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Effect of farm and animal-level factors on youngstock mortality and growth on calf rearing farms

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ABSTRACT

Both calf mortality and daily weight gain have a crucial impact on profitability of calf rearing farms. In addition, high calf mortality rates represent an animal welfare problem. Mortality rates on calf rearing farms have been reported in several studies in different countries, but scant data regarding daily weight gain of the calves are available. The objectives of this observational retrospective study were to determine the average mortality and daily weight gain of calves and youngstock on Finnish calf rearing farms and to identify factors associated with these production parameters. National cattle register and national herd health register databases together with meat companies' databases were used to collect weight, age, breed, medication, and origin farm data for 28 228 calves transported to the 87 calf rearing farms between 1 January and 1 October 2016. A telephone questionnaire was completed by selected farms to collect management and farm-specific data.

Calves were retrospectively followed for maximum 180 days since arrival to the farm. Average arrival age of the calves were 24 days (SD 14). Average calf mortality on Finnish calf rearing farms was 4.5 %. Mortality was 5.3 % on fattening farms buying milk calves, 4.6 % on specialized calf rearing farms, and 2.5 % on fattening farms buying weaned calves. Size of the calf rearing farms varied, being smallest on fattening farms for weaned calves and largest on specialized calf rearing farms. Average daily gain of the study calves was 1.074 kg/day (SD 0.166). Multilevel mixed effects logistic and linear regression models, where herd and calf batch were used as random effects, were generated to study calf level mortality and daily gain, respectively. Activities preventing transmission of pathogens between arrival batches and different age groups of animals, including application of the all in/all out principle and proper washing and disinfection of compartments for milk feeding calves between arrival batches, were associated with lower mortality and increased daily gain. In addition, higher arrival age was associated with lower mortality during the rearing period and relatively higher arrival age of the calf, compared to other calf in a same arrival batch, was associated with higher daily gain. By contrast, increased number of individual medications during the rearing period was associated with both increased mortality and decreased daily gain. There was no significant difference in mortality between farm types. Current study highlights several factors that can be affected in future to further develop the beef production chain.

1. Introduction

Low mortality and good growth rates are two fundamental components of successful beef production. In addition to direct economic impact, high mortality represents also an animal welfare issue (Ortiz-Pelaez et al., 2008). Public concern of animal welfare and excessive use of antibiotics in meat production forces the industry to introduce new practices to enhance animal welfare in the beef production chain

Abbreviations: BRD, bovine respiratory disease; NSAID, non-steroidal anti-inflammatory drug.

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(Spooner et al., 2014). Bovine respiratory disease (BRD) may be caused by several different pathogens and is one of the most common causes of increased mortality on calf rearing farms (Bähler et al., 2012; Lava et al., 2016b). Earlier studies have shown an association between calf mortality on calf rearing farms and several individual and environmental factors, including breed (Lava et al., 2016b), weight, clinical condition and dehydration status of the calf upon arrival to the farm (Renaud et al., 2018a), calf vaccination status against BRD (Lava et al., 2016b), calf serum immunoglobulin-G level on arrival (Renaud et al., 2018b), calf group size at the calf rearing farm and weight dispersion within the group (Lava et al., 2016b), and too high or low temperature inside the rearing unit (Egberts et al., 2019).

Despite the large volume of veal calf meat produced in Europe and North America, data on management factors associated with calves' growth performance are scant. One study demonstrated the negative impact of BRD and diarrhea on hot carcass weight of veal calves in slaughter (Pardon et al., 2013). Renaud et al. (2018c) described a positive association between higher arrival weight of calves and daily weight gain. They also described a negative association between dehydration of calves on arrival and future daily gain. In addition, increased concentration of acute phase protein (serum amyloid A) in calf serum on arrival has been associated with decreased daily gain on the calf rearing farm (Seppä-Lassila et al., 2018).

Finnish beef production and calf rearing farms differ from common veal calf operations in other countries. In Europe, veal calves are traditionally slaughtered at the age of 6–8 months (Pardon et al., 2013). In Finland, calves directed to beef production are reared until an average age of 18–20 months before slaughter (Haapala et al., 2019). Beef production in Finland is mainly based on bull calves and beef breed crossbred heifer calves born on dairy farms. Two-thirds of these calves are transported to specialized calf rearing farms at the age of 10–30 days. Calves are reared on these specialized farms for 4–6 months before further transportation to separate finishing farms, where heifers are fattened for 6–10 months and bulls for 12–16 months. The remainder (one-third) of the calves are transported either as milk calves at an age of 10–30 days or after weaning straight to the fattening farms rearing cattle until slaughter. The meat companies in Finland organize animal transportations between farms. On calf rearing farms, calves are reared in groups of varying size, not in individual pens. Conventionally, calves are weaned from milk at the age of 50–70 days. After weaning some of the farms feed calves with total mixed ratio and others allow calves free access to silage and provide separately concentrates two times a day.

The primary objectives of this study were to determine the overall mortality and daily weight gain of calves on Finnish calf rearing farms and to evaluate the associations of different farm and calf-specific factors on these variables. By identifying these factors and actively influencing them, it is possible to increase animal welfare alongside economic profitability of the entire beef production chain.

2. Materials and methods

2.1. Study population and study design

An observational retrospective study was designed to determine the average mortality and daily weight gain of calves on Finnish calf rearing farms and to examine the factors associated with these outcomes. The majority of Finnish beef producers have a contract with one of the three large meat companies in Finland. Study farms were selected among all contract farmers of these companies. The number of study farms was divided evenly between the meat companies. Random sampling was stratified based on the proportion of different calf rearing types in Finland (specialized calf rearing farms, fattening farms buying milk calves, fattening farms buying weaned calves). If the number of the meat company's contract farms was too small to fill the predetermined sample size, missing farms were compensated by including more farms of the same farm type from the other two meat companies. If the meat company had more contract farms than needed to fulfil the sample size, a lottery was conducted by one of the study group members to select the study farms among the contract farms. As inclusion criteria, farms needed to have settled production without any major changes in farm facilities or calf management practices during the study period (1 January to 1 October 2016) and to receive more than 50 calves per year. In total, our stratified sample consisted of 155 calf rearing farms, including 65 specialized calf rearing farms, 60 fattening farms buying milk calves, and 30 fattening farms buying weaned calves. Geographical location of the farms varied and did not affect the selection process.

Selected farms were first approached by letter and asked to contact the meat company if they were unwilling to participate in the study. Only 7 out of 155 farms refused to participate and provide farm data for study purposes. Two farms were excluded from the study due to incomplete registry data. In addition, one farm received only calves older than 150 days and was excluded. The rest of the farms (145/155) were telephoned by the study veterinarian to conduct the questionnaire. Four farmers were reluctant to answer the questionnaire and were excluded. Of the remaining 141 farms, 54 farms were excluded from the study because accurate medication data were unavailable or the farmer was reluctant to make the extra effort to deliver the study data. In total, 87 calf rearing farms fulfilled the inclusion criteria and were included in the final study sample.

In total, 28 687 calves were transported to the selected 87 calf rearing farms between 1 January and 1 October 2016. From these calves, 365 were excluded from the data due to later transportation time (≥60 days in specialized calf rearing farms and fattening farms for milk calves, ≥180 days in fattening farms for weaned calves). Five farms had dairy cattle or suckler cows in addition to calf rearing facilities. Heifer calves born in these dairy herds and all calves born in suckler herds, in total 66 calves, were excluded from the study. In addition, 19 calves were excluded from the study because the rearing period was less than 60 days. Eight calves were excluded because of unexplained arrival age of zero days and one calf because of implausible daily weight gain. Calves arriving to the same farm were assigned retrospectively to a certain batch according to arrival dates and questionnaire results. In total, 28 228 calves were included in the final sample.

