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Effects of the novel concept 'outdoor veal calf' on antimicrobial use, mortality and weight gain in Switzerland

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ABSTRACT

The aim of the intervention study 'outdoor veal calf' was to evaluate a novel concept for calf fattening which aimed at reducing antimicrobial use without compromising animal health. Management practices such as commingling of calves from multiple birth farms, crowding, and suboptimal barn climate are responsible for high antimicrobial use and mortality in the veal calf population. The risk of selecting bacteria resistant to antimicrobials and of economic losses is accordingly elevated. The 'outdoor veal calf' concept, implemented in nineteen intervention farms (IF), is based on three main measures: 1. purchased calves are transported directly from neighboring birth farms to the fattening facility instead of commingling calves in livestock dealer trucks; 2. each calf is vaccinated against pneumonia after arrival and completes a three-week quarantine in an individual hutch; and 3. the calves spend the rest of the fattening period in outdoor hutches in groups not exceeding 10 calves. The covered and bedded paddock and the group hutches provide shelter from cold weather and direct sunshine, constant access to fresh air is warranted. Nineteen conventional calf fattening operations of similar size served as controls (CF). Every farm was visited once a month for a one-year period, and data regarding animal health, treatments, and production parameters were collected. Treatment intensity was assessed by use of the defined daily dose method (TI_{DDD} in days per animal year), and calf mortality and daily weight gain were recorded in both farm groups.

Mean TI_{DDD} was 5.3-fold lower in IF compared to CF (5.9 ± 6.5 vs. 31.5 ± 27.4 days per animal year; $p < 0.001$). Mortality was 2.1-fold lower in IF than in CF (3.1% ± 2.3 vs. 6.3 % ± 4.9; $p = 0.020$). Average daily gain did not differ between groups (1.29 ± 0.17 kg/day in IF vs. 1.35 ± 0.16 kg/day in CF; $p = 0.244$). A drastic reduction in antimicrobial use and mortality was achieved in the novel 'outdoor veal calf' system without compromising animal health. The principles of risk reduction used in designing the system can be used to improve management and animal health, decrease the need for antimicrobial treatments and thus selection pressure on bacteria in veal operations.

1. Introduction

Beside the production of commercial milk with cows selected unilaterally for high milk yield potential since decades, the modern dairy industry also produces male calves and excess female calves that will not be used for further breeding. In Switzerland, these calves are sold to fattening facilities generally at the age of four weeks (Lava et al., 2016b), which is in accordance with the animal protection legislation (Tierschutzgesetz, 2017) and with recommendations of non-governmental stakeholders (Swiss Calf Fattening Association, 2019). Meat from bovine male and female calves fattened mainly with milk and/or milk replacer is sold as 'veal'. In Switzerland, veal calves are slaughtered at the age of approximately 160 days. Even though veal is attributed to the premium meat sector, the profit margin for the farmers is limited and producing veal can be challenging (Bundesamt für Landwirtschaft, 2017). Unlike other European countries, Swiss calves are fattened predominantly in small family-run farms beside other production branches such as milk or cereals (Lava et al., 2016a; Bundesamt für Statistik, 2019). Investments in management and buildings are often limited (Bundesamt für Landwirtschaft, 2019), and it is common to convert buildings initially intended for other purposes into calf barns. Such non-standard barns can be difficult to assess when

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designing measures to optimize the calves' environment, e.g. to reduce air drafts and improve hygiene. Veal calf housing is important because young calves are particularly susceptible to infectious agents as their immune system is not yet fully developed at the age of relocation to the fattening farm (Kampen et al., 2006). Therefore, the calves should be kept in an environment providing minimal stress and a low infection pressure of pathogens causing classical calf diseases. Suboptimal animal health is frequently associated with antimicrobial treatments. The main indications for antimicrobial treatment in veal calves are, in decreasing order of importance, bovine respiratory disease (BRD), digestive disorders, omphalitis and lameness (Luginbühl et al., 2012; Schnyder et al., 2019a). Likewise, the main causes for mortality are respiratory and digestive disorders (Sargeant et al., 1994; Pardon et al., 2012b; Lava et al., 2016b). Premature death represents a serious economic loss for calf producers (Mee, 2008), and calves that die before the age of slaughter have often been treated with antimicrobials before succumbing to disease. Mortality rates in veal calves, i.e. death during the fattening period before reaching the intended age of slaughter, have been reported to range from 3.6% to 8.9% in Europe and North America (Sargeant et al., 1994; Bähler et al., 2012; Pardon et al., 2012b; Lava et al., 2016b; Santman-Berends et al., 2018; Schnyder et al., 2019a).

Most antimicrobial drugs applied to veal calves are given orally to all calves of a group by adding the substance to the feed as a metaphylactic treatment (Lava et al., 2016b; Jarrige et al., 2017). In 2017, 32.3 tons of antimicrobial drugs were sold for use in animals in Switzerland, of which 65.1% were administered orally (ARCH-Vet, 2018). Different methodologies have been used in the past for calculation of treatment incidence, which makes comparison of results from various studies difficult. In Dutch veal operations, 21.2 defined daily doses of antimicrobials per animal year have been reported in 2014 (Dorado-García et al., 2016). In Belgium, 32.3 daily doses were reported to be administered per animal year in 2014–2016 (Bokma et al., 2019). The treatment incidence reported in veal operations with improved welfare conditions in Switzerland was 21 ± 15 (mean ± sd) average daily doses per animal year in 2014 (Lava et al., 2016b).

Excessive or inappropriate use of antimicrobials can lead to the selection of resistant bacteria, both in veterinary and human medicine (WHO, 2015). The spread of resistant bacteria via humans, animals and the environment has been observed, including transfer of resistant bacteria from animals to humans and vice versa (Stefani and Agodi, 2000; Martins et al., 2007; Fernando et al., 2010; Lupo et al., 2012; Johnning et al., 2013; Stedt et al., 2015). Despite possible long-distance transfer, the development and persistence of certain antimicrobial resistances over time in a given farm have been shown to be linked to the on-farm use of antimicrobials (Berge et al., 2006; Catry et al., 2016), indicating that the occurrence of resistant bacteria may rather depend primarily on local use than on environmental contamination. Both local rise and regional spread of resistance determinants could be decreased by implementing a management and housing concept supporting improved animal health, thus resulting in lower antimicrobial treatment incidence and reduced selection pressure.

