Preventive Veterinary Medicine 232 (2024) 106312

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Evaluation of a data-driven youngstock rearing quality system in Dutch dairy herds (2019–2022)

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ARTICLE INFO

Keywords:
Dairy calves
Young stock
Rearing management

ABSTRACT

In recent years, the Netherlands exhibited an increased focus on improving youngstock rearing. Several data-driven tools were developed to assess and benchmark calf rearing practices based on key indicators, stimulate farmers to improve their youngstock rearing and reduce calf mortality. KalfOK is such a data-driven tool in which a farm-level overview with 15 indicators of youngstock rearing quality is communicated to participating farmers. In this study we assessed which farm characteristics are associated with A) a continuously high or low KalfOK score and B) frequent usage of KalfOK. Data from KalfOK and the identification and registration system were available for all participating herds over a period between 2019 and 2022 (Dataset A). Additionally, a sample of 324 dairy farmers, randomly selected from the entire Dutch dairy population (Dataset B), participated in a voluntary survey. Multivariable (logistic) regression models were used to A) identify differences in characteristics between farms with a continuously high- and farms with a continuously low KalfOK score and B) assess which farm characteristics were associated with frequent use of the KalfOK report. The results of analysis A showed multiple factors associated with having a low or high KalfOK score, including replacement rate, closed farming system, limited growth in herd size and the region where a farm was located. Sociological factors might also partly explain the difference between high and low scoring farms. Analysis B showed that approximately half of the surveyed farmers indicated that they do not frequently use their KalfOK overview in their calf rearing management. The KalfOK score of farmers who regularly use their KalfOK report was higher – and consequently better - compared to the KalfOK score of farmers who sometimes or never use KalfOK. Additionally, farmers using a milk robot and those discussing KalfOK regularly with their veterinarian, used KalfOK more often. Thirty four percent of the surveyed farmers made adjustments to their youngstock rearing management since the start of participation. The study's insights into patterns in KalfOK utilization and associations with farm characteristics provide valuable information for ongoing efforts to enhance calf rearing practices via the use of KalfOK. It is important to consider what is needed to convince farmers that do not use the KalfOK tool to frequently start using their KalfOK report. Future research incorporating sociological aspects can provide a more comprehensive understanding of other dynamics influencing calf rearing and contribute valuable insights for enhancing the effectiveness of programs like KalfOK in promoting calf health and welfare.

1. Introduction

Young stock rearing is an essential part of dairy management given that calves are raised as replacement for milking cows, and it should occur optimally to maximize health and welfare (Hultgren and Svensson, 2009; Sandgren et al., 2009; De Vries et al., 2011; Santman-Berends et al., 2021). An important indicator to assess the quality of calf rearing is the calf mortality rate (Ortiz-Pelaez et al., 2008; Kelly et al., 2013), where, in general, a higher mortality rate in calves is associated with poor young stock rearing and poor animal welfare (Sandgren et al., 2009; De Vries et al., 2011). For the farmer, high calf mortality leads to economic loss, additional labour and loss of potential breeding stock

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https://doi.org/10.1016/j.prevetmed.2024.106312
Received 18 January 2024; Received in revised form 8 July 2024; Accepted 8 August 2024
Available online 14 August 2024

(Mee et al., 2008; Torsein et al., 2011; Klein-Jöbstl et al., 2014) with a potential effect on herd's genetic improvement. Between 2009 and 2017, a slight but steady increase in calf mortality was observed in Dutch dairy farms (Santman-Berends et al., 2014, 2019). Previous research showed that many Dutch dairy farmers with suboptimal young stock rearing and high mortality were not aware of the fact that calf mortality was high at their farm (Santman-Berends et al., 2014). Also, many did not know how to decrease calf mortality or were not prepared to adjust their management. Based on these results several actions were initiated in the Netherlands and, amongst others, multiple data-driven tools were developed; (i) the voluntary information tool "KalfOK" (Santman-Berends et al., 2018), (ii) national surveillance of calf mortality at herd level (Santman-Berends et al., 2019) and (iii) the implementation of a calf tracking system for veal calves. The aim of these tools was to benchmark calf rearing by several key indicators for performance of young stock, to stimulate dairy farmers to improve young stock husbandry and to consequently reduce calf mortality.

KalfOK is a voluntary data-driven information tool, supported by the dairy industry, in which more than 90 % of Dutch dairy farmers are enrolled to date. It focusses on the improvement of young stock rearing at Dutch dairy farms, with the purpose to optimize animal health and welfare, and to decrease calf mortality (Santman-Berends et al., 2018). It provides farmers with insights in points of improvement for young stock rearing. During the development of the tool, it was demonstrated that a high KalfOK score is associated with a high quality of young stock rearing according to an on-farm veterinary assessment (Santman-Berends et al., 2018).

Since the implementation of KalfOK and other initiatives in 2018, a decline in perinatal calf mortality, postnatal mortality up to 14 days, mortality in dairy calves between 15 and 56 days old and mortality in dairy calves between 56 days and two years old has been seen (Santman-Berends et al., 2021). However, the decline has become less prominent since 2022 and seems to move towards stabilisation. To continue the reduction in calf mortality, it is important to evaluate the current monitoring system and assess characteristics of its users. The objectives of this study were (A) to assess which farm characteristics are related to obtaining a continuously high or a continuously low KalfOK score, and (B) to assess which farmer characteristics are associated with the usage of KalfOK.

2. Material & methods

2.1. Study population

According to the national Identification and Registration system (I&R), the total cattle population in the Netherlands in 2022 comprised of approximately 14,500 dairy herds (Rijksdienst voor Ondernemend Nederland (RVO), Assen, the Netherlands).

2.2. Available data

2.2.1. Part A: herds with a continuously high KalfOK score (Dataset A)

The study population of dataset A consisted of over 90 percent of the Dutch dairy farms (n=13,343) that participate in KalfOK, for which consent for using anonymous data was obtained. KalfOK is in use since 2018. In the first year the number of participants increased quickly. Since 2019, the percentage of KalfOK participants has been stable. Therefore, it was decided to include data from the first quarter of 2019 to the third quarter of 2022 in this study.

For all participating herds, data was available from KalfOK. The KalfOK scoring system and underlying key indicators are described by Santman-Berends et al. (2018). In short; in KalfOK, farmers digitally receive a quarterly report with their herd specific value for 15 key indicators related to calf health (Appendix I) and a benchmark. For twelve out of fifteen key indicators farmers can earn points which together can sum op to a maximum score of 100 points. The sum of these points results is their overall KalfOK score for each quarter of the year. For this study, for each farmer participating in KalfOK, the scores and values for underlying parameters of KalfOK were used (Dataset A) (Fig. 1).