The final study sample included 45 specialized calf rearing farms with 23 946 calves, 28 fattening farms buying milk calves with 3746 calves, and 14 fattening farms buying weaned calves with 536 calves. Mortality, medications, and daily weight gain of these calves were retrospectively followed for 180 days (starting from day of arrival to the calf rearing farm) or until further transportation or death of the calf, whichever came first. Calves were individually weighed on the scales of the truck by the carrier before every transportation. Daily weight gain was only available for 21 087 calves with a second weight measurement at a maximum of 180 days from arrival to the farm.

2.2. Data collection

The questionnaire was designed to examine overall calf management and medication policy followed on the study farms. It was proofread beforehand by several experts (herd health veterinarians and a farm management adviser) and piloted by comparing the questionnaire results of five farms to the pre-checked reality on these farms. After validation, the project veterinarian telephoned the contact person of each farm and presented the questionnaire. The questionnaire comprised 49 closed questions, and response to the questionnaire took 15–30 min. Questions were divided into four sections: overall management on the farm, management of calves in milk feeding, management of calves after weaning, and policies related to use of medications and treatments. Predictors related to milk feeding were not available for farms buying weaned calves. In the questionnaire, milk feeding compartments referred to the sections of the barn that were separated from each other with walls. In these milk feeding compartments, calves were kept either in a single or several separate pens. Size of the calf farm (herd size) in the year 2016 was inquired from the farmer as part of the questionnaire (maximum number of cattle on the farm simultaneously).

Calves were identified by EU identification number. Individual calf-level data (calf breed, sex, birthdate, date of arrival and further transportation, and possible date and cause of removal from the herd) together with the calf origin farm data (size of the origin farm and calf mortality on the origin farm (until the age of six months, stillborns included)) were collected from the national cattle register. In the national cattle register, crossbred calves are registered according to their sire's breed. Size of the origin farms of the calves was presented as the average number of animals at the farm in the year 2016. Calves removed from the herd because of death or euthanasia were used to calculate mortality in calf rearing farms.

Data on weight of the calves were collected from the meat companies' databases. All calves were weighed at arrival to the calf rearing farm and again at the time of possible further transportation to the finishing farm. Daily weight gain was calculated for 21 087 calves that were reared in specialized calf rearing farms and had two separate weight measurements a minimum of 60 days and a maximum of 180 days apart.

Availability of accurate medication records of the calves was queried in the questionnaire. All medication records were collected for all individual calves arriving at the farms between 1 January and 1 October 2016. Accurate electronic individual medication data of 66 farms were available and collected from the databases of the national cattle register and national cattle herd health register (Naseva). In addition, medication data of 21 farms were kept as paper records, and thus, collected via email, mail, or visiting the farm. All collected medication data were combined into one spreadsheet. Before the combination, all medications other than antibiotics or non-steroidal anti-inflammatory drugs (NSAIDs) were deleted from the data (*e.g.* vaccines, antiparasitic medicines). In addition, all the medication given more than 180 days from calf arrival to the calf rearing farm were deleted. Electronic medication records collected from the databases included information about the medicine used, date of medication, amount of medicine used, length of treatment course, indication for treatment, and identification of the medicine giver in addition to the EU identification number of the medicated calf. All medication records separately collected from the farms included at least the information about the medicine used, date of medication, indication for medication, and EU identification number of the medicated calf. Number of overall medications given to each calf was calculated so that medications were calculated as separate if there was at least seven days between the given medications regardless of the medicine used. All collected data (questionnaire, register data, weight data, and medication data) were combined into one spreadsheet.

2.3. Statistical analysis

The sample size was calculated so that it allowed us to detect less than 1 % difference in daily weight gain and mortality of calves with a power of 0.9 and a significance level of 0.05 when taking into account clustering within herds (ICC = 0.1). All statistical analyses were performed in Stata/MP 14.1 for Windows (StataCorp LP, Texas, USA).

Individual calf was used as the experimental unit in statistical analysis. Descriptive statistics were calculated separately at both farm and calf level as presented in Tables 1 and 2. Chi-square test was used to compare categorized variable about the average number of calves reared in milk feeding compartments between different farm types. Outcome variables were daily gain (calves with two weight measurements) and calves' death (0/1) during the rearing period (all calves). Univariable analysis was performed on 21 calf- and farm-level predictor variables before modelling (Tables 1 and 2). Breed of calf was categorized so that rarer breeds, including Brown Swiss, crossbred Hereford, crossbred Charolais, crossbred Simmental, Highland, Jersey, Montbéliard, and rural Finnish cattle, were combined into one category termed other breed. More common breeds of Ayrshire, Holstein, crossbred Limousine, crossbred Blonde d'Aquitaine, and crossbred Aberdeen Angus were treated as their own breeds. Both herd size of the rearing farm and herd size of the calf's origin farm were presented in analysis as divided by 100 to clarify the results. For the clarification of the results, also calf mortality on the origin farm was categorized into four categories so that as even number of observations as possible were categorized to each category. Variables such as number of calves in milk-feeding compartments and size of calf groups in milk feeding compartments were categorical based on the questionnaire (Table 1). Univariable analysis was conducted using mixed linear regression analysis for the daily gain and mixed logistic regression analysis for mortality. Daily weight gain of the calves was normally distributed. Rearing farm and arrival batch of the calf were used as grouping variables in both univariable analyses. A predictor variable tested in univariable analysis was selected to the multivariable models if it was associated with the outcome variable at $p < 0.2$. If the correlation coefficient between two significant predictor variables was > 0.6, only the biologically more meaningful predictor was used in the model.

Multilevel mixed-effects logistic regression model for mortality and multilevel mixed-effects linear regression model for daily gain were constructed stepwise-backwards, excluding the non-significant variables. Finally, seven independent factors were included in the mortality model and 14 in the daily weight gain model (Tables 4 and 5). Clustering of the collected data at meat company-, farm-, and arrival batch levels was taken into account in the models used. Arrival batch and rearing farm were both used as random variables, whereas meat company was used as a fixed effect in the models. The significance level was set at $p < 0.05$ in both models. All biologically significant interactions were scrutinized by adding interaction terms to the models. None of these seemed to have a marked effect, and no interaction terms were included in the models. Besides that, random slopes were considered when non-additive herd effects were estimated. However, no random slopes seemed justified to be included to the models. Possible confounders observed from composed causal diagrams were tested in both models. Age and breed of the arriving calves and number of animals per farm were forced into both models to control the confounding effect. Farm type did not have marked effect on any coefficient so it was dropped from the models. Arrival weight and age of the calf were strongly correlated (correlation coefficient 0.73). Arrival age was retained in the analysis instead of arrival weight due to its better clinical usability in the future. Due to contextual effect between predictor variables "arrival age of the calf" and "average arrival age of the calves in a same arrival batch", we reformulated the subject-level variable "calf arrival age" as a within-group "average arrival age of calves in same arrival batch" centered version of the variable to avoid collinearity and improve interpretability (Dohoo et al., 2014). In the multilevel mixed-effects logistic regression model for calf mortality, 27 692 calves were included in the model and 536 calves were excluded due to missing milk feeding compartment management data. By contrast, 19 791 calves were included in the multilevel mixed-effects linear regression model for daily gain and 8437 calves were excluded due to missing or incomplete data of origin farm herd size (two calves), calf management at the farm (1294 calves), or weight (7141 calves). Final multilevel mixed-effects logistic regression model for mortality included only calves reared in specialized calf rearing farms and fattening farms for milk calves and multilevel mixed-effects linear regression model for daily gain included only calves reared in specialized calf rearing farms.

For brief model diagnostics, the basic assumptions of both models were inspected regarding data structure and nature of the outcome variables. In addition, residuals were scrutinized at different levels of models. Logistic regression model fit was assessed visually by plotting the predicted successes against the observed successes. No serious breaches of the underlying assumptions were detected. Furthermore, the area under the ROC curve (0.75) was evaluated to assess predictive ability of logistic model.