Many factors that influence animal health in calf fattening facilities have been described in different countries (Zucali et al., 2013; Lava et al., 2016a, 2016b; Santman-Berends et al., 2018; Bokma et al., 2019; Schnyder et al., 2019a). The 'outdoor veal calf' concept is based on an extensive risk factor assessment for antimicrobial use and mortality in Swiss calf fattening operations belonging to the same label with improved welfare standards and sustainability (IP-SUISSE, 2019) as the farms included in the present study (Lava et al., 2016a, 2016b). The risk factor analysis for antimicrobial group treatment upon arrival in the fattening operation conducted in 619 farms showed that the strongest association was observed for calf purchase (Odds Ratio (OR) = 8.9, $p < 0.001$) (Lava 2016a). In a more in-depth analysis of 91 farms where calves born on the farm and purchased calves were fattened, the most important factors associated with increased antimicrobial use were a shared air space for several calf groups (+9.7 daily doses per animal year (dd/ay), $p < 0.01$), the lack of quarantine after arrival of purchased calves (+8.3 dd/ay, $p = 0.03$), and the lack of clinical examination upon arrival (+7.9 dd/ay, $p = 0.04$) (Lava 2016b). Risk factors associated with increased mortality included weight differences ≥50 kg within a group (OR = 2.0 for differences > 100 kg vs. ≤50 kg, $p < 0.01$), no vaccination against BRD (OR = 1.9, $p < 0.001$), and group size (OR = 1.4 per 10 calves, $p < 0.01$) (Lava et al., 2016b).

The concept 'outdoor veal calf' was designed to address the main risk factors identified in these previous studies, with emphasis on purchase (and related factors such as transport and commingling), clinical examination prior to purchase, quarantine, vaccination, group size and composition, and shared air space. Fattening farms with high purchase rates (> 50%) were selected for the study in order to reflect real-life conditions, given that the abolition of calf purchase is currently not realistic in the Swiss veal calf industry. The study was conducted to test the hypothesis that farms implementing the 'outdoor veal calf' concept will have a treatment incidence that is at least 50% lower than in control farms. This concept implies management changes which improve calf health and welfare and is tested in herds that purchase at least 50% of their veal calves.

2. Materials and methods

2.1. Study design and farm selection

A prospective non-randomized controlled intervention study was performed. The study population consisted of 38 farms (19 intervention farms, IF, and 19 control farms, CF) which were recruited from October 2016 to March 2017 and followed during a period of a minimum of 12 months. The IF managers committed to fulfilling the 'outdoor veal calf' regulations (described in detail in 2.2.); in contrast, CF were not subjected to any management changes, and these farmers only agreed to provide the same data as IF. All farmers produced veal under label conditions (IP-SUISSE, 2019) exceeding the minimum requirements of the Swiss animal welfare legislation (Tierschutzgesetz, 2017). These label requirements include, among others, a minimum age of 3 weeks at purchase, groups with ≤40 calves per pen for all-in/all-out systems or ≤15 for continuous stocking, the feeding of ≥1000 kg of fresh milk per calf (feeding milk replacer in addition is permitted), a total floor surface area of ≥4.5 m^2 for calves above 150 kg, of which a minimum of 1.8 m^2 must be straw-bedded and ≥1.3 m^2 must be a non-roofed outside pen area which is constantly accessible, and various measures aiming at increasing biodiversity (IP_SUISSE, 2015; Direktzahlungsverordnung, 2018). Measures to increase biodiversity can be chosen from a list and aim at increasing species richness (e.g. flower diversity on pastures) and/or structural richness (e.g. dry stone walls, hedges).

Intervention farms were recruited first. It was not possible to randomly assign farms to the intervention or control group because IF had to thoroughly change their housing and management system. The central criteria for eligibility as an IF were an annual number of 40–80 fattened calves with a minimum purchase rate of 50%, the availability of a flat 200 m^2 floor area for installation of calf hutches, being a dairy operation producing commercial milk, being situated within a 100 km radius from Bern, Switzerland, and the willingness to work according to the project requirements. After enrollment, all project requirements had to be fulfilled. These are described in detail in 2.2.

To recruit IF managers, all Swiss veal producers (contacted via newspaper), all IP-SUISSE veal producers (e-mail) and all farmers of the Bernese Calf Fattening Association (e-mail) were contacted. Farmers who expressed interest for participation and whose farms were situated within a 100 km radius from Bern were contacted and eligibility was confirmed by performing a two-stage process: first, a telephone interview was conducted and, if seemingly suitable, eligibility was confirmed in a second step by conducting a farm visit. A total of 83 farmers replied, 31 farm visits were performed, and 20 farms were confirmed to be eligible. The reasons for non-inclusion comprised insufficient flat surface to install the calf hutches (7) and personal reasons (4). Of 19 final study participants (IF), 16 were already affiliated with IP-SUISSE at the moment of recruitment, of whom 4 were already affiliated with veal calves and 12 with other branches but not veal calves. Intervention farms were admitted to the label program if necessary (i.e. if they were not affiliated yet) and if label requirements were fulfilled.

The CF were selected by searching for the 5 IP-SUISSE veal producers fattening between 20 and 80 calves per year (according to IP-SUISSE records) and geographically closest to an IF to avoid a systematic bias in the geographical distribution of the IF vs. CF. These 5 farmers were randomly ranked from 1 to 5 by computer and asked by phone whether they were interested in participating in the study. The first farmer who agreed was included in the study. If none of the five farmers agreed to participate, the radius of the search was increased and the selection process was repeated. Requirements for participation in the study as a CF included membership in the IP-SUISSE label, production of commercial milk, fattening 40–80 calves per year during the study period, purchasing ≥50% of the calves, and willingness to provide the requested data.

A sample size calculation was performed with the online tool Ausvet EpiTools (https://epitools.ausvet.com.au) to detect a difference in antimicrobial use of ≥50% between IF and CF with a power of 80% and a confidence level of 95% including a correction for clustering at the level of the farm as a treatment observation period of at least 12 months was planned for each farm to investigate potential seasonal variations. The calculation was based on the previously reported treatment incidence TI (in average daily doses per animal year, TI_{ADD}) in IP-SUISSE farms of 21 ± 15 dd/ay (Lava et al., 2016b). The sample size was adapted for the design effect, assuming a maximum intraclass correlation coefficient (ICC) of 0.4. The design effect was calculated as:

$$DE = 1 + (n - 1)\rho$$

where DE is the design effect, n is the average cluster size (e.g. 12 months per farm), and ρ is the ICC. This resulted in an uncorrected sample size of 33 observation months per group, a design effect of 5.4, and thus an effective sample size of 179 monthly observations per group (33 months*5.4), or 15 farms per group (179/12 months). To accommodate for potential losses to follow-up, 20 farms per group were recruited. Assuming the same design effect, power and confidence level, this sample size was sufficient to detect an OR of at least 6 for mortality odds between the groups, assuming a baseline mortality of 4.1% (Lava et al., 2016b) (n = 227 observations and 19 farms). For average daily weight gain (ADG), a difference in mean ADG of at least 0.1 kg/day could be detected with the effective sample size, assuming a mean ADG of 1.4 kg/day and a standard deviation of 0.16 (Schnyder et al., 2019a).