In addition to the KalfOK data, for part A of the study animal movement data was used from the identification and registration system (I&R), which provided information on unique herd identification numbers (UHI's), birth, mortality and animal movement records. Variables that might link data back to the farm were anonymized by an external enterprise specialised in data encryption (IDTS, Deventer, the Netherlands). The same encryption code was used for all data sets to enable combining them.

2.2.2. Part B: survey on the use of KalfOK (Dataset B)

The study population of dataset B consisted of the total dairy population of 14,500 dairy herds. From these, a random selection of 300 Dutch dairy farmers, both participants and non-participants, were targeted. Assuming a response percentage of 25 %, 1200 randomly selected farmers (out of the total dairy farm population) were contacted (Fig. 1) (Dataset B). A questionnaire was developed to assess which farmer characteristics are associated with the usage of KalfOK. Farmers were approached via phone and email in the period February-March 2023. For analysis, data from the following sources were included:

- Survey: Years of working experience, to what extent the farmer is responsible for care of the calves, whether there are people employed at the farm, who is responsible for the youngstock, whether the farmer has given their veterinarian permission to access their KalfOK report and whether KalfOK is discussed with their veterinarian (never/sometimes/regularly).
- KalfOK data: KalfOK score of a farm if the respondent was a KalfOK participant (moving average KalfOK score for 2022).
- Location where a farm is situated (province), milk factory (anonymized), number of calves born in 2022 (as a proxy for farm size), milking system (milking robot present yes/no), all derived from the Cattle Health Surveillance System as described by Santman-Berends et al., (2016).

2.3. Analyses

All data validation and analyses were performed using STATA/SE version 16.1. A first analysis was conducted on dataset A to assess which farm characteristics were associated with having a high or low KalfOK score. Additionally, a second analysis was conducted on the survey data, dataset B, to assess which farmer characteristics are associated with his usage of KalfOK.

2.3.1. Part A: herds with a continuously high KalfOK score (Dataset A)

The aim of the first analysis was to assess which farm characteristics were associated with the probability of belonging to farms with a continuously high or a continuously low KalfOK score, using a matched case-control design. To classify herds as either a herd with a continuously high or low score, first the "annual moving average score", being the average KalfOK score a farm has obtained over the past four quarters, was calculated for four time points (2019, 2020, 2021 and 2022). These annual scores were used instead of the quarterly KalfOK scores to account for seasonality. A case farm was defined as a farm with a continuously high KalfOK score, with "continuously high" being defined as an annual moving average KalfOK score equal to or above the 75th percentile of the study population in at least three out of four selected time points (2019, 2020, 2021 and 2022). This yielded a total of 2247 case farms (Fig. 1). A control farm was defined as a farm with a continuously low KalfOK score, with "continuously low" being an annual moving average KalfOK score equal to or below the 25th percentile of the study population in at least three out of four selected time points (2019, 2020, 2021 and 2022). A total of 2099 control farms were selected (Fig. 1).

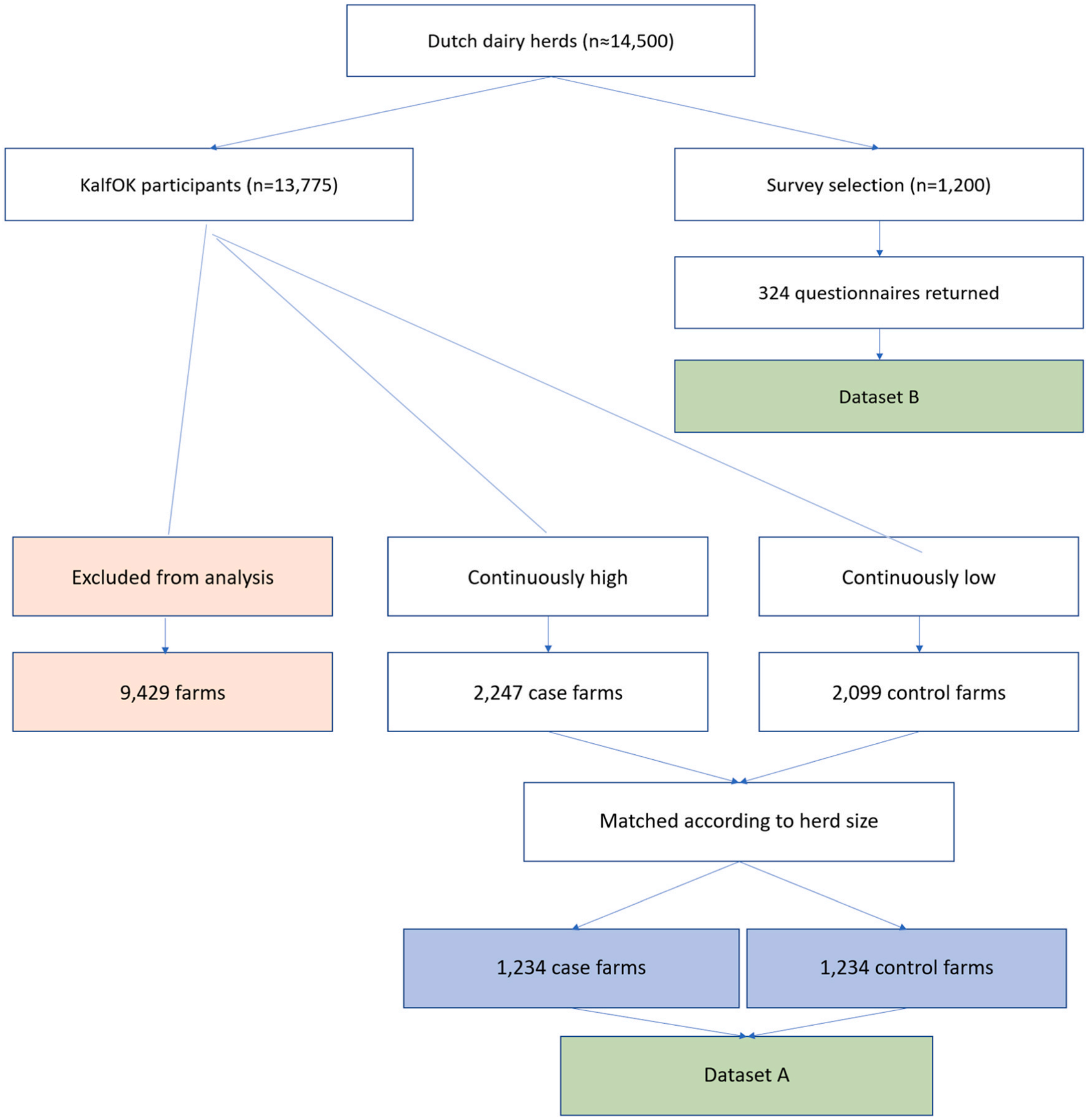

Fig. 1. Overview of the study population, data collection and selection of case and control herds for the multivariable analysis of dataset A and B.

