the past 12 months									
No	49 %	Reference		Reference		Reference		Reference	
Sporadic (1/2 cattle/year)	9 %	0.98 ^{ns}	0.96 - 1.00	1.00 ^{ns}	0.96 - 1.04	0.91	0.87 - 0.95	0.91	0.87 - 0.96
Yes (>2 cattle/year)	42 %	0.95	0.93 - 0.96	0.92	0.90 - 0.95	0.82	0.79 - 0.85	0.77	0.75 - 0.80
Price for a dairy calf at 14d of age	€ 73	X		1.01	1.00–1.01	1.00 ^{ns}	1.00–1.00	0.99 ^{ns}	0.99 - 1.00
Herd health status									
BHV-1-free (vs. non-free)	39 %	0.97	0.95 - 0.99	0.98 ^{ns}	0.95 - 1.01	0.95	0.92 - 0.99	0.91	0.87 - 0.94
BVD-free (vs. non-free)	45 %	0.98	0.96 - 0.99	0.96 ^{ns}	0.93 - 0.99	0.90	0.87 - 0.93	0.86	0.83 - 0.89
Salmonella-unsuspected (vs. indication of infection)	93 %	0.97 ^{ns}	0.95 - 1.00	0.88	0.84 - 0.91	0.79	0.76 - 0.83	0.85	0.81 - 0.90
Paratuberculosis unsuspected (vs. indication of an infection)	80 %	0.99 ^{ns}	0.97 - 1.00	0.91	0.88 - 0.94	0.89	0.85 - 0.93	0.87	0.84 - 0.91

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Table A1 (*continued*)

Parameter	Description	Perinatal calf mortality		Postnatal calf mortality		Preweaned calf mortality		Weaned calf mortality	
		IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*	IRR	95 % CI*
Proportion of calves relative to adult cattle									
≤17 % (indicative for outsourcing young stock rearing)	8 %	X		Reference		Reference		Reference	
>17 ≤ 25 %	10 %	X		1.01 ns	0.93 - 1.09	0.79	0.72 - 0.86	1.02 ns	0.89 - 1.17
>25 % (indicative of with-herd young stock rearing)	82 %	X		0.93	0.86 - 1.01	0.54	0.49 - 0.59	1.04 ns	0.91 - 1.19
Trend in time (quarter)		1.01	1.01 - 1.01	1.02	1.02, 1.03	1.03	1.02, 1.03	1.01 ns	1.00–1.01
Province	12 provinces	Miscellaneous		Miscellaneous		Miscellaneous		Miscellaneous	

*95 CI: 95 % confidence interval.
ns = not significant at $P < 0.01$.
X: not included in the model.

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