2.2. The ‘outdoor veal calf’ concept

The fields of action of the ‘outdoor veal calf’ concept include factors related to the purchase of calves (transport, quarantine, BRD vaccination), reduction of infection pressure (in particular for pathogens causing BRD), housing and feeding, and is based on the main risk factors identified in previous Swiss studies (Lava et al., 2016a, 2016b).

A minimum of 50% of all calves fattened in an IF during the observation period (defined in 2.4.1.) had to be purchased from neighboring farms and transported directly to the IF by car with a driving time of 30 min or less. A private trailer for calf transportation had to be available. Purchasing calves from or having calves transported by livestock dealers was not permitted. Farmers were allowed to transport up to 10 calves at a time if they originated from the same farm. Commingling with other calves from third parties during the transport was not permitted in order to avoid potential transmission of infectious agents other than those of the home flora. The transport vehicle had to be washed and disinfected after each transport (using a disinfectant containing chlorcresol according to the manufacturer’s instructions), thus additionally limiting the transmission of infectious agents via inanimate objects. The calves were examined by the farmer for signs of disease (reduced general condition, nasal discharge, coughing, and signs of diarrhea, swollen navel or joints) and only calves not showing any of these signs were allowed to be transported. Furthermore, only calves that had received sufficient colostrum (two liters in the first three hours of life and a total of four liters within the first eight hours of life, based on the seller’s information) were purchased. For calves born on IF, colostrum supply as described was mandatory. The correct cleaning of the trailer, the purchase of clinically healthy calves and the correct colostrum supply could not be verified directly for practical reasons, these measures were considered to be implemented based on farmers' oral and written (contractual) confirmation. For calves born on IF, inclusion criteria for health did not apply and no evaluation was performed on a given day. Sick calves were treated if necessary by the farm veterinarian, and the treatments were recorded accordingly. Purchased calves were vaccinated upon arrival on the fattening farm by the farmer or, if born on the fattening farm, according to the manufacturer’s instructions (in the second week of life) with a live attenuated intranasal vaccine against Parainfluenza-3 virus and Bovine Respiratory Syncytial virus (Rispoval intranasal®, Zoetis, Delémont, Switzerland), which was provided free of charge to the farmers in the frame of the study. Subsequently, the calves were kept in individual hutches for a quarantine period of at least 3 consecutive weeks. The individual hutches (VDK Products, item number 050450, Moergestel, Netherlands) provided a straw-bedded shelter and an uncovered outside pen with a suckler bucket, a water bowl and a hay feeder, where the provision of straw bedding was optional (Figs. 1 and 2). The total floor surface area of the individual quarantine hutches was 4.1 m^2. The minimal distance between an outside pen and a potential source of infection such as animals in neighboring pens or fenced pastures had to be ≥1 m. Farmers were encouraged to use the quarantine hutches for newborns immediately after birth but were allowed to first keep newborns in an existing barn prior to the 3-week quarantine period. After the quarantine period, a group (≤10 calves with estimated weight differences ≤50 kg) was constituted and moved to a group hutch. Group composition remained unchanged until slaughter, with emphasis on the fact that no animal could be added after the group was constituted. Sick calves could be isolated in an individual hutch for treatment and reintroduced into the original group. Group housing (Zimmermann Stalltechnik, item number 02060010, Fulenbach, Switzerland) consisted of a straw-bedded (thickness 30 – 40 cm), roofed (height 2.8–3.3 m) and fenced paddock (32.5 m^2) with access to a hemispheric hutch (13.5 m^2) with roof aeration (Figs. 1 and 3). The devices were equipped with water supply (with heated water supply hoses to avoid freezing in winter), a hay feeder and a ten-place feeding grid with feeder buckets. Farmers committed to cleaning and disinfecting the

Fig. 1. Overview of an ‘outdoor veal calf’ facility: 12 individual hutches with outdoor pens and two group hutches with sheltered and straw-bedded outdoor pens were used in each of the 19 intervention farms. After birth or arrival after purchase, the calves completed a three-week quarantine period in individual hutches and were subsequently fattened in groups not exceeding ten calves.

Fig. 2. Detailed view of individual hutches: Calves are quarantined in individual hutches with a minimal distance of 1 m between pens to allow for visual contact among calves but prevent potential exchange of pathogens.

Fig. 3. Detailed view of a group pen: Both the ground of the hutch and the outside pen are straw-bedded (minimal depth of the straw bed: 30 cm). The roof prevents soaking of the bedding due to rainfall and provides shade. Thus, calves can stay in the sheltered outside pen by any weather condition and have constant access to outdoor air quality.

hutches using a disinfectant containing chlorcresol (Neopredisan 135-1, Vital AG, Oberentfelden, Switzerland) after each use. A mobile heated milk tank ('Milk Taxi', Holm&Laue, Westerrönfeld, Germany) with a pump for efficient milk delivery to the calves was provided for each IF. The amount of fresh milk and supplements (milk replacer, vitamins and/or minerals) fed daily were determined by the farmers. The necessary equipment (hutches and 'Milk Taxi') was provided to the IF free of charge for the duration of the study. All components and procedures of the concept were approved by the competent authority (authorization number BE 71/16) and fully complied with the Swiss animal welfare legislation. The managers of CF did not alter their daily routine and their calves were fattened in accordance with the IP-SUISSE label requirements including constant access to a non-roofed outdoor pen. Correspondingly, no bedding was provided outdoors to avoid soaking of bedding material and no shelter from weather was available outdoors. In 15 of 19 CF, groups of calves were housed in barns where they shared the air space with other calf groups or cows. Calves purchased for fattening in CF were transported by livestock dealers where mixing of calves from different birth farms occurs (Schnyder et al., 2019b).