Subsequently, farms in case and control groups were matched according to their herd size, since it is known that herd size is associated with the KalfOK score and this factor was not of interest. Farms were divided into one of four herd size categories. Within each category more cases were present than controls. Thus, a case to control ratio of 1:1 was used in which case farms were matched to a control farm in the same herd size category (Table 1). One case was randomly sampled per control within each herd size category resulting in 1234 case farms and 1234 control farms. (Fig. 1).

Table 1
Frequency of case and control farms per farm size category after being matched according to herd size, based on the farm size in 2019.

Category	Farm size	Frequency case farms	Frequency control farms
1 (<25th percentile)	<63 cows	115	115
2 (>=25th percentile & <50th percentile)	>=63 cows & <96 cows	463	463
3 (>= 50th percentile & < 75th percentile)	>=96 cows & <136 cows	423	423
4 (>= 75th percentile)	>=136 cows	233	233
Total		1234	1234

Farm characteristics obtained via dataset A were used as independent variables for analysis (Appendix II). For the variables “stimulant” (whether they can receive a monetary reward from their dairy company if they have a sufficiently high yearly KalfOK score), “multiple locations”, “import”, “farming system” and “calving pattern”, data of the fourth quarter of 2019, 2020, 2021 and 2022 was used to determine a status per herd for each of these variables. To qualify for a specific status, a variable had to fall within a particular category, such as "closed" or “open” for farming system, for at least three out of the four selected years. If a value did not qualify for these specific categories, meaning that for example it only fell within a certain category for two out of the four selected years, the variable was labelled as “changing over time”. For the continuous variables “replacement rate”, “growth percentage”, “average age of the cows” and “average age of the total number of cattle”, the average of the whole study period was calculated. Based on the result, herds were classified in one of four categories based on quartile values of the study population.

The associations between farm characteristics and KalfOK score status were then analysed using a population averaged conditional multivariable logistic regression model (*clogit*). The model is described as:

$$logit[P(Z_j = 1)] = \mu_j + \mu_1 Prov_j + \mu_2 Stimulant_j + \mu_3 MultLoc_j + \mu_4 ReplaceRate_j + \mu_5 GrowthRate_j + \mu_6 Import_j + \mu_6 Agecows_j + \mu_7 Agecattle_j + \mu_8 CalvPat_j + \mu_9 Farm\ system_j + \varepsilon_j$$

where *Zj* is the dichotomous dependent variable indicating whether farm *j* is a case or control farm; *μj* the intercept for farm *j*; $Prov_j$ the province where farm *j* is located; $Stimulant_j$ whether farm *j* receives a financial incentive for participation in KalfOK (yes/no); $MultLoc_j$ whether farm *j* outsources (yes/no); *ReplaceRatej* the replacement rate (<25th percentile/ 25th-50th percentile/ 50th-75th percentile / >75th percentile) of farm *j*; *GrowthRatej* the growth rate (<25th percentile/ 25th-50th percentile/ 50th-75th percentile / >75th percentile) of farm *j*; *Importj* whether farm *j* imports cattle (yes/no); *Agecowsj* the average age category of cows (<25th percentile/ 25th-50th percentile/ 50th-75th percentile / >75th percentile) at farm *j*; *Agecattlej* the average age category of all cattle (<25th percentile/ 25th-50th percentile/ 50th-75th percentile / >75th percentile) at farm *j*; *CalvPatj* the calving pattern (seasonal/not seasonal) of cows at farm *j*; *Farm systemj* the farming system (open/closed/variable over time) of farm *j*; and *Ɛj* the random error for farm *j*. In the regression analysis, the sample mean was established as reference category for all continuous variables that were categorized, as well as for the variable "province".

All independent variables were subjected to univariable pre-screening of having potential to be included in the subsequent multivariable analysis. Variables with a *p*-value ≤0.20 in the univariable screening were selected for inclusion in the multivariable model. The final multivariable model was obtained using a forward stepwise selection procedure, adding each variable with a univariable *p*-value smaller than 0.05. Confounding of variables was monitored during this procedure by the change in coefficient values. If the change exceeded at least 25 %, or > 0.1 when the value of the coefficient was between −0.4 and 0.4, the added value was considered a potential confounder and re-entered in the model. For all model parameters, a check for collinearity was performed using a correlation matrix. If two variables were highly correlated (>0.50), they were re-entered in the model separately. The variable resulting in the best model fit was included in the final model. In the final model, biologically relevant two-way interactions were tested, and a likelihood ratio test (*lrtest*) was used to assess whether the interaction term improved the model significantly (*p*-value <0,05).

The goodness-of-fit of the final multivariable model was determined by calculation of the accuracy of the model since conventional Pearson or Hosmer-Lemeshow goodness-of-fit tests (*estat gof*) are not available in STATA for conditional logistic regression with a 1:1 matched case-control design. Predicted values for being classified as case or controls were obtained using STATA's predict function using a cut-off value of 0.5. The predicted numbers of cases and controls were compared with the observed numbers using a 2×2 matrix.