Statistical differences in calf mortality between calves excluded (n =

Table 1
Descriptive statistics of categorical variables of 28 228 calves on 87 farms and univariable associations of predictor and outcome variables of mortality and daily gain. Milk feeding variables are only available for specialized calf rearing farms and integrated beef production farms. Daily gain has been calculated for calves with two weight measurements.

Variable	Total Calves / Farms	Proportion (%) Calves / Farms	Mortality				Daily gain			
			n	%	p-value	Missing	n	kg/ day	p-value	Missing
Farm type										
Specialized calf rearing farms	23,946 / 45	84.8 / 51.7	1066	4.5	ref.	0	21,014	1.074	ref.	2932
Fattening farms buying milk calves	3746 / 28	13.3 / 32.2	189	5.0	0.982	0	0	–	–	3746
Fattening farms buying weaned calves	536 / 14	1.9 / 16.1	15	2.8	0.087	0	0	–	–	536
Sum:	28,228 / 87	100 / 100	1270			0	21,014			7214
Missing:	0 / 0	0 / 0								
Wald-test:					0.217				0.378	
Contract meat company										
Company A	18,304 / 40	64.8 / 46.0	913	5.0	ref.	0	14,867	1.076	ref.	3437
Company B	7819 / 39	27.7 / 44.8	264	3.4	0.108	0	4605	1.073	0.059	3214
Company C	2105 / 8	7.5 / 9.2	93	4.4	0.400	0	1615	1.065	0.653	490
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Wald-test:					0.189				0.114	
Self-collecting calves*										
No	24,697 / 67	87.5 / 77.0	1123	4.5	ref.	0	18,469	1.080	ref.	6228
Yes	3531 / 20	12.5 / 23.0	147	4.2	0.457	0	2618	1.035	0.122	913
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Calf mortality on origin farm										
0–2%	4463 / -	15.8 / -	192	4.3	ref.	0	3231	1.067	ref.	1232
2.1–5.9 %	8617 / -	30.5 / -	389	4.5	0.319	0	6354	1.070	<0.001	2263
6–9.9 %	7435 / -	26.3 / -	314	4.2	0.865	0	5637	1.075	<0.001	1798
10% or more	7713 / -	27.4 / -	375	4.9	0.198	0	5865	1.083	<0.001	1848
Sum:	28,228 / -	100 / -	1270			0	21,087			7141
Missing:	0 / -	0 / -								
Wald-test:					0.272				<0.001	
Calf breed										
Ayrshire	10,818 - /	38.3 / -	577	5.3	ref.	0	7884	1.063	ref.	2934
Holstein	11,405 / -	40.4 / -	349	3.1	<0.001	0	8655	1.099	<0.001	2750
Crossbred Aberdeen Angus	1111 / -	3.9 / -	35	3.2	0.001	0	840	1.061	0.162	271
Crossbred Blonde d'Aquitane	2563 / -	9.1 / -	145	5.7	0.569	0	1961	1.033	<0.001	602
Crossbred Limousine	1331 / -	4.7 / -	131	9.8	<0.001	0	988	1.018	<0.001	343
Other breeds	1000 / -	3.5 / -	33	3.3	0.016	0	759	1.103	<0.001	241
Sum:	28,228/ -	100 /-	1270			0	21,087			7141
Missing:	0 / -	0 / -								
Wald-test:					<0.001				<0.001	
Number of calves in one milk feeding compartment										
1–20 calves	1014 / 11	3.6 / 15.1	56	5.5	ref.	0	279	0.943	ref.	735
21–40 calves	6272 / 28	22.7 / 38.3	292	4.7	0.580	0	3957	1.073	0.125	2315
41–80 calves	17,098 / 27	61.7 / 37.0	757	4.4	0.928	0	13,966	1.069	0.032	3132
81–100 calves	3308 / 7	12.0 / 9.6	150	4.5	0.604	0	2885	1.115	0.005	423
Sum:	27,692 / 73	100 / 100	1255			0	21,087			6605
Missing:	536 / 14	0 / 0								
Wald-test:					0.672				0.017	
Size of calf groups in milk feeding compartments										
More than 30 calves	13,079 / 23	47.2 / 31.5	567	4.3	ref.	0	10,296	1.101	ref.	2783
1–10 calves	516 / 4	1.9 / 5.5	19	3.7	0.375	0	331	1.055	0.969.	185
11–20 calves	4437 / 25	16.0 / 34.2	215	4.9	0.626	0	2280	1.042	0.004	2157
21–30 calves	9660 / 21	34.9 / 28.8	454	4.7	0.171	0	8180	1.050	0.004	1480
Sum:	27,692 / 73	100 / 100	1255			0	21,087			6605
Missing:	536 / 14	0 / 0								
Wald-test:					0.513				0.006	
Milk feeding compartments operated as all in/all out										
Yes	26,145 / 63	94.4 / 86.3	1126	4.3	ref.	0	20,297	1.074	ref.	5848
No	1547 / 10	5.6 / 13.7	129	8.3	0.003	0	790	1.081	0.244	757
Sum:	27,692 / 73	100 / 100	1255			0	21,087			6605
Missing:	536 / 14	0 / 0								
Cleaning the milk feeding compartment between batches										
Washing and disinfection	17,093 / 40	61.7 / 54.8	740	4.3	ref.	0	13,252	1.072	ref.	3841
Washing	9402 / 25	34.0 / 34.2	438	4.7	0.325	0	7115	1.085	0.793	2287
Mechanical cleaning	1161 / 7	4.2 / 9.6	77	6.6	0.527	0	684	1.014	0.907	477
No cleaning	36 / 1	0.1 / 1.4	0	0	omitted	36	36	0.913	0.141	0
Sum:	27,692 / 73	100 / 100	1255			36	21,087			6605
Missing:	536 / 14	0 / 0								
Wald-test:					0.419				0.488	
Separate air space from older calves										
Yes	10,630 / 43	38.9 / 59.7	479	4.5	ref.	0	7310	1.068	ref.	3320
No	16,700 / 29	61.1 / 40.3	764	4.6	0.434	0	13,425	1.078	0.137	3275
Sum:	27,330 / 72	100 / 100	1243			0	20,735			6595

(*continued on next page*)

Table 1 (*continued*)