Both IF and CF were visited once a month for a minimum period of 12 months. Prior to the study period, a test period of 1–2 groups of calves (i.e. 4–5 months) with monthly visits was performed in IF. Animals from the test period and their respective data (e.g. treatment and mortality data) were collected but excluded from later analyses. Each farmer was provided a specially designed treatment record booklet where detailed information on disease symptoms and treatment results were recorded in addition to the statutory requirements (first and last application date of the drug, identification number of the treated animal(s), indication for treatment, name and dosage of the drug, application route, and withdrawal period). Only products containing antimicrobials were taken into consideration for the calculation of treatment incidence. No advice regarding treatment strategies was given to the participating farmers (IF and CF), and all treatments were administered by local veterinarians according to their therapeutic protocols without consultation with the study team. All veterinarians working on the respective farms were informed about the study. Farmers committed to a contractual relationship for correct collaboration and provided written informed consent for confidential use of farm and animal data, including access to the Swiss animal tracing database (TVD; Tierverkehrsdatenbank, 2011).

2.3. Data acquisition and monthly farm visits

Farm visits were performed by a team of 3 veterinarians according to established protocols (Welfare Quality Protocol, Welfare Quality® Consortium, 2009) after instruction of two of them (AH, DW) by the main investigator on the project (JB) who developed adapted protocols and performed 70% of the farm visits.

During each farm visit, relevant data on calf level (identification number, date of birth and date of purchase if applicable, birth farm and distance to the fattening farm, sex, breed, date of death) were registered.

Frequent farm visits allowed for plausibility checks of the treatment records and for completing and adding missing entries, if any.

At the last visit before slaughter, the condition of calves was assessed at the individual level (including body condition and signs of diseases such as BRD, diarrhea and skin lesions).

After slaughter, further animal data were recorded on calf level (date and place of slaughter, carcass weight, carcass conformation, fat covering and meat color) for analysis of ADG and of carcass quality. Carcasses were routinely classified according to the CH-TAX system in use in Swiss slaughterhouses that classifies conformation (C = very good conformation to X = very poor conformation, 9 levels according to defined subgrades, (Proviande, 2015)) and fat covering (1 = very low fat, 5 = very high fat) in defined categories. In the Swiss meat processing industry, meat color (lightness, L*) is measured with a chroma meter ('Minolta CR 410'; Proviande, 2015) and price deductions are made for meat considered to be too red (based on the assumption of a lower customer acceptance for red veal).

Farm data were registered by conducting an extensive interview addressing parameters such as agricultural zone, staff, working habits, and other species held on-site.

Finally, an overall questionnaire on management practices (among others provision of colostrum, dam vaccination, cleaning routines) was conducted once in each farm.

2.4. Data management and analysis

Commercial software programs were used for data management (Microsoft Access® and Microsoft Excel®, Microsoft, Redmont, WA, USA).

2.4.1. Animal and slaughter data

Animal data were checked for accuracy using the TVD database. Calves were assigned to three groups depending on the breed: dairy breed, dual-purpose breed, and crossbreds (offspring of dairy breed dams and beef breed bulls). To assess the transport distance from the birth farm to the fattening farm for each calf, the fastest itinerary by road was calculated and the corresponding distance (in km) was attributed to the respective purchase. The ADG was calculated on animal level to allow for comparisons between farm groups and own vs. purchased calves. For the calculation of ADG in kg live weight gain per day, the following values were used based on the results of previous studies: body weight at the beginning of the observation period = 72.1 kg; body weight at slaughter in kg = carcass weight/0.56; fattening period = observation period (defined as the number of days from the age of purchase until the age of death or slaughter for purchased calves, and as the number of days from the mean purchase age of all purchased calves of the respective farm until the age of death or slaughter for calves born on the farm) (Bähler et al., 2012; Schnyder et al., 2019a). The percentages of carcasses allocated to one of the 3 best conformation levels (C, H, and T+) and to the optimal fat score (3) were calculated for each farm separately.

2.4.2. Antimicrobial use and mortality data

Antimicrobial use was calculated using values published by the European Medicines Agency (EMA) which define the amount of active substance needed to treat one 'standard' calf for one day (EMA, 2013, 2016). The outcome value is the treatment incidence in defined daily doses (TI_{DDD}); the unit is the number of daily doses per animal year (dd/ay). The administration of preparations containing two antimicrobials was counted as two treatments.

Calculation of TI_{DDD} requires the amount of active substance applied (extracted from the treatment records), the standard weight published by the EMA (80 kg), the number of days at risk (i.e. observation period) registered for each calf individually. Treatment incidence (in dd/ay, TI_{DDD}) was calculated first on calf level in order to draw comparisons between IF and CF as well as between own and purchased calves. The TI_{DDD} was calculated for each farm according to the following formula:

$$TI_{DDD} = \frac{total\ amount\ of\ drug\ administered\ (mg)}{DDD\ (mg/kg)\ x\ number\ of\ calf\ days\ at\ risk\ x\ standard\ weight\ (kg)} * 365$$

For calculation of overall TI_{DDD} on group level (first calculated separately for each IF and CF), the sum of all daily doses of all calves of one farm was divided by the sum of the observation periods of all calves of the respective farm (treated and non-treated calves).

To assess the calf's age at treatment, the first day of the respective treatment was used.

Mortality was defined as death caused by either euthanasia or sickness during the observation period.

Mortality was calculated per farm as deaths over the total number of calves entering the fattening process. In order to evaluate the influence of seasonality on the variables TI_{DDD}, mortality and ADG, corresponding data were calculated on monthly level. For this calculation, treatments were attributed to the month of the first day of treatment. The number of daily doses for each calf in the respective month was calculated and daily doses of all calves were cumulated, and the total number of days calves spent on the farm in the respective month (calf-days) was calculated. Finally, one treatment incidence value per calf was obtained for each month. Months were grouped to seasons regardless of the year as follows: March-May (spring), June-August (summer), September-November (autumn), and December-February (winter). For calculation of percentages of single antimicrobial substances used, the actual days under treatment were used for each calf and the sum of all days under treatment of the same category (e.g. all treatment days applied by oral route) was set as 100%. For calculation of monthly mortality values, the number of calves that died in the respective month was calculated. For calculation of monthly purchase rates, purchase rates were defined for each month as percentage of purchased calves present in the respective month. Whether calves spent the whole month or only a fraction of the month on the farm was not taken into account. The mean ADG value of all calves slaughtered in the respective month was calculated for each farm.

Animal health parameters were also assessed during the farm visits, details of health and welfare assessments will be reported elsewhere.