2.3.2. Part B: survey on the use of KalfOK (Dataset B)

For the second analysis, survey data was used to assess whether usage of a farm's KalfOK report was associated with the KalfOK score. Usage was defined as whether and how often a farmer looks into their KalfOK overview, divided into frequent usage (regularly/sometimes) and non-frequent usage (never). Survey responses were linked to the KalfOK scores of the respondents, if they participated in KalfOK, and then anonymized. First, answers were analysed descriptively, followed by a logistic regression with "frequent usage of the KalfOK report: yes or no" as the dependent variable. The model is described as:

$$logit[P(Z_j = 1)] = \mu_j + \mu_1 Prov_j + \mu_2 Dairy\ company_j + \mu_3 Nr\ calves_j + \mu_4 Robot_j + \mu_5 KalfOK_j + \mu_6 Veterinarian_j + \mu_6 KalfOKdisc_j + \mu_7 Experience_j + \mu_8 Independent_j + \mu_9 Calves_j + \varepsilon_j$$

where *Zj* is the dichotomous dependent variable indicating whether farmer *j* is a frequent user of their KalfOK overview or not; *Provj* the province where farm *j* is located; $Dairy\ company_j$ the dairy company (anonymized) farmer *j* delivers milk to; $Nr\ calves_j$ the amount of calves born on farm *j* in 2022; $Robot_j$ whether a robot milking system is present at farm *j* (Conventional/Robot/Unknown); $KalfOK_j$ the moving averaged KalfOK score of farm *j* in 2022; $Veterinarian_j$ whether the farmer *j* has provided their veterinarian with permission to access their KalfOK report (Yes/No); $KalfOKdisc_j$ whether the farmer *j* discusses the KalfOK report with their veterinarian (Never/Sometimes/Regularly); $Experience_j$ the work experience of farmer *j* in years; $Independent_j$ whether someone else is also taking care of the cows and calves on farm *j* next to the farmer; $Calves_j$ whether farmer *j* takes care of the preweaned calves by themselves or not; and *Ɛj* the random error for farm *j*.

The model validity was checked using a Pearson or Hosmer-Lemeshow goodness-of-fit test (estat gof) (Hosmer and Lemeshow, 2013), assuming proper goodness-of-fit at p ≥ 0,05.

3. Results

3.1. Part A: Herds with a continuously high KalfOK score (Dataset A)

3.1.1. Descriptive results

The study population consisted of 13,343 Dutch dairy herds in 2022. The average size of all dairy herds that were included in this study was 108 (median 95) cows (≥2 years old) and 25 (median 21) cattle (1–2 years old) in 2022. More descriptive results of these herds can be found in Table 2.

The median KalfOK score of the study population showed a seasonal trend, with the highest scores in spring and the lowest scores in winter months. This seasonal trend is most noticeable in farms with lower KalfOK scores and appears to be less prominent in the higher scoring farms (Fig. 2). An overview of the results of the underlying KalfOK indicators related to successful births and rearing, is provided in Fig. 3. Over time, some of the indicators show an improvement which was also concluded by Santman-Berends et al., (2021).

3.1.2. Multivariable results

Detailed results of univariable farm characteristics that showed potential to be associated (P<0.2) are presented in Appendix II. In short, variables that were excluded from further analysis based on the univariable results include "farm size", "multiple locations" and "calving pattern". The remaining eight variables entered the multivariable model, of which five were significant in the final model: "stimulant", "farm growth percentage", "replacement rate", "farming system" and "province" (Fig. 4). None of the biologically logical interaction terms were significant and were therefore not included in the final model.

Table 2
Description of herd characteristics of the study population of 13,343 Dutch dairy herds in 2022.

Herd characteristic	Mean (median)	10th and 90th percentile
Herd size		
Cows ≥ 2 years old	108 (95)	46 – 184
Youngstock (1–2 years old)	25 (21)	4 – 47
Ear tagged calves < 1 year old	36 (30)	11 – 64
Replacement percentage*	23.6 % (22.6 %)	15.2 % - 32.5 %

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

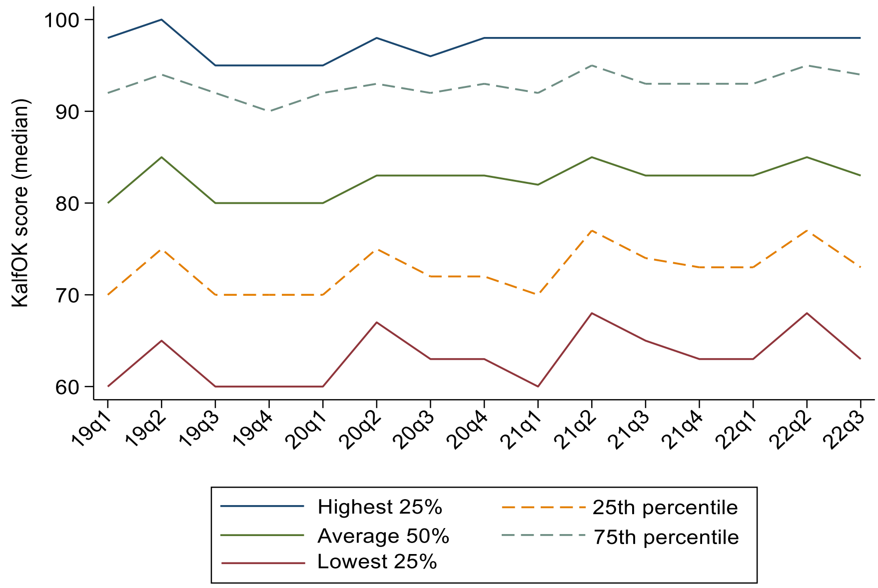

Fig. 2. Median KalfOK score per quarter for the highest scoring 25 %, lowest scoring 25 % and average 50 % of participating herds. The 25th and 75th percentile, determining in which group herds are categorized, are also displayed. Herds can alternate between groups over time.