Variable	Total Calves / Farms	Proportion (%) Calves / Farms	Mortality				Daily gain			
			n	%	p-value	Missing	n	kg/day	p-value	Missing
Missing:	898 / 15	0 / 0								
Location in the farm										
Separate buildings for milk feeding calves, weaned calves, and finishing cattle	3767 / 6	13.8 / 8.3	121	3.2	ref.	0	2701	1.120	ref.	1066
Separate building only for milk feeding calves	1913 / 9	7.0 / 12.5	84	4.4	0.706	0	1242	1.098	0.471	671
Milk feeding calves in same building with older calves, but with separate air space	12,074 / 36	44.2 / 50.0	525	4.3	0.944	0	8858	1.073	0.077	3216
Milk feeding calves in same building and compartment with older calves with air connection	8669 / 14	31.8 / 19.5	426	4.9	0.582	0	7724	1.054	0.161	945
All animals in same compartment	867 / 7	3.2 / 9.7	87	10.0	0.030	0	229	1.105	0.551	638
Sum:	27,290 / 72	100 / 100	1243			0	20,754			6536
Missing:	938 / 15	0 / 0								
Wald-test:					0.098				0.120	
Handling of calves after weaning										
Calves relocated to new compartment	19,647 / 54	78.5 / 79.4	774	3.9	ref.	0	14,371	1.070	ref.	5276
Calves remain in same compartment	6679 / 14	21.5 / 20.6	385	5.8	0.039	0	5755	1.081	0.005	924
Sum:	26,326 / 68	100 / 100	1159			0	20,126			6200
Missing:	1902 / 19	0 / 0								
Subjective opinion (farmer) about air quality										
Poor in all compartments	2692 / 10	9.5 / 11.5	134	5.0	ref.	0	1779	1.060	ref.	913
Poor in some compartments	13,742 / 38	48.7 / 43.7	727	5.3	0.496	0	10,088	1.072	0.039	3654
Good in all compartments	11,794 / 39	41.8 / 44.8	409	3.5	0.038	0	9220	1.080	0.053	2574
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Wald-test:					0.040				0.101	
Fever measured to detect sick calves										
Yes	20,416 / 54	73.4 / 62.1	912	4.5	ref.	0	15,877	1.074	ref.	4539
No	7812 / 33	26.6 / 37.9	358	4.6	0.426	0	5210	1.076	0.357	2602
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Medicines stored at the farm										
Yes	26,850 / 66	95.1 / 75.9	1194	4.4	ref.	0	20,848	1.077	ref	6002
No	1378 / 21	4.9 / 24.1	76	5.5	0.769	0	239	0.844	<0.001	1139
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Use of vaccination against BRD**										
Yes	1293 / 4	4.6 / 4.6	65	5.0	ref.	0	1143	1.123	ref.	150
No	26,935 / 83	95.4 / 95.4	1205	4.5	0.853	0	19,944	1.072	0.152	6991
Sum:	28,228 / 87	100 / 100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Individual treatments per calf***										
No treatment	10,793	38.2	446	4.1	ref.	0	7084	1.082	ref.	3709
One treatment	8158	28.9	354	4.3	0.539	0	6268	1.076	<0.001	1890
Two treatments	5036	17.8	226	4.5	0.102	0	4179	1.072	<0.001	857
Three treatments	2565	9.1	135	5.3	0.001	0	2174	1.060	<0.001	391
Four treatments	1110	3.9	64	5.8	<0.001	0	935	1.056	<0.001	175
Five or more treatments	566	2.0	45	8.0	<0.001	0	447	1.062	<0.001	119
Sum:	28,228	100	1270			0	21,087			7141
Missing:	0 / 0	0 / 0								
Wald-test:					<0.001				<0.001	

* Farms that either retrieve all or some calves by themselves without using the services of a meat company.
** Bovilis Bovipast RSP parenteral vaccination was used on every farm.
*** Medication (antibiotic or NSAID) given more than 7 days from the previous medication is calculated as new treatment.

10 751) and included (n = 28 228) in the model were tested with logistic regression analysis. Mortality data was available for all excluded and included calves. Average calf mortality for included calves was 4.5 % and for excluded calves 5.7 %. Herd size, farm type, meat company and arrival age of the calves were added to the model to control confounder effect. Herd size data was missing from four of these farms (1898 calves). There was no significant difference in mortality between included and excluded calves (OR 0.763, p = 0.078, 95 % CI 0.564–1.031). At farm level, average calf mortality on 87 included farms was 4.5 % (SD 4.2) and on 58 excluded farms 5.7 % (SD 4.4). Differences in mortality at farm level between included and excluded farms were not statistically significant when tested with Student's *t*-test (p = 0.09). Statistical differences in daily weight gain between calves excluded (n = 4110) from the model and included (n = 21 148) in the model were tested with linear regression analysis. Daily gain was not available for 13 721 calves out of 38 979. Herd size, meat company and arrival age of the calves were added to the model to control confounder effect. Herd size data was missing from 1489 calves (three farms). There was no significant difference in daily gain between included and excluded calves (Coeff.−0.001, p = 0.985, 95 % CI -0.059–0.058). Similarly, no significant difference in daily gain was observed in farm level when included (n = 47) and excluded farms (n = 23) were compared (1.045 kg/day versus 1.024 kg/day, p = 0.47). Size of the included and excluded calf rearing farms was not significantly different (average herd size 288.7 versus 221.4, respectively, p = 0.12).

Table 2
Descriptive statistics of continuous variables of 28 228 calves on 87 farms and univariable associations of predictor and outcome variables. The study included 23 946 calves reared on 45 specialized calf rearing farms, 3746 calves reared on 28 integrated beef production farms, and 536 calves reared on 14 finishing farms for weaned calves.

	n Calves / Farms	Average* Calves / Farms	SD** Calves / Farms	Mortality n	Mortality OR	Mortality p-value	Mortality Missing	Daily gain n	Daily gain Coeff.	Daily gain p-value	Daily gain Missing
Herd size	28,228 / 87	628 / 289	446 / 296	1270	0.999	0.791	0	21,087	<0.001	0.062	7141
Missing:	- / -										
Origin farm herd size	28,226 / 87	122 / 117	104 / -	1270	0.999	0.048	0	21,085	<0.001	<0.001	7143
Missing:	2 / -										
Arrival age of calf, days											
Specialized calf rearing farm	23,946 / 45	23 / 22.3	9.2 / 3.7								
Fattening farms buying milk calves	3746 / 28	21.5 / 21.0	8.7 / 3.6								
Fattening farms buying weaned calves	536 / 14	97.4 / 97.6	33.2 / 23.8								
Total:	28,228 / 87	24.2 / 34.0	14.4 / 29.7	1270	0.987	<0.001	0	21,087	0.004	<0.001	7141
Missing:	- / -										
Arrival weight of calf, kg											
Specialized calf rearing farm	23,536 / 45	58.5 / 58.6	10.1 / 2.6								
Fattening farms buying milk calves	3659 / 28	57.5 / 57.3	9.4 / 2.9								
Fattening farms buying weaned calves	529 (14)	117.4 / 117.9	39.4 / 21.3								
Total:	27,724 / 87	59.5 / 67.7	14.1 / 23.9	1238	0.984	<0.001	0	21,087	0.003	<0.001	7141
Missing:	504 / 0										
Second weight of the calf, kg											
Specialized calf rearing farm	21,087/45	216.8/214.6	34.4/23.5								
Fattening farms buying milk calves	61/2	214.6/214.8	23.9/0.66								
Fattening farms buying weaned calves	0/0	0/0	0/0								
Total:	21,148	216.8/214.6	34.4/23.0								
Missing:	7080										
Length of follow-up (max 180 days)											
Specialized calf rearing farm	23,946 / 45	146.4 / 148.6	26.1 / 13.6								
Fattening farms buying milk calves	23,746 / 28	174.8 / 174.2	24.2 / 5.8								
Fattening farms buying weaned calves	536 / 14	177.3 / 177.7	18.9 / 4.0								
Total:	28,228 / 87	150.8 / 161.5	27.8 / 17.1								
Missing:											

* Average numbers are calculated separately in calf level and in farm level.
** Standard deviation.

3. Results

3.1. Descriptive statistics

Descriptive statistics are presented in Tables 1 and 2. In the study sample, specialized calf rearing farms were the most frequent farm type (n = 45), followed by fattening farms for milk calves (n = 28) and fattening farms for weaned calves (n = 14). Of the included farms, 40 had a contract with meat company A, 39 with meat company B, and 8 with meat company C.

The average size of the calf rearing farms varied between different farm types and contract meat companies. The average number of cattle on specialized calf rearing farms was 340 (median 660, range 36–1500), on fattening farms buying milk calves 309 (median 350, range 84–1500), and on fattening farms buying weaned cattle 83 (median 80, range 69–100). Fattening farms buying milk calves had significantly less calves in one milk feeding compartment than specialized calf rearing farms when compared with chi-square test (p-value < 0.001). In addition, 78.6 % of specialized calf rearing farms and 41.6 % of fattening farms buying milk calves had more than 40 calves in each milk feeding compartment. The average age of calves transported to the fattening farms buying weaned calves was significantly higher (97.4 days, SD 33.2) than that of specialized calf rearing farms (23.0 days, SD 9.2) or fattening farms buying milk calves (21.5 days, SD 8.7). No significant difference was present in average size of the origin farms of calves in different types of calf rearing farms.