2.4.3. Statistical analyses

Descriptive analysis of continuous variables was done to provide mean, standard deviation, median, minimum and maximum values. Exploratory analysis of differences between IF and CF was performed with either Wilcoxon rank-sum test or t-test depending on data distribution. These analyses were done using Microsoft Excel® (Microsoft, Redmont, WA, USA) and 'R' Version 3.5.1 (R Core Team; packages data.table, descr, dplyr, MASS, tidyr).

The dependent variables TI_{DDD}, mortality and ADG were analyzed on monthly level by use of regression models in SAS 9.4 (SAS Institute Inc., Cary, USA). Data were analyzed on monthly level to allow for assessing seasonal effects. For TI_{DDD}, a zero-inflated negative binomial model resulted in the best model fit, due to a considerable number of months without treatment in both groups (SAS PROC GLIMMIX with independent covariance structure). For mortality, neither Poisson nor negative binomial models resulted in an acceptable model fit. Therefore, mortality was dichotomized at a cutoff of > 0 (dead calves observed in the farm in the respective month, yes/no), and analyzed with a mixed logistic model (PROC GENMOD with independent covariance structure). The variable ADG was analyzed with a mixed linear model with SAS PROC MIXED with variance components as covariance structure. All models corrected for clustering at the herd level by including the herd as a random effect. The independent variable group (IF or CF) was included in all models. In addition, the potential explanatory variables '% purchased calves', '% male calves', '% crossbreds', '% dual-purpose breeds' (each categorized into three categories with approximately the same number of farms per category as shown in Tables 3 and 5), and season were offered to all models. A stepwise backward selection procedure was carried out by, first, offering all variables to the model. In a second step, the variable with the largest p-value was removed. In the following steps, remaining variables were removed, each time prioritizing the variable with the highest p-value. Only variables which changed the effect of the variable group by more than 10% or which had a significant effect on the outcome were maintained in the models. The level of significance was set at $p < 0.05$. Variables were checked for correlation among each other. If phi values > 0.7 had been observed, the variable with the largest expected biological effect on the outcome (based on the available scientific literature) would have been offered to the models. While this did not occur for any of the variables, the potential explanatory variables '% purchased calves', '% male calves', '% crossbreds', and '% dual-purpose breeds' were all moderately correlated with each other (phi 0.64-0.68). The interaction between group and season was also offered to the models to assess whether the effect of the 'outdoor veal calf' system depends on seasonal conditions. From the final models, the intraclass correlation coefficient was calculated from the covariance parameter estimates with the formula:

$$ICC = var(farm)/(var(farm) + var(residual))$$

where ICC is the intraclass correlation coefficient, var(farm) is the covariance parameter estimate of the random effect farm, and var(residual) is the residual covariance parameter estimate.

Model fit was evaluated by visual assessment of residuals for all models, and by AIC and BIC. In addition, model fit of the linear model was assessed by normality test of residuals.

3. Results

3.1. Farms and farm data

A total of 20 farms per group (IF and CF) were gradually included in the study and observed for at least 12 months each between October 2016 and July 2018. One farm per group was excluded during the course of the study (one IF due to lack of compliance of the farmer and one CF because veal production was stopped). A total of 306 and 229 visits were conducted on IF and CF, respectively. All farms were located in central and western Switzerland at moderate altitudes (IF: 626 ± 130 m, CF: 715 ± 236 m above sea level; p = 0.163). The IF were visited over a longer period of time than CF (IF: 432 ± 58 days, CF: 349 ± 41; p = 0.002) because the number of fattened calves per year was lower (Table 1). The number of birth farms per 10 calves did not differ significantly (IF: 2.26 ± 1.10; CF: 3.01 ± 1.91; p = 0.189) but IF calves were transported over significantly shorter distances (IF: 19.0 ± 25.4 km; CF: 37.8 ± 42.0 km; p = 0.007). At the end of the study period, four farmers had purchased less than the expected 50% of the fattened calves (1 IF with a purchase rate of 48.6 %; 3 CF with purchase rates of 41.9%, 45.9% and 46.7%, respectively). All IF fed their calves twice daily with the heated tank ('Milk Taxi'), all CF provided continuous access to automated milk feeding machines. Ten of 19 IF declared compliance with instructions for disinfecting the hutches, 3

Table 1
Characteristics of veal calves and purchase processes in 19 intervention farms (IF, outdoor veal farms) and 19 control farms (CF) in Switzerland.

Parameter	Unit	Farm type	N[a]	Mean	SD	Median	Min	Max	p-value
Calves fattened per farm	calves/365 days	IF	900	40.96	11.30	37.76	13.39	58.09	0.002
		CF	1005	53.59	11.83	53.09	32.64	72.21	
Mean duration of the fattening period	days	IF	885	121.19	24.92	120	0	220	0.603
		CF	997	116.02	26.08	118	7	217	
Purchase rate	%	IF	19	62.67	11.08	60	48.57	86.27	0.137
		CF	19	70.84	18.13	72.97	41.86	93.15	
Farms of origin per 10 calves	n	IF	207	2.26	1.10	2.13	0.49	4.79	0.189
		CF	306	3.01	1.91	2.58	0.86	8.57	
Mean age at purchase	days	IF	562	32.97	12.00	31	2	88	0.311
		CF	739	30.12	13.20	29	1	85	
Mean transport distance	km	IF	19	18.96	25.42	11.70	0.10	147	0.007
		CF	19	37.78	41.94	21.40	0.10	237	
Male calves	%	IF	900	77.17	15.47	80.58	45.45	98.33	0.307
		CF	1005	72.12	14.54	71.11	50.68	98.39	
Dairy breeds	%	IF	19	32.94	30.05	21.67	0	91.43	0.511
		CF	19	27.01	25.62	17.54	0	91.94	
Dual-purpose breeds	%	IF	19	29.28	25.17	22.73	0	82.61	0.414
		CF	19	31.93	19.05	29.85	3.45	72.92	
Crossbreds	%	IF	19	37.78	26.29	31.71	0	76.79	0.610
		CF	19	41.06	23.18	73.93	0	79.41	

[a] Indicates the total number of calves or farms used for calculation.

only disinfected individual hutches, 1 used other disinfectants, 3 did not disinfect, and 2 did not disclose their procedures.