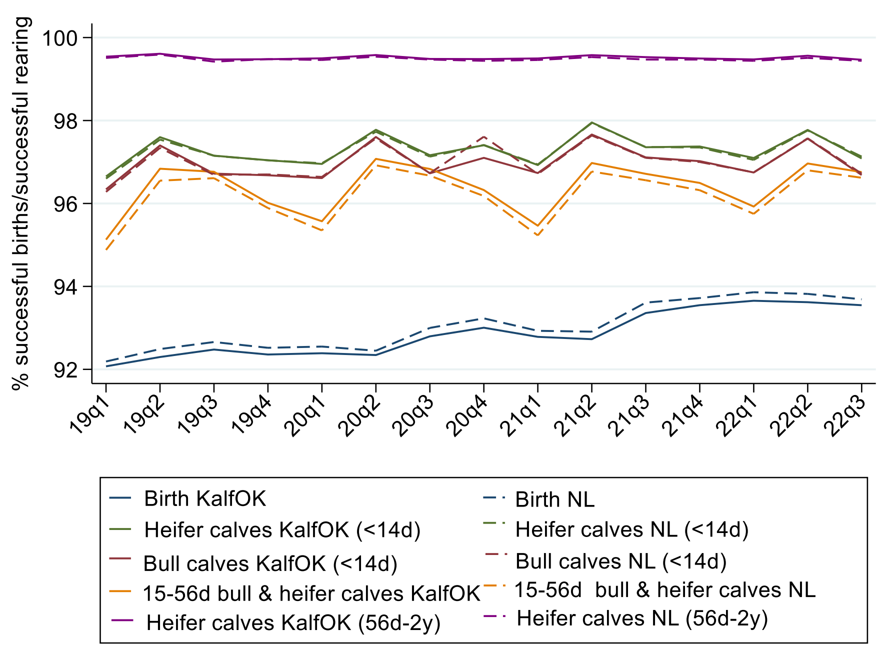

Fig. 3. Average percentage of live births and successful rearing (bull calves <14d, heifer calves <14d, bull & heifer calves 15–56d, heifer calves 56d – 2 y) per quarter (solid line) for all herds participating in KalfOK. The average percentage of live births and successful rearing in all Dutch dairy farms are also displayed as a reference (dashed line).

"Replacement rate", "farming system" and "province" were considered as potential confounders and forced in the model. The classification table to evaluate the distribution of observed and predicted values by the model reached a prediction accuracy rate of 79,7 % indicating an accurate prediction (Table 3) From this we can conclude that the model quality is sufficient and the results thus valid.

Farms not provided with a stimulant to participate/or reach a certain score in KalfOK were 1.7 times less likely to have a continuously high KalfOK score compared to farms that were provided with a stimulant. Farms with a closed farming system had a 2.45 higher odds for belonging to the herds with a continuously high KalfOK score compared to farms with an open farming system. Participating farms with a replacement rate <19.4 % and farms with a replacement rate between 19.4 and 22.4 percent had a higher odds to have a continuously high KalfOK score (OR=2.9 OR=1.3) than farms with a replacement rate between 22.4 and 26.0 percent and farms with a replacement rate >26.0 percent (OR=0.71; OR=0.37). Farms with a growth percentage >3.55 % were less likely to have a continuously high KalfOK score (OR=0.80), while farms with a limited growth in herd size (-0.80 % up to 1.25 %) were more likely to have a continuously high KalfOK score (OR=1.34). Furthermore, the results showed statistically significant regional differences (Fig. 4).

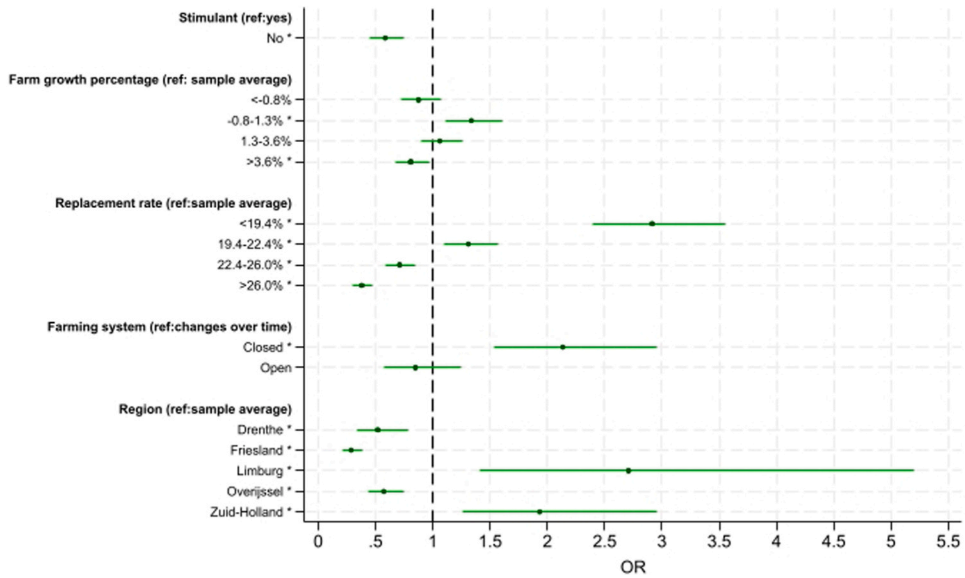

Fig. 4. Significant odds ratios of farm characteristics associated with the probability of having a continuously high KalfOK score. Significant odds ratios are indicated by an asterisk. For the farm characteristic "region" only the significant regions are displayed.

Table 3
- Classification table to evaluate the distribution of observed and predicted values.

Predicted values	Observed values		
	Control	Case	Total
Control	983	249	1232
Case	251	985	1236
Total	1234	1234	2468

3.2. Part B: Farm survey on the use of KalfOK (Dataset B)

3.2.1. Descriptive results

In total, 324 out of the 1200 farmers that were contacted replied (response rate of 27 %) and were included in this part of the study. Of the respondents, 200 were contacted through email, and 124 were contacted via phone. The distribution of the participating herds across the country was representative for all Dutch dairy herds, with a majority being located in the Northern and eastern part of the Netherlands. The majority of the farmers had been farming >20 years. Of the farmers, 63 % used a conventional milking system and 37 % used a milking robot. On average, there were 107 (median: 95) calves born per farm in 2022. This was comparable to the average of 112 (median: 97) births per farm in 2022 for all Dutch dairy farmers. Of the farmers, 92 % reared their own youngstock in comparison to 5 % who outsourced the young stock rearing and 3 % who did not keep any youngstock. The KalfOK scores of the respondents had an annual moving average score of 83 (median: 84, min-max: 37–100) points in the fourth quarter of 2022. This was comparable to the moving average year score of 82 (median: 84, min-max: 28–100) of all KalfOK participants.

Nineteen respondents indicated that they are not enrolled in KalfOK. Of the participating respondents (n=305), 53 percent indicated to frequently use their KalfOK report. Of those frequent users, 57 % used KalfOK to obtain more insight in calf mortality on their farm and 46 % used the report for comparative purposes (to see how their calves were doing compared to calves on other farms). For farmers who indicate frequent use of KalfOK, the majority affirms that their KalfOK score is a good representation of the health of youngstock and calves on their farm. The farmers who indicated that they do not frequently use KalfOK while they did receive the quarterly report and were officially enrolled in the system (44 %), were asked which modification could be made to the system, so that they would start using the reports in their day-to-day management. Part of these farmers (38 %) did not have an answer to this question, or did not see added value in using KalfOK, while 14 % stated that they did not have any problems with their calves and youngstock and where therefore not interested in detailed figures. Four percent of the farmers stated that the availability of the results is not timely enough and 7 % stated only to have a look at the data because it is required by their dairy company.