3.2. Predictors associated with calves' mortality during the rearing period

Mortality data were collected for all calves in the 87 study herds (n = 28 228). Average follow-up of the calves was 150.8 days (SD 27.8, range 0–180) and median 154 days, including untimely dead and early transported calves. In total, 1270 out of 28 228 calves died during the study period. Average mortality was similar at farm (4.5 %) and calf level (4.5 %), but varied between different rearing farm types, being on average 4.6 % (median 3.8 %, range 0–15.1 %) on specialized calf rearing farms, 5.3 % (median 3.1 %, range 0–21.8 %) on fattening farms for milk calves, and 2.5 % (median 1.0 %, range 0–11.9 %) on fattening farms for weaned calves (Table 3, Fig. 2). Average time between calves' arrival and untimely death was 79 days (median 72, range 0–180), and mortality was higher in the first quarter of the rearing period (Fig. 1). At farm level, the average time between calves' arrival and untimely death was also 79 days (median 77, range 16–163).

Results of the mixed multivariable logistic regression model are presented in detail in Table 4. In the model, higher age of the calf at arrival to the calf rearing farm lowered the odds for an untimely death (OR 0.985, p < 0.001, 95 % CI 0.978–0.992). Holstein and crossbred Aberdeen Angus were associated with decreased odds and crossbred Limousine calves with increased odds to die during the study period compared with Ayrshire calves. In addition, calves medicated on more

Table 3
Descriptive statistics of outcome variables of 28 228 calves on 87 farms. The study included 23 946 calves reared on 45 specialized calf rearing farms, 3746 calves reared on 28 integrated beef production farms, and 536 calves reared on 14 finishing farms for weaned calves.

	n Calves / Farms	Average Calves / Farms	SD* Calves / Farms
Calf mortality, %			
Specialized calf rearing farm	23,946 / 45	4.5 / 4.6	- / 3.2
Fattening farms buying milk calves	3746 / 28	5.0 / 5.3	- / 5.6
Fattening farms buying weaned calves	536 / 14	2.8 / 2.5	- / 3.6
Total:	28,228 / 87	4.5 / 4.5	- / 4.2
Missing:	- / -		
Daily gain, kg**			
Specialized calf rearing farm	21,087 / 47	1.074 / 1.047	0.166 / 0.105
Fattening farms buying milk calves	0 / 0	–	–
Fattening farms buying weaned calves	0 / 0	–	–
Total:	21,087 / 47	1.074 / 1.047	0.166 / 0.105
Missing:	7141 / 40		

* Standard deviation.
** Daily gain was calculated for calves with two weight measurements.

Table 4
Mixed-effect multivariable logistic regression model to evaluate the association between calf mortality and predictor variables in 87 herds. Calves were retrospectively followed for maximum 180 days from arrival to the farm. Average arrival age was 24 days (SD 14). In total, 1270 calves out of 28 228 suffered an untimely death during the study period (4.5 %).

Predictor variable	Odds ratio	p-value	95 % Confidence interval	
Contract meat company				
A	ref.	ref.		
B	0.847	0.444	0.554	1.296
C	1.124	0.717	0.597	2.114
Wald-test:		0.549		
Herd size / 100 calves*	0.962	0.165	0.911	1.016
Milk feeding compartments operated as all in/all out				
Completely all in/all out	ref.	ref.		
Continuous filling	2.236	0.002	1.349	3.705
Breed of calf				
Ayrshire	ref.	ref.		
Holstein	0.547	0.000	0.476	0.629
Crossbred Aberdeen Angus	0.576	0.002	0.404	0.820
Crossbred Blonde D'Aquitaine	1.073	0.476	0.883	1.305
Crossbred Limousine	2.106	0.000	1.710	2.593
Other breeds**	0.648	0.021	0.448	0.937
Wald-test:		0.000		
Age of calf on arrival, days	0.985	0.000	0.978	0.992
Older animals transported to the same unit***	1.536	0.042	1.015	2.324
Number of medications during rearing time****				
Zero times	ref.	ref.		
One time	1.016	0.848	0.860	1.201
Two times	1.130	0.237	0.923	1.384
Three times	1.414	0.006	1.105	1.808
Four times	1.664	0.002	1.209	2.289
Five or more times	3.001	0.000	2.056	4.382
Wald-test:		0.000		

* Number of cattle on farm divided by 100.
** Brown Swiss, Hereford, Charolais, Simmental, Highland, Jersey, Montbéliard, and rural Finnish cattle.
*** Calves transported ≥60 days of age to specialized calf rearing farms and fattening farms for milk calves or ≥180 days of age to fattening farms for weaned calves.
**** Medications (antibiotic, NSAID, or combination) more than seven days apart were calculated as separate.

Table 5
Mixed-effect multivariable linear regression model to evaluate the association between calf daily gain and predictor variables in 19 791 calves on 41 specialized calf rearing farms. Calves were retrospectively followed for maximum 180 days from arrival to the farm. Average arrival age was 23 days (SD 9).

Predictor variable	Coefficient	p-value	95 % confidence interval	
Herd size / 100 *	0.007	0.003	0.002	0.011
Size of the origin farm / 100 *	0.009	0.000	0.007	0.011
Contract meat company				
A	ref.	ref.	ref.	ref.
B	−0.125	0.000	−0.176	−0.074
C	−0.064	0.103	−0.141	0.013
Wald-test:		0.000		
Sex				
Male	ref.	ref.	ref.	ref.
Female	−0.168	0.000	−0.174	−0.162
Breed				
Ayrshire	ref.	ref.	ref.	ref.
Holstein	0.032	0.000	0.028	0.037
Crossbred Aberdeen Angus	0.050	0.000	0.040	0.060
Crossbred Blonde D'Aquitaine	0.031	0.000	0.024	0.038
Crossbred Limousine	0.011	0.018	0.002	0.020
Other breeds**	0.075	0.000	0.065	0.086
Wald-test:		0.000		
Arrival age of the calf (centered version)***	0.005	0.000	0.004	0.005
Average arrival age of calves in a same arrival batch	<-0.001	0.743	−0.002	0.001
Older animals (≥ 60 days) transported to the same unit	−0.119	0.000	−0.171	−0.060
Season of arrival of the calf				
June–August	ref.	ref.	ref.	ref.
January–February	0.065	0.000	0.047	0.082
March–May	0.046	0.000	0.031	0.059
September	−0.045	0.000	−0.061	−0.028
Wald-test:		0.000		
Number of medications during rearing time****				
Zero times	ref.	ref.	ref.	ref.
One time	−0.013	0.000	−0.019	−0.008
Two times	−0.034	0.000	−0.040	−0.027
Three times	−0.054	0.000	−0.062	−0.046
Four times	−0.061	0.000	−0.072	−0.050
Five or more times	−0.066	0.000	−0.081	−0.051
Wald-test:		0.000		
Medicines stored at the farm				
Yes	ref.	ref.	ref.	ref.
No	−0.201	0.000	−0.276	−0.125
Washing and disinfection of milk feeding compartments between batches				
Wash and disinfection	ref.	ref.	ref.	ref.
Wash	0.024	0.162	−0.009	0.056
Mechanical cleaning	−0.095	0.003	−0.158	−0.033
No cleaning	−0.126	0.038	−0.245	0.007
Wald-test:		0.000		
Calves relocated to other compartment after weaning				
Yes	ref.	ref.	ref.	ref.
No	0.046	0.014	0.009	0.083
Compartmentation of different age groups (unweaned, weaned, finishing cattle)				
All groups in separate buildings	ref.	ref.	ref.	ref.
Only unweaned in separate building	−0.102	0.004	−0.171	−0.034
Unweaned in same building with others, but own air space	−0.052	0.042	−0.101	−0.002
Unweaned calves in separate compartment, but in same air space with older cattle	−0.067	0.013	−0.120	−0.014
All groups in a same compartment	0.074	0.210	−0.042	0.189
Wald-test:		0.003		

* Number of cattle on farm divided by 100.
** Brown Swiss, Hereford, Charolais, Simmental, Highland, Jersey, Montbéliard, and rural Finnish cattle.
*** Number of days the individual calf's age differs from the average arrival age of the calves in same calf batch. Negative if younger and positive if older.
**** Medications (antibiotic, NSAID, or combination) more than seven days apart were calculated as separate.