3.2. Animal data

Details on calves are given in Table 1. A total of 1905 calves were included in the study, of which 1418 (74.4%) were male and 487 (25.6%) female. Of these, 759 (39.8%) were crossbred, 593 (31.1%) belonged to milk breeds, and 553 (29.0%) to dual-purpose breeds. A total of 1790 (94.0%) calves were slaughtered, 93 died (4.86%) and 22 calves (1.15%) were still alive at the end of data collection. These 22 animals were sold by the owners or kept on the farm for breeding purposes instead of being slaughtered as veal calves. These animals were kept normally in the veal calf groups and complete data (in particular antimicrobial treatment data) were available and were included in the analyses, except for results related to slaughter. Calves from IF and CF were purchased at a similar age (IF: 33.0 ± 12.0 days; CF: 30.1 ± 13.2 days; $p = 0.311$). Calves in IF were moved from the individual hutches to the group hutches at a mean age of 65.3 ± 20.9 days, exceeding the minimal mandatory quarantine period by 11 days on average. Out of all 900 enrolled calves on IF, 40 (4.4%) did not complete the prescribed 21-day quarantine period.

3.3. Antimicrobial use and treatment incidence

For the entire duration of the observation period, one complete treatment record booklet per farm was available for 37 of the 38 farms. Treatment data of 1 CF which provided data for 6 months were included for this period only (due to reduced compliance of the farmer for treatment recording), resulting in a shorter observation period concerning antimicrobial use data on this farm. However, farm visits were performed and other data was collected as in other CF. A total of 495 monthly treatment records were available and a total of 1864 antimicrobial drug treatments was registered, of which 1243 (66.7%) were group treatments and 621 (33.3%) individual treatments; 234 treatments (12.5%) were administered on IF, 1630 (87.4%) on CF.

The mean total farm treatment incidence (TI_{DDD}) on IF corresponded to 18.9% of treatment incidence on CF (5.9 ± 6.5 vs. 31.5 ± 27.4 dd/ay; $p < 0.001$; Table 2, Fig. 4). No antimicrobials were administered in 3 IF during the entire study period. The main indication for treatments was pneumonia (70.6%), followed by diarrhea (8.7%), reduced general condition (8.6%) and metaphylactic treatments (4.7%). The most frequently administered active substances were chlortetracycline (35.8%), amoxicillin (17.9%) and doxycycline (12.1%) for group treatments, and oxytetracycline (28.5%), procaine benzylpenicillin (12.7%), and florfenicol (11.4%) for individual treatments. Chlortetracycline (38.4%), amoxicillin (19.0%) and doxycycline (11.6%) were the most frequently administered drugs by oral route, and oxytetracycline (32.1%), tulathromycin (17.1%) and florfenicol (14.6%) by parenteral route. Most group treatments were applied per os (95.7%) and individual treatments per injection (85.0%). Three CF had lower TI_{DDD} values than the mean TI_{DDD} of IF. The mean age at treatment was 84.2 ± 35.3 days in IF and 62.7 ± 31.2 days in CF ($p = 0.024$). Assuming a constant weight gain throughout the fattening period (Quigley et al., 2006; Khan et al., 2011; Johnson et al., 2018), the estimated live weight at treatment was 138.2 ± 45.6 kg in IF and 116.0 ± 42.2 kg in CF ($p < 0.001$). Overall, the TI_{DDD} was lowest in autumn, followed by winter and summer, and highest in spring. The analysis stratified by group showed that spring was, however, the season with the lowest TI_{DDD} in IF, indicating that the increase of treatment incidence in spring was only due to treatments in CF. In the negative binomial regression model, group, season and their interaction also had a significant association with TI_{DDD}. Generally, IF had a lower TI_{DDD} than CF, and this effect was significantly larger in spring than in summer. Lower proportions of purchased calves and of male calves were also significantly associated with reduced TI_{DDD} (Table 3). The ICC for the random farm effect was 0.06.

Table 2
Characteristics of the main outcomes antimicrobial use (TI_{DDD}), mortality and average daily weight gain (ADG), and of related parameters in Swiss veal operations (intervention farms, IF, and control farms, CF).

Parameter	Unit	Farm type	N[a]	Mean	SD	Median	Min	Max	p-value
Mean farm treatment incidence (TI_{DDD})	days/animal year	IF	19	5.90	6.53	4.58	0	25.01	< 0.001
		CF	19	31.50	27.39	19.96	3.54	97.48	
Mortality	%	IF	19	3.07	2.34	2.63	0.00	8.57	0.020
		CF	19	6.29	4.93	4.48	0.00	20.97	
Mean ADG	kg /day	IF	846	1.29	0.17	1.32	0.91	1.49	0.244
	CF	918	1.35	0.16	1.33	1.09	1.65		
Mean farm treatment incidence (TI_{DDD}) for individual treaments	days/animal year	IF	19	3.42	3.19	2.46	0	9.07	0.025
		CF	19	7.86	7.26	6.34	0	28.19	
Mean farm treatment incidence (TI_{DDD}) for group treatments	days/animal year	IF	19	2.48	5.80	0	0	20.62	< 0.001
		CF	19	23.64	26.15	17.66	0	97.48	
Treated animals	%	IF	19	15.10	11.54	16.00	0	45.71	< 0.001
		CF	19	56.00	24.33	58.13	24.29	98.38	
Mean number of treatments per treated animal	n	IF	16	1.66	0.59	1.65	1.00	2.88	0.004
		CF	19	2.43	0.86	2.71	1.21	4.04	
Best carcass meat conformation	%	IF	354	40.47	27.02	40.00	2.44	86.05	0.080
		CF	530	57.50	26.84	64.81	2.04	92.00	
Best carcass fat score	%	IF	407	46.53	19.70	44.64	4.88	78.12	0.003
		CF	608	63.88	17.33	68.52	12.50	81.82	
Mean meat colour	lightness (L*)	IF	19	44.19	3.26	43.64	37.85	55.72	0.908
		CF	19	44.08	3.31	43.63	34.48	55.13	

[a] Indicates the total number of calves or farms used for calculation.

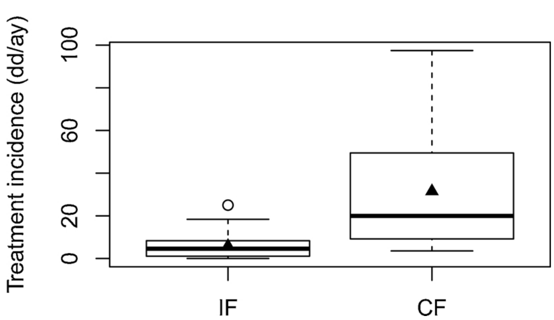

Fig. 4. Antimicrobial use (treatment incidence in defined daily doses (TI_{DDD}) per animal year (dd/ay) in intervention (IF, outdoor veal calf) and control farms (CF). Triangles indicate mean values.