The majority of the farmers participating in the system discuss their KalfOK report sometimes (48 %) or regularly (16 %) with their veterinarian. There is no significant interaction between the height of a farms' KalfOK score and frequency of usage of the KalfOK overview. Additionally, 71 % of the participating farmers have authorized their veterinarian to access KalfOK, while 23 % does not know whether their veterinarian has access to their report or not (while they are the ones that need to give access to the veterinarians). Farmers who have authorized their veterinarian, discussed their report more regularly with a veterinarian (19 %) compared to farmers who did not know whether their veterinarian is authorized (9 %) (proportion test, $p<0.05$). According to 82 % of the respondents, the health of their calves/youngstock did not improve, since they started participating in KalfOK, while 18 % of farmers indicated that they did see improving health. Of the participating farmers, 34 % indicated to have adjusted their youngstock rearing management since the start of participation, such as improvements in feeding (e.g. colostrum), housing (e.g. ventilation) and/ or vaccinations (of cows and/or youngstock).

3.2.2. Multivariable results

Model results were based on 254/324 complete cases. The Pearson or Hosmer-Lemeshow goodness-of-fit test (estat gof) was sufficient with a goodness-of-fit with $p \geq 0,05$, indicating that the model results are valid. Fig. 5 outlines the results of the regression analysis for the association between farmer characteristics and frequency of usage of the KalfOK reports (Appendix IV). Farmers utilizing a milk robot engage with KalfOK 1.95 times more frequently than those employing conventional milking systems. Farmers who occasionally or regularly discuss KalfOK with their veterinarian exhibit a heightened frequency of KalfOK utilization (OR=3.6 and 2.6, respectively) compared to counterparts who never discuss KalfOK with their veterinarian. A discernible pattern was observed wherein farms with high KalfOK scores, particularly surpassing 80 and 90 points, demonstrate more frequent utilization of KalfOK in

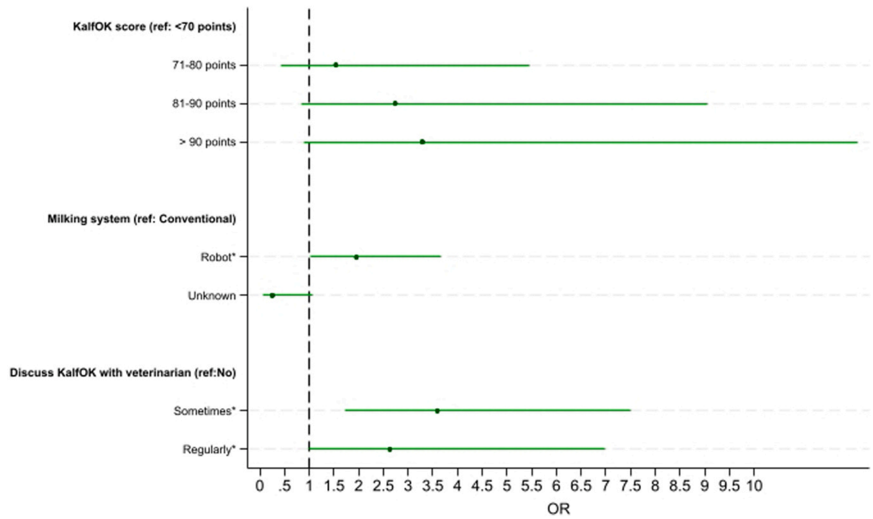

Fig. 5. Odds ratios of farmer characteristics associated with the frequency of usage of a farm's KalfOK report. Only variables with a p-value <0.1 are displayed. Significant odds ratios are indicated by an asterisk.

comparison to farms with lower KalfOK scores (below 70 points) (p-value<0.10). There is no association between the frequency of use of KalfOK and the following farm characteristics: years of experience, whether employees are working at the farm, calf care responsibilities, the number of births at a farm, whether a veterinarian is authorized to see a farmer's KalfOK report, and farm location (province).

4. Discussion

In this study, the data-driven calf rearing monitoring system "KalfOK" was evaluated by assessing its use since 2019 and characteristics of its users. In part A of this study, farms with a continuously high and a continuously low KalfOK score, were compared to assess associated farm characteristics. The results showed multiple factors associated with having a low or high KalfOK score. First, a statistically significant difference in KalfOK score between farms with a low and high replacement rate was found. This finding was in concordance with previous studies that have reported an association between healthy calves, maximized cow health and long-term productivity (Hultgren and Svensson, 2009; De Vries et al., 2011; Soberon et al., 2012), all potentially leading to a lower replacement rate. Herds with a lower replacement rate generally have a closed farming system more often, given there is less need to introduce additional cattle. In our study a closed farming system was also associated with a higher odds of belonging to the group of herds with a continuously high KalfOK score. A closed farming system prevents introductions of infectious diseases such as BVD and IBR (Van Schaik et al., 2001), which would typically lead to more antimicrobial use and higher mortality rates lowering the KalfOK scores. Furthermore, the results showed statistically significant regional differences. Possible explanations for these regional differences could be regional differences in sociological factors, the influence of the dairy processor or an influence of veterinarians. Veterinarians are often perceived as a primary source of information on animal health and welfare by farmers (Gunn et al., 2008; Heffernan et al., 2008; Ellis-Iversen et al., 2010; Vande Velde et al., 2015; Biesheuvel et al., 2021). It may be that there is an association where more active use of KalfOK with follow-up discussion between veterinarians and farmers leads to actions and improved rearing quality. However, this study only evaluated associations and cannot prove causality. Previous engagements with farmers about usage of KalfOK and interactions about it with their veterinarian revealed that there are multiple reasons to not discuss the report with the veterinarian, which range from distrust of the system to no need because the calf rearing is going well and there is no reason to add focus on this part of the management. Therefore, the interaction between veterinarians and farmers, and how to work together and use the KalfOK report to improve calf management warrants more study. Also sociological factors might partly explain the difference between high and low scoring farms. Santman-Berends et al. (2014), showed that the mindset of farmers was associated with calf mortality and thus rearing practices. Additionally, in recent years increasing evidence became available on the influence of factors such as farmers 'perceived risk, perceived knowledge, perceived control, incentivization, emotions and normative beliefs on farmers decision making (Valeeva et al., 2007; Jansen et al., 2009; Shortall et al., 2016; O'Kane et al., 2017; Doidge et al., 2021), while it was previously assumed that farmers' decision making processes were primarily driven by aspects related to financial costs and benefits (Biesheuvel et al., 2021). The regression analysis in part A of this study did not focus on inclusion of the sociological aspects as it evaluated routinely collected data. It is recommended to evaluate the effect of social aspects on calf rearing in future research such as awareness for calf health and welfare.