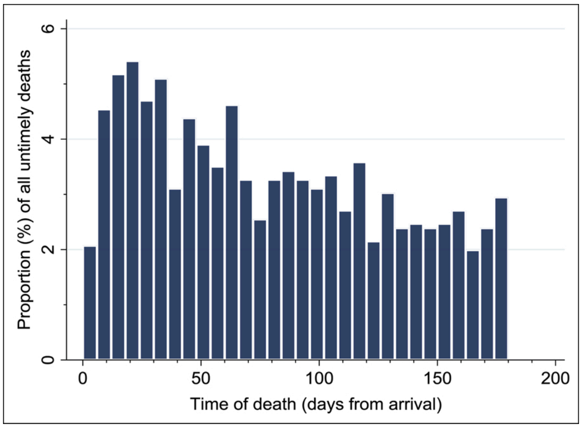

Fig. 1. Histogram presenting the distribution of untimely deaths during the study period (0-180 days). In total, 1270 calves out of 28 228 died during the study period (4.5 %). Mean time from arrival to the calf rearing farm to the untimely death was 79 days (SD 51.1, median 72).

than two separate occasions during the rearing period had significantly increased odds to die during the study period such that the odds ratio for calves increased with every added medication event. Continuous filling without emptying calf compartments from animals between batches led to increased odds for an untimely death (OR 2.236, $p = 0.011$, 95 % CI 1.349–3.705). The effect of both calf rearing farm and calf's arrival batch on calf mortality was small. Moreover, the similarity of values between calves reared on the same rearing farms or in the same batches was low; intraclass correlation coefficient for rearing farms was 0.093 and for calf's arrival batch 0.135.

3.3. Predictors associated with daily gain during the rearing period

Daily gain was calculated for the 21 087 calves with two separate weight measurements available. These calves were reared on 45 specialized calf rearing farms. Average calf level daily gain during the rearing period was 1074 g/day (SD 166, range 320–1828) (Table 3). Similarly, farm level average daily gain was 1047 g/day (SD 105, range 657–1249) (Fig. 3). Average follow up on the specialized calf rearing farms was 146.9 days (SD 17.6, range 60–180) and average batch level arrival age was 23.0 days (SD 5.3).

In the mixed multivariable linear regression model, relatively higher arrival age of the calf compared to other calves in the same arrival batch was associated with increased daily weight gain during the follow up (coeff. 0.005, $p < 0.001$, 95 % CI 0.004–0.005) (Table 5). Also bigger herd size of the rearing farm and the calf's origin farm were both positively associated with daily weight gain (coeff. 0.007, $p = 0.003$, 95 % CI 0.002–0.011 and coeff. 0.009, $p < 0.001$ 95 % CI 0.007–0.011, respectively). In addition, leaving calves to grow in the milk feeding compartment after weaning from milk increased the daily weight gain (coeff. 0.046, $p = 0.014$, 95 % CI 0.009–0.083). Crossbred Aberdeen Angus, Blonde d'Aquitaine, Limousine, combined rarer breeds, and pure Holstein breed were all associated with higher daily weight gain compared to Ayrshire calves. During the study period calves transported to the calf rearing farms between January and May gained weight significantly faster than calves transported during the summer months (June to August). Calves transported in September had even lower daily gain than calves transported during the summer months. Female sex, receiving also older cattle to the farm ($\geq$60 days), higher average arrival age of calves in the same batch, increased number of medications during the rearing period, and no medicines stored at the farm for future needs were all negatively associated with daily weight gain. Lower daily

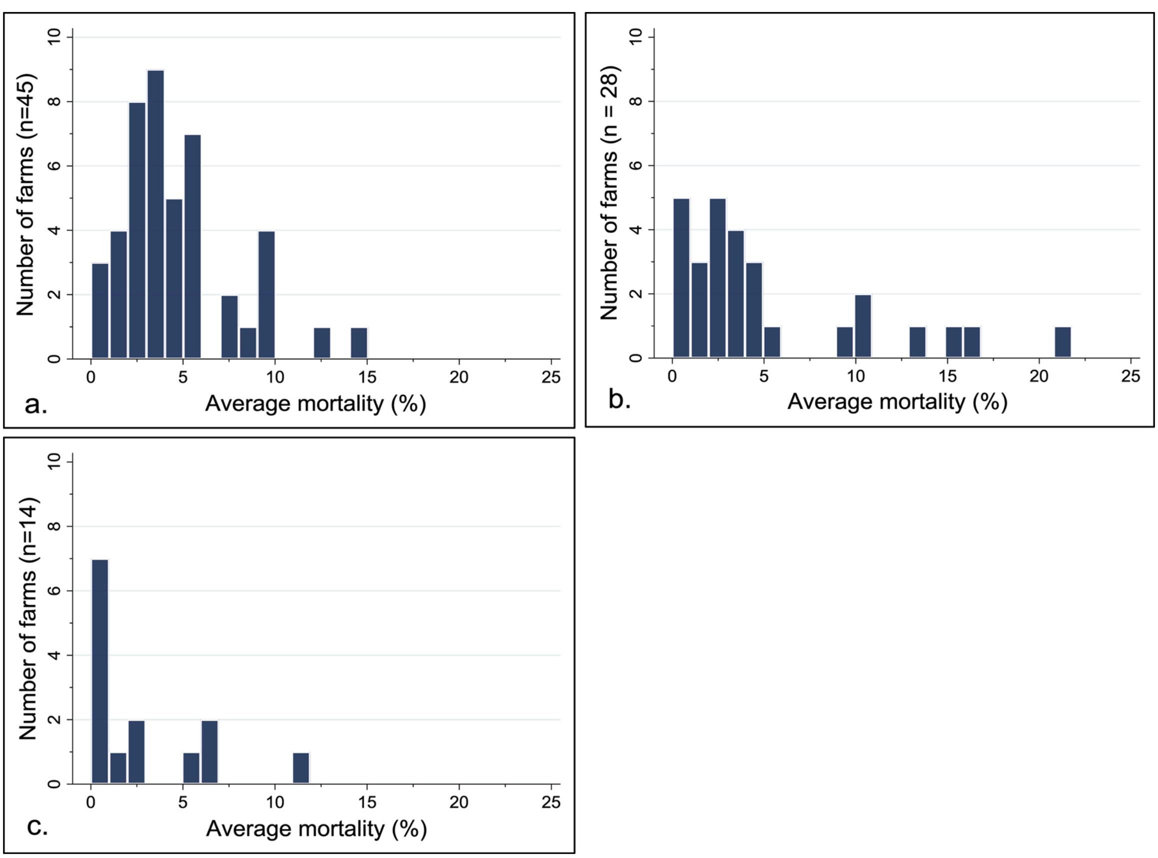

Fig. 2. Distribution of farm level calf mortality in different farm types. Average calf mortality in specialized calf rearing farms (a.) was 4.6 % (SD 3.2), in fattening farms for milk calves (b.) 5.3 % (SD 5.6) and in fattening farms for weaned calves (c.) 2.5 % (SD 3.6).