3.4. Mortality

Mean mortality on IF was 48.8% of the rate on CF (3.1% ± 2.3 and 6.3% ± 4.9, respectively; p = 0.020; Table 2). Calves in IF and CF died at a mean age of 100.7 (± 6) days and 94.8 (± 4) days, respectively (p = 0.873). The causes of death reported by the farmers included BRD (IF: n = 2, CF: n = 21), diarrhea (IF: 4, CF: 2), poor growth (IF: 2, CF: 4), and unknown reasons (IF: 18, CF: 40). Necropsy was not performed systematically on the dead calves. Mortality was ≤10.0% in all farms with exception of two outliers in CF (15.1% and 21.0%). In the mixed logistic regression model, only group and season were significantly associated with monthly mortality risk (Table 4). There was no clustering of mortality at the level of the farm (ICC = 0). Intervention farms had significantly lower odds of mortality than CF (OR for mortality in CR in the univariable analysis = 2.4, p < 0.001). Mortality occurred less frequently in spring (OR = 0.32) and winter (OR = 0.41) than in summer.

3.5. Average daily weight gain and carcass traits

The mean calculated ADG was 1.29 ± 0.17 kg in IF and 1.35 ± 0.16 kg in CF (p = 0.244). Modelling ADG in a mixed linear regression provided non-significantly higher ADG for CF by 50 g/d (p = 0.07). There was no association of the season of slaughter with ADG. The only explanatory variable with a significant association was the percentage of crossbreds (Table 5). The ICC for the random farm effect was 0.40. The proportion of carcasses allocated to the three highest quality categories differed between groups for fat score but no differences were observed for carcass conformation and meat color (Table 2).

4. Discussion

The drastic reduction of antimicrobial use observed in ‘outdoor veal calf’ farms in comparison to conventional operations was achieved by implementing relatively simple measures such as direct purchase and transport from farms in the vicinity of the fattening farm, quarantine and vaccination upon arrival, and sheltered outdoor housing during the entire fattening period. These measures compensated for conditions that compromise animal health and are yet inherent to veal production such as purchase of calves from other farms and the calf’s immature immune system at the beginning of the fattening period (Kampen et al., 2006; Lava et al., 2016a; Schnyder et al., 2019a). Although the reduction of TI_{DDD} was more distinct in group treatments, individual treatments were also significantly reduced in IF compared to CF. The reduced antimicrobial use observed in IF was, therefore, not only due to the differences in metaphylactic antimicrobial use. The percentage of animals that received treatment as well as the number of treatments per treated animal were also reduced. Hence, it can be concluded that the need for treatments in IF was lower than in CF. Strict application of the

Table 3
Results of the zero-inflated negative binomial regression model for monthly treatment incidence (TI_{DDD}) in Swiss veal operations (19 intervention farms, IF, and 19 control farms, CF).

Parameter	Category	Estimate[a]	95% CI		p-value
Estimates of the negative binomial model			Lower	Upper	
Intercept		4.49	4.44	4.55	< 0.001
Group	IF	−0.91	−1.01	−0.82	< 0.001
	CF	Ref.			
Season	Spring	0.63	0.58	0.69	< 0.001
	Autumn	−0.58	−0.65	−0.51	< 0.001
	Winter	−0.13	−0.19	−0.06	< 0.001
	Summer	Ref.			
Intervention/Spring		−0.88	−1.03	−0.74	< 0.001
Intervention/Autumn		0.00	−0.16	0.16	0.98
Intervention/Winter		0.00	−0.16	0.16	0.97
Intervention/Summer; all seasons of control farms[a]		Ref.			
Purchased calves present (per farm and month)	≤ 55%	−0.58	−0.63	−0.53	< 0.001
	> 55% to ≤75%	−0.45	−0.51	−0.39	< 0.001
	> 75%	Ref.			
Proportion of male calves present (per farm and month)	≤ 65%	−0.30	−0.35	−0.25	< 0.001
	> 65% to ≤ 80%	−0.12	−0.17	−0.06	< 0.001
	> 80%	Ref.			
Proportion of dual-purpose breeds present (per farm and month)	≤ 20%	0.41	0.36	0.46	< 0.001
	> 20% to ≤ 35%	−0.08	−0.14	−0.02	0.01
	> 35%	Ref.			
Zero-inflation parameter estimates					
Group	IF	1.08	0.72	1.44	< 0.001
	CF	Ref.			

[a] For interaction section, reference lines are taken together for presentation purposes. For IF, the reference is summer. For CF, the references are the results of CF in all seasons. Estimates indicate relative TI_{DDD} values per calf and month.

project principles likely reduced the risk of infection when the animals were regrouped. Pathogen buildup is less likely to occur in susceptible animals that remain healthy, which, in turn, lessens the risk of pathogen transmission (Costa et al., 2016).

In comparison with other studies (Pardon et al., 2012a; Bähler et al., 2016; Catry et al., 2016; Dorado-García et al., 2016; Lava et al., 2016b; Jarrige et al., 2017; MARAN, 2018; Bokma et al., 2019), the mean TI_{DDD} in IF (5.9 daily doses per calf-year, corresponding to 2.0 days of treatment in average for a single calf fattened in IF) was low. In contrast, the TI_{DDD} in CF (31.5 days per calf-year, corresponding to 10.0 days under treatment per calf) was in accordance with other studies (Lava et al., 2016b; Jarrige et al., 2017; Bokma et al., 2019).

The assumed standard weight of 80 kg used for the calculation of TI_{DDD} according to the recommendations of the European Medicines Agency (EMA, 2013) did not correspond to the actual estimated weight of the calves at the time of treatment: the calves were treated at a mean age of 12 weeks in IF and 9 weeks in CF, when they were estimated to be considerably heavier than 80 kg (138 and 116 kg on average in IF and CF, respectively). This leads to an overestimation of treatment incidence due to underestimated weight in both groups. Additionally, the weight at treatment probably differed between IF and CF, as IF calves were estimated to be heavier by 22 kg on average. As a consequence, the overestimation of TI_{DDD} is even more pronounced in IF. The comparison of TI_{DDD} in individual IF and CF leads to the observation that IF did not systematically perform better (3 CF had lower TI_{DDD} than the mean TI_{DDD} of IF).

Table 4
Results of the mixed logistic model for mortality > 0 in Swiss veal operations (19 intervention farms, IF, and 19 control farms, CF).