For part B of this study we assessed which characteristics were associated with KalfOK usage. For this, a random sample of Dutch dairy farms was selected instead of a sample of KalfOK users. This was done because the Dutch interpretation of the GDPR does not allow preselection of herds and because we were interested in the answers of both users and non-users. The included study herds were approached either via an online survey or by phone. It cannot be ruled out that the farmers who replied to the online survey (n=124) are more "data minded", meaning that they get along better and work more with computer systems, than the group approached via phone (n=200). It may be that there are sociological differences between farmers who are more "data-minded" in general compared to farmers who hold back from using data. Furthermore, other farmer characteristics could also potentially influence their KalfOK usage, such as their values, ambitions and intrinsic motivation (Kristensen and Enevoldsen, 2008; Santman-Berends et al., 2014; Biesheuvel et al., 2021). Given the range of constructs existing to impact behavior change, it would be desirable to see if certain interventions (e.g. persuasion, incentivization, changes to environment/social contexts, marketing and communication (Michie et al., 2014)) could persuade farmers to use KalfOK more frequently.

For farmers who indicate active use of KalfOK, the majority affirm that their KalfOK score is a good representation of the health of youngstock and calves on their farm. Furthermore, part B of this study showed that the KalfOK score of farmers who regularly use their KalfOK report, tends to be higher than the KalfOK score of farmers who sometimes or never use KalfOK. It is unknown whether regular use of KalfOK leads to improvements and higher scores or whether farmers with high rearing quality are more motivated to look at KalfOK to check their benchmarking as it reflects their good performance with high scores. Farmers with a low KalfOK score could on the other hand be less motivated to regularly review their report. From part B of this study it cannot be concluded whether a KalfOK score improves due to regular use of the KalfOK report (and awareness of calf rearing quality), or whether a higher score leads to a more frequent use of the report. Thirty four percent of the surveyed farmers made adjustments to their young-stock rearing management since the start of participation. This could indicate an increased awareness of calf rearing quality/welfare amongst these farmers. Approximately half of the surveyed farmers indicated that they do not actively use their KalfOK overview in their calf rearing management. It is important to consider what is needed to convince this group of farmers to actively start using their KalfOK report. This could be achieved by bringing the program under the attention of farmers again, and emphasizing the added value of KalfOK to their rearing management. Veterinarians can also have a contribution in this. Future research incorporating sociological aspects can provide a more comprehensive understanding of how farm characteristics are associated with KalfOK scores and of other dynamics influencing calf rearing and provide valuable insights for enhancing the usage and effectiveness of programs like KalfOK in promoting calf health and welfare.

To conclude, part A this study shows differences in farm characteristics between herds with a continuously high and continuously low KalfOK score. Part B showed several farmer characteristics which were associated with a farmer's level of KalfOK usage. The study's insights into patterns in KalfOK utilization and associations with farm characteristics provide valuable information for ongoing efforts to enhance calf rearing practices via the use of KalfOK. Future research incorporating sociological aspects can provide a more comprehensive understanding of other dynamics influencing calf rearing and contribute valuable insights for enhancing the effectiveness of programs like KalfOK in promoting calf health and welfare.

CRediT authorship contribution statement

Gustavo A. Monti: Writing – review & editing, Supervision, Conceptualization. **Lourens Heres:** Writing – review & editing. **Thomas Dijkstra:** Writing – review & editing. **Inge M.G.A. Santman-Berends:** Writing – review & editing, Supervision, Conceptualization. **Cathérine E. Paarlberg:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Conceptualization. **Anouk Veldhuis:** Writing – review & editing, Supervision, Conceptualization.

Declaration of Competing Interest

None

Acknowledgements

This study was financed by the producer organization for dairy (ZuivelNL, The Hague, the Netherlands). We acknowledge all farmers, veterinarians, and stakeholders [Dutch Federation of Agriculture and Horticuliture (LTO), The Hague, the Netherlands; The Dutch Dairy Association (NZO), The Hague, the Netherlands; Sustainable Dairy Association (DZK), The Hague, the Netherlands] that participated in the development of KalfOK.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevtmed.2024.106312.

References

Biesheuvel, M.M., Santman-Berends, I.M.G.A., Barkema, H.W., Ritter, C., Berezowski, J., Guelbenzu, M., Kaler, J., 2021. Understanding farmers' behavior and their decision-making process in the context of cattle diseases: a review of theories and approaches. Front. Vet. Sci. 8, 687–699. https://doi.org/10.3389/fvets.2021.687699.

De Vries, M., Bokkers, E.A.M., Dijkstra, T., Van Schaik, G., De Boer, I.J.M., 2011. Invited review: Associations between variables of routine herd data and dairy cattle welfare indicators. J. Dairy Sci. 94, 3213–3228. https://doi.org/10.3168/jds.2011-4169.

Doidge, C., Ferguson, E., Lovatt, F., Kaler, J., 2021. Understanding farmers' naturalistic decision making around prophylactic antibiotic use in lambs using a grounded theory and natural language processing approach. Prev. Vet. Med. 186, 105–226. https://doi.org/10.1016/j.prevetmed.2020.105226.

Ellis-Iversen, J., Cook, A.J.C., Watson, E., Nielen, M., Larkin, L., Wooldridge, M., 2010. Perceptions, circumstances and motivators that influence implementation of zoonotic control programs on cattle farms. Prev. Vet. Med. 93, 276–285. https://doi.org/10.1016/j.prevetmed.2009.11.005.

Gunn, G.J., Heffernan, C., Hall, M., McLeod, A., Hovi, M., 2008. Measuring and comparing constraints to improved biosecurity amongst GB farmers, veterinarians and the auxiliary industries. Prev. Vet. Med. 84, 310–323. https://doi.org/10.1016/j.prevetmed.2007.12.003.

Heffernan, C., Nielsen, L., Thomson, K., Gunn, G., 2008. An exploration of the drivers to bio-security collective action among a sample of UK cattle and sheep farmers. Prev. Vet. Med. 87, 358–372. https://doi.org/10.1016/j.prevetmed.2008.05.007.