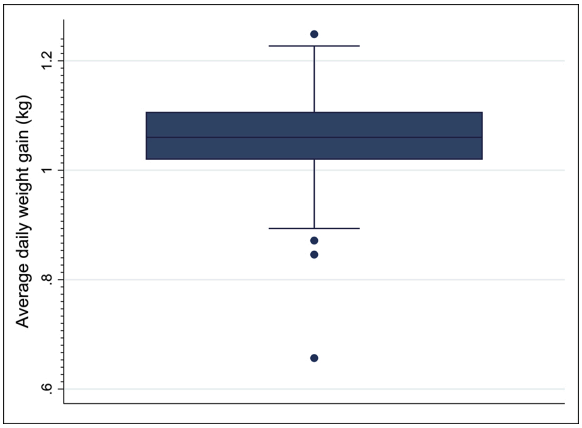

Fig. 3. Tukey boxplot of average daily weight gain of the 45 specialized calf rearing farms during the rearing period in average 147 days (SD 17.6). Average daily weight gain in farm level was 1.047 kg (SD 0.105, range 0.657–1.249).

weight gain was also seen if either unweaned or weaned calves were reared in the same building with older cattle, compared with rearing all age groups in different buildings. In addition, mere mechanical cleaning of milk feeding compartments between arrival batches was negatively associated with daily weight gain compared with washing and disinfecting the compartments between batches (coeff. −0.095, p = 0.003, 95 % CI −0.158–−0.033). The effect of both calf rearing farm and calf's arrival batch on daily weight gain was small. Also, similarity of values between calves reared on the same rearing farms or in the same batches was low such that intraclass correlation coefficient for rearing farms was 0.065 and for calf's arrival batch 0.188.

4. Discussion

4.1. Mortality on calf rearing farms

Overall mortality on Finnish calf rearing farms was 4.5 %. Calf mortality rates between 2.9 % and 7 % have been reported in previous studies conducted in calf rearing farms in different countries: 5.3 % in Belgium in 2007–2009 (Pardon et al., 2012), 3.6 % in Switzerland in 2013 (Lava et al., 2016a), 4.9 % in the Netherlands in 2011–2014 (Santman-Berends, I. M. G. A. et al., 2018), 2.9 % in the Netherlands in 2014–2016 (Bokma et al., 2019), 7 % in Canada in 2016 (Renaud et al., 2018a), and 5.1 % in Switzerland in 2016–2017 (Schnyder et al., 2019). Although comparison of mortality rates between countries is difficult due to variable calf rearing operations and between studies due to different study methods, our results show that calf mortality on Finnish calf rearing farms is close to the international average. In our data, mortality varied between farms and different farm types (Fig. 2). BRD is the most common cause of increased mortality in calf rearing operations, and a decrease in morbidity results in a decrease in mortality (Sargeant et al., 1994; Pardon et al., 2012). By following mortality rates of the farms, it is possible to better target counseling to these farms. Oral group treatments with antibiotics are still a fairly common practice in veal calf operations in Europe and might explain the low mortality rates demonstrated in some studies (Bokma et al., 2019). Oral group treatments of calves with antibiotics are not used in Finland, and the vast majority of calves are treated individually only when needed. In our study, after two courses of individual medications calf odds to suffer untimely death increased significantly after every additional course of medication (antibiotics and NSAIDs included). Bähler et al. (2012) have also reported that a higher number of individual daily doses of antibiotics is a risk factor for calf death on calf rearing farms. Higher number of medical courses and related increased mortality, are both probably the result of either incurable sickness of the calf or some predisposing factor leading to repetitive infections and inflammations. Availability of medicines in farms and farmers willingness to medicate sick calves also partly explains the difference in mortality between farms.

Operating milk feeding compartments without emptying compartments from animals between arrival batches was associated with higher odds of a calf dying during the rearing period. This finding is congruent with the results of Santman-Berends et al. (2018) in Dutch veal calf operations. BRD and diarrhea, as the most common causes of increased morbidity and mortality on calf rearing farms, are both easily transmitted from calf to calf (Pardon et al., 2012). It is evident that continuous filling of the calf compartment increases the infection pressure by enabling transfer of pathogens between arrival batches and different-aged animals. In addition, this might partly explain the finding that calves, reared on calf rearing farms receiving also older cattle, had higher odds to die during the rearing period than calves reared on farms not receiving older cattle.

Higher age of the calf at time of arrival is a protective factor against mortality on calf rearing farms. Several earlier studies have reported an association between higher arrival weight or body mass index of the calf and lower mortality risk during the rearing period (Winder et al., 2016; Santman-Berends et al., 2018; Scott et al., 2019). In our study population, the correlation between arrival age and weight of the calves was high (0.73), and the final model was tested first with weight and then with age as an independent factor. No significant difference emerged between the results of these models. Younger calves are probably more susceptible to infection like BRD and diarrhea than older calves due to an immature immune system, and increased morbidity could be one explanatory factor for increased mortality (Barrington and Parish, 2001). In addition, breed was significantly associated with mortality risk on calf rearing farms. Pure Holstein and crossbred Aberdeen Angus breeds were both associated with lower mortality compared to the pure Ayrshire breed. On the other hand, crossbred Limousine was associated with significantly higher mortality compared to pure Ayrshire. To our knowledge, there is no earlier published data on mortality differences between Holstein and Ayrshire calves. Higher mortality in Limousine calves in our data was tracked afterwards to be highly affected by one extensively used Limousine sire bull, whose calves had much higher mortality than the average (results not shown). In addition, a recently published study showed how young stock mortality can be affected by selection of the sire (Davis et al., 2020). Our results only partly support earlier studies that have shown lower mortality in crossbred calves than in pure dairy and beef breed calves (Pardon et al., 2012; Lava et al., 2016b). Breeds in the national cattle herd register are registered according to the sire's breed. Because of this, we cannot be sure what is the breed of the dam. In Finland, practically all the calves arriving to calf rearing farms originate from dairy farms and so these calves rarely are pure beef breed. On the other hand, our data does not separate pure milk breeds from crossbred milk breeds. However, cross breeding milk breeds is a rather uncommon practice in Finland.

4.2. Weight gain on calf rearing farms

Average daily weight gain of the calves in our study was 1.074 kg/day. The result is similar to that in earlier studies conducted with similarly aged calves (Renaud et al., 2018c; Seppä-Lassila et al., 2018). In our study, daily weight gain of the individual calf on rearing farm was affected by the average arrival age of the calves in the same arrival batch. Higher daily gain was seen in calves that were older at the time of arrival in relation to the other calves in a same arrival batch. According to our results, every additional day the calf was older at the time of arrival compared to the average arrival age of the calves in same arrival batch, increased the daily gain 4.7 g. This finding is a result of the contextual effect between the individual calf arrival age and average arrival age of the calves in same calf batch. In calf rearing farms, calves are mainly reared in group pens, which might favor relatively older calves due to their stronger starting point in competition of resources and also possible better capacity to tolerate stressors. In addition, the immature immune system of younger calves may predispose them to such diseases as BRD and diarrhea, which have been demonstrated to decrease the daily gain (Pardon et al., 2013). It is also possible that sometimes a very poorly growing calf that has been sick earlier is transported to the unit at an older age. These calves raise the overall arrival age of the arrival batch and at the same time they might spread infections and cause poorer growth of the other calves in the batch. In addition, this formerly poorly growing calf might grow even faster due to compensatory growth when proper feed is offered. More studies are needed to completely understand this phenomenon. Earlier studies have also associated higher arrival age, weight, and body mass index of the calf with increased daily weight gain in calf rearing operations (Renaud et al., 2018b; Seppä-Lassila et al., 2018; Scott et al., 2020). Seppä-Lassila et al. (2018) found in their study conducted on one calf rearing farm that each added day to the calf's transportation age increased daily weight gain 10.9 g in the milk feeding period (until weaning) and 2.1 g in the entire follow-up period (200 days). Higher daily weight gain in calves transported to the calf rearing farm at an older age might be partly the result of naturally higher daily gain of older calves in the first months of life (Virtala et al., 1996). One weakness in our study was that all calves were manually allocated to the arrival batches according to the date of arrival and questionnaire results. Especially on farms with continuous filling of milk feeding compartments, separating calves to the batches was not always clear. However, only 5.9 % of the calves were reared on farms with continuous filling of milk feeding compartments. Additionally to calf age, calf sex and breed also had significant association to daily gain. Predictably, female calves had significantly lower daily gain compared to male calves. Every other breed, including combined breed variable "other breeds", had significantly higher daily gain compared to Ayrshire calves. These findings are well congruent with the breeding features of these breeds.