Parameter	Category	Odds Ratio	95% CI		p-value	overall p-value
			Lower	Upper		
Intercept					0.01	
Group	IF	0.36	0.22	0.61	< .0001	< 0.001
	CF	Ref.				
Season	Spring	0.32	0.14	0.71	0.01	0.02
	Autumn	0.62	0.32	1.22	0.17	
	Winter	0.41	0.20	0.86	0.02	
	Summer	Ref.				

Table 5
Results of the mixed linear model for average daily gain (ADG) in Swiss veal operations (19 intervention farms, IF, and 19 control farms, CF).

Parameter	Category	Estimate	95% CI estimate Lower	Upper	p-value	overall p-value
Intercept		1.40			< 0.001	
Group	IF	−0.05	0.00	−0.10	0.07	0.07
	CF	Ref.				
Proportion of crossbreds present (per farm and month)	≤ 20%	−0.13	−0.07	−0.18	< 0.001	< 0.001
	> 20% to ≤ 50%	−0.09	−0.02	−0.15	0.01	
	> 50%	Ref.				

Relatively more calves received (often metaphylactic) treatment at a young age as a consequence of purchase and commingling in CF, thus lowering the overall mean age of treatment compared to IF. In contrast, direct purchase and stepwise entering in the fattening unit in IF made treatment at the beginning of the fattening period unnecessary, and the mean age of 84 days (sd, ± 35.3) at the time of treatment represents approximatively the middle of the fattening period, reflecting the fact that treatments were evenly distributed over the entire fattening period (data not shown). The managers of IF reported that they did not observe any signs of compromised animal health after regrouping the calves from individual to group hutches.

Fattening calves according to the 'outdoor veal calf' concept in IF posed a significantly lower risk for mortality, as the percentage of dead calves was halved in IF compared to CF (approximately 3% vs. 6%). Mortality in both farm groups was close to the range of values reported by others in Switzerland with values between 3.6% and 5.1% (Bähler et al., 2012; Lava et al., 2016b; Schnyder et al., 2019a), and rather low in international comparison where values between 5.3% and 8.9% have been described (Sargeant et al., 1994; Pardon et al., 2012b; Renaud et al., 2018a). Mortality is an important reason of economical loss in calves (Mee, 2008), and a reduction would be of great importance with regard to the poor margin of profit for Swiss veal farmers (Bühler, 2002).

No significant difference in ADG was found between groups in the descriptive analysis, and modeling showed a slight, non-significant effect of farm group on ADG. This might be associated with the significantly lower percentage of carcasses with the best fat coverage in IF compared to CF. The slightly lower ADG in IF could also be explained by the feeding strategy. Calves in IF were fed milk twice daily with the mobile heated tank whereas calves in CF were provided constant access to an automated feeding machine. However, average total dry matter intake (DMI) did not differ significantly between groups (IF: 259.9 ± 26.5 kg/calf vs. CF: 266.2 ± 46.0 kg/calf, $p = 0.964$, data not shown). Potentially colder outside air temperatures in IF might have been associated with higher energy requirements for thermoregulation and might have contributed to the tendency of lower ADG in IF calves. From an economical point of view, the minimally higher calculated numerical mean ADG value in CF may be compensated for by the drastically lower values of TI_{DDD} and mortality in IF, i.e. reduced costs for treatments and animal losses. Details on economic aspects of the 'outdoor veal calf' concept will be reported elsewhere.

Assuming a lower ADG of 50 g/day in IF would lead to lighter body weight (6.1 kg in live weight or 3.4 kg of carcass weight) representing 2.6% of a standard IF carcass. Providing (weather-proofed) automated feeders in 'outdoor veal calf' operations in the future may lead to higher DMI and ADG values in IF.

When comparing two fattening strategies regarding the use of antimicrobials, it is imperative to measure parameters indicative of animal health and welfare (henceforth named 'animal health'): the reduction of antimicrobials may not be achieved at the cost of the individual animal, i.e. animals in need of treatment may not be left untreated even if the declared goal of the study is to develop a new system to reduce antimicrobial use. Indeed, several parameters indicative of animal health were better in IF than in CF, confirming that the reduction of TI_{DDD} was due to better animal health in IF (L. Moser, personal communication). The results of the health and welfare analyses will be reported elsewhere.

Purchase is known to be associated with increased TI, administration of metaphylactic antimicrobial treatment upon arrival at the fattening farm and later in the fattening period, and increased mortality (Lava et al., 2016a; Schnyder et al., 2019a). The results of the present study provide evidence that implementation of the 'outdoor veal calf' concept mitigated the negative effects of purchase. This result is crucial for the Swiss veal sector as calf purchase cannot be eliminated completely given the interdependence of dairy farmers, who need to sell supernumerary calves, and veal producers, who need to complete fattening groups with purchased calves. Transport has been shown to cause stress and increase disease susceptibility (Masmeijer et al., 2019). The fact that IF calves were transported directly over short distances and in the farmers' own trailers likely attenuated negative transport-related effects. Purchase is closely related to commingling, which is an integral part of the 'outdoor veal calf' concept although it is a well-known risk factor for stress and transmission of infectious agents (Assié et al., 2009; Wilcox et al., 2013). However, commingling occurs only after a 3-week quarantine period when the calves are moved from the individual to group hutches. Commingling could be postponed whenever individual calves were showing signs of disease at the end of the anticipated quarantine period. Hereby the risk of transmitting pathogens from a diseased individual to the group could likely be lowered.

The respective contributions of the single components of the 'outdoor veal calf' concept, such as quarantine, vaccination, limited age differences within a group or limited group size, to the overall results cannot be estimated, as the objective of the study was to test the efficacy of the novel concept as a whole. Furthermore, the single effects of the different factors taken into consideration in the development of the 'outdoor veal calf' concept have already been quantified in previous studies in Switzerland (Lava et al., 2016a, 2016b; Schnyder et al., 2019a) and in other countries (Brscic et al., 2012; Bokma et al., 2019).

Cold seasons have been reported to be associated with increased morbidity (Andrews, 1976; Busato et al., 1997; Fertner et al., 2016; Bokma et al., 2019). Both autumns of 2017 and 2018 were unseasonably sunny and warm, which may explain why autumn was not associated with an increase of TI_{DDD} in the model. Also winter was not associated with an increased TI_{DDD}, but spring was. This seasonal overall increase during spring was caused by an increase of antimicrobial use in CF only (detailed descriptive data not shown). Surprisingly, the highest mortality rates were not observed during cold seasons but in the summer, which was in contrast with other studies where fall and/or winter were associated with highest risk of death (Svensson et al., 2006; Bleul, 2011; Renaud et al., 2018a) or no seasonality was observed (Sargeant et