Hosmer, D.W., Lemeshow, S., 2013. Applied Logistic Regression. Wiley, New York.

Hultgren, J., Svensson, C., 2009. Heifer rearing conditions affect length of productive life in Swedish dairy cows. Prev. Vet. Med. 89, 255–264. https://doi.org/10.1016/j.prevetmed.2009.02.012.

Jansen, J., van den Borne, B.H.P., Renes, R.J., van Schaik, G., Lam, T.J.G.M., Leeuwis, C., 2009. Explaining mastitis incidence in Dutch dairy farming: the influence of farmers' attitudes and behaviour. Prev. Vet. Med. 92, 210–223. https://doi.org/10.1016/j.prevetmed.2009.08.015.

Kelly, P.C., More, S.J., Blake, M., Higgins, I., Clegg, T., Hanlon, A., 2013. Validation of key indicators in cattle farms at high risk of animal welfare problems: a qualitative case-control study. Vet. Rec. 172 https://doi.org/10.1136/vr.101177.

Klein-Jöbstl, D., Iwersen, M., Drillich, M., 2014. Farm characteristics and calf management practices on dairy farms with and without diarrhea: A case-control study to investigate risk factors for calf diarrhea. J. Dairy Sci. 97, 5110–5119. https://doi.org/10.3168/jds.2013-7695.

Kristensen, E., Enevoldsen, C., 2008. A mixed methods inquiry: How dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program. Acta Vet. Scand. 50, 1–12. https://doi.org/10.1186/1751-0147-50-50.

Mee, J.F., Berry, D.P., Cromie, A.R., 2008. Prevalence of, and risk factors associated with, perinatal calf mortality in pasture-based Holstein-Friesian cows. Animal *2*, 613–620. https://doi.org/10.1017/S1751731108001699.

Michie, S., Atkins, L., West, R., 2014. The Behaviour Change Wheel: A Guide to Designing Interventions. Silverback Publishing, London.

O'Kane, H., Ferguson, E., Kaler, J., Green, L., 2017. Associations between sheep farmer attitudes, beliefs, emotions and personality, and their barriers to uptake of best practice: the example of footrot. Prev. Vet. Med. 139, 123–133. https://doi.org/10.1016/j.prevetmed.2016.05.009.

Ortiz-Pelaez, A., Pritchard, D.G., Pfeiffer, D.U., Jones, E., Honeyman, P., Mawdsley, J.J., 2008. Calf mortality as a welfare indicator on British cattle farms. Vet. J. 176, 177–181. https://doi.org/10.1016/j.tvjl.2007.02.006.

Sandgren, C.H., Lindberg, A., Keeling, L.J., 2009. Using a national dairy database to identify herds with poor welfare. Anim. Welf. 18, 523–532. https://doi.org/10.1017/S0962728600000944.

Santman-Berends, I.M.G.A., Brouwer, H., ten Wolthuis-Bronsvoort, A., De Bont-Smolenaars, A.J.G., Haarman-Zantinge, S., van Schaik, G., 2018. Development of the Young stock Rearing Quality score system: an objective and uniform scoring method to evaluate the quality of rearing in Dutch dairy herds. J. Dairy Sci. 101, 8383–8395. https://doi.org/10.3168/jds.2018-14460.

Santman-Berends, I.M.G.A., Brouwer-Middelesch, H., Van Wuijckhuise, L., de Bont-Smolenaars, A.G.J., Van Schaik, G., 2016. Surveillance of cattle health in the Netherlands: Monitoring trends and developments using routinely collected cattle census data. Prev. Vet. Med. 134, 103–112. https://doi.org/10.1016/j.prevetmed.2016.10.002.

Santman-Berends, I.M.G.A., Buddiger, M., Smolenaars, A.J.G., Steuten, C.D., Roos, C.A., Van Erp, A.J., Van Schaik, G., 2014. A multidisciplinary approach to determine factors associated with calf rearing practices and calf mortality in dairy herds. Prev. Vet. Med. 117, 375–387. https://doi.org/10.1016/j.prevetmed.2014.07.011.

Santman-Berends, I.M.G.A., Nijhoving, G.H., van Wuijckhuise, L., Muskens, J., Bos, I., van Schaik, G., 2021. 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. Prev. Vet. Med. 191, 105344 https://doi.org/10.1016/j.prevetmed.2021.105344.

Santman-Berends, I.M.G.A., Schukken, Y.H., van Schaik, G., 2019. Quantifying calf mortality on dairy farms: challenges and solutions. J. Dairy Sci. 102, 6404–6417. https://doi.org/10.3168/jds.2019-16381.

Shortall, O., Ruston, A., Green, M., Brennan, M., Wapenaar, W., Kaler, J., 2016. Broken biosecurity? Veterinarians' framing of biosecurity on dairy farms in England. Prev. Vet. Med. 132, 20–31. https://doi.org/10.1016/j.prevetmed.2016.06.001.

Soberon, F., Raffrenato, E., Everett, R.W., Van Amburgh, M.E., 2012. Preweaning milk replacer intake and effects on long-term productivity of dairy calves. J. Dairy Sci. 95, 783–793. https://doi.org/10.3168/jds.2011-4391.

Torsein, M., Lindberg, A., Sandgren, C.H., Waller, K.P., Törnquist, M., Svensson, C., 2011. Risk factors for calf mortality in large Swedish dairy herds. Prev. Vet. Med. 99, 136–147. https://doi.org/10.1016/j.prevetmed.2010.12.001.

Valeeva, N.I., Lam, T.J.G.M., Hogeveen, H., 2007. Motivation of dairy farmers to improve mastitis management. J. Dairy Sci. 90, 4466–4477. https://doi.org/10.3168/jds.2007-0095.

Van Schaik, G., Nielen, M., Dijkhuizen, A.A., 2001. An economic model for on-farm decision support of management to prevent infectiuous disease introduction into dairy farms. Prev. Vet. Med. 51, 289–305. https://doi.org/10.1016/S0167-5877(01)00224-0.

Vande Velde, F., Claerebout, E., Cauberghe, V., Hudders, L., Van Loo, H., Vercruysse, J., 2015. Diagnosis before treatment: identifying dairy farmers' determinants for the adoption of sustainable practices in gastrointestinal nematode control. Vet. Parasitol. 212, 308–317. https://doi.org/10.1016/j.vetpar.2015.07.013.