Every medication given during the rearing period was linearly associated with decreased daily weight gain of the calf. Daily growth was reduced by 13.4, 33.7, 53.9, 60.7, and 65.9 g if calf was medicated one, two, three, four, or five or more times, respectively, during the rearing period. According to authors' knowledge, similar findings have not been reported before. Earlier studies have though clearly demonstrated how common diseases, such as BRD and diarrhea, decrease the daily weight gain of calves (Pardon et al., 2013). According to these findings, our results may also reflect the strict individual medication policy on Finnish farms, where only clearly sick calves are medicated. Our results are contrary to those of Seppä-Lassila et al. (2018) who conducted their study on one specialized calf rearing farm. In their study, calves medicated more than four separate times with antibiotics were associated with higher daily gain in milk feeding period than calves medicated never or only once with antibiotics. In this specialized calf rearing farm, usage of antibiotics was very high which might propose that calves were medicated in low threshold. Medicating mildly sick calves with antibiotics might lead to better growth performance due to growth promoting effect of the antibiotics (Berge et al., 2005). Our results also showed that calves reared in farms which had medicines stored in the farm, had higher daily gain compared to calves reared in farms which had to always call a veterinarian to treat sick animals. Sick animals are probably more often and also earlier treated if medicines are easily accessible, which might explain this finding.

We found that calves reared on farms where milk feeding compartments were not washed and disinfected properly between arrival batches had significantly lower daily weight gain than calves reared on farms with proper washing and disinfecting routines between arrival batches. In addition, rearing unweaned and/or weaned calves in the same building (within or without the same air space) with older cattle significantly decreased the daily weight gain of calves. Both of these findings are probably the consequence of the increased morbidity of the calves due to higher infection pressure and transmission of pathogens between animals of different age groups. Same factors might also explain the reasons for decreased daily gain of the calves reared in farms receiving older (≥60 days) calves. These older calves might even cause new epidemic when commingled with older calves in the farm. Moving and commingling of the calves are always a potential causes of stress and infections for cattle and may explain our result where we observed that leaving calves to rear in same milk feeding compartment, without moving them after weaning, significantly increased the daily gain. According to our results, calves born on larger farms with more cattle had better daily gain than calves born on smaller farms of origin. According to author's knowledge, there is no studied data about the immunity statuses of calves born in different size farms. We can still theorize that calves born in larger farms might have more effective immunity against a wider scale of pathogens and that makes them better protected against various pathogens encountered at the rearing farm after comingling with calves from other farms. Smaller dairy farms might be more often free from many diseases that are common on calf rearing farms, which makes calves born in these smaller farms immunologically more susceptible to these diseases. Also bigger farm size of calf rearing farm increased the daily gain of calves. These finding could be partly explained by more professional caretaking and feeding of calves in bigger herds where calf rearing is the main source of income.

Calves transported to the calf rearing farms from January to February or from March to May gained 65.3 and 45.5 g more weight per day, respectively, than calves transported from June to August. However, calves transported in September gained 44.9 g of weight per day less than calves transported from June to August. Our results parallel earlier findings in a Canadian veal calf operation, where calves transported in summer and autumn months gained weight significantly slower than calves transported during winter months (Renaud et al., 2018b). Though a cold environment is known to cause an increase in energy consumption in calves, and it might lead to a reduced rate of weight gain, this effect was not observed in our results (Roland et al., 2016). However, most calf rearing barns in Finland are insulated and heated if needed in the winter months. Based on clinical experience, respiratory diseases in calves seem to be more common in late autumn and early winter when weather conditions, humidity, and temperatures vary greatly. An increase in respiratory disease incidence might be one explanatory factor for this decreased daily weight gain (Pardon et al., 2013). The current study sample did not represent all seasons of the year, but only calves that were transported to the calf rearing farms between 1 January and 1 October in a single year, and thus, accurate conclusions about seasonal effect on the studied factors cannot be drawn.

4.3. Study population

Farms were randomly selected to participate in the study. Most of the excluded farms were excluded because of missing medication data or unwillingness to provide the data for research purposes. Due to a change in legislation, veterinarians who have made an animal health care contract with the farmer can now legally hand over certain injectable antibiotics and NSAIDs to the farmer for potential future use for indications assessed by the veterinarian (Finlex MMM 2008/14/2014). To store medicines on the farm, the farms are obligated to have regular animal health care visits by a contracted veterinarian and to keep electronic medical bookkeeping in the national cattle herd health register. This practice has made it possible and easier to collect medication data from the farms. This opportunity provided by the legislation has been widely taken advantage of larger calf rearing farms where consumption of medicines is reasonably high. However, the same practice is not economically profitable for rearing farms where the animals remain relatively healthy. These farms might keep their medication records in some other form than in the national cattle health care system. Collecting medication data for these farms would have required an extra effort from the farmer, which may have led to exclusion of some potentially good farms with low morbidity and mortality rates or, on the other hand, farms that were not so precise in their work and responsibilities (missing bookkeeping). These regulations set by legislation apply also to the veterinarian and disregarding them may also reflect on the precision of the veterinarian handling the animal health care on the farm. During the statistical analysis we tested the differences in mortality and daily gain between included and excluded calves using logistic and linear regression and Student's *t*-test. There were no significant differences in calf mortality or daily weight gain between excluded and included calves. This indicates that our results represents well the overall situation in Finnish calf rearing farms.

5. Conclusions

Our results can be applied to help the beef production industry in Finland and in other countries identify ways to improve veal and beef production. The findings emphasize the importance of breaking the chain of infection on calf rearing farms by preventing contacts between different-aged animals and ensuring that new animals arrive to empty and properly cleaned and disinfected compartments. Our results also show the large negative association between individual medication courses, which reflects clinical episodes of disease, and performance of calves. Every additional medication course linearly decreased daily gain of the calves and after two separate individual medication courses was also associated with increased odds for untimely death of the calf. According to our results, increasing the arrival age of calves would lower the mortality on calf rearing farms. In addition, higher arrival age of an individual calf in relation to the other calves in same arrival batch increases the daily weight gain in rearing farm, but more studies are needed to determine whether an overall increase in arrival age of calves would benefit calf rearing farms and the entire beef production chain.

Declaration of Competing Interest

Tuomas Herva is employed by the private meat company (Atria LTD) that contracts the farms participating in this study. Heidi Härtel also is employed by a private meat company (HK Scan Finland LTD) that contracts the farms participated in the study. Other authors have no conflicts of interest to declare.

Authors' contributions

AS was a major contributor to writing the manuscript and participated in designing the study, data collection, and statistical analysis. HS started the project, applied the funding, and participated in designing the study, data collection, statistical analysis, and writing the manuscript. OH participated in statistical analysis and writing the manuscript. HH and TH participated in designing the study, data collection, and writing the manuscript. TS, LSL, and HR participated in designing the study and writing the manuscript. ET participated in data collection and writing the manuscript. All authors read and approved the final manuscript.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2021.105416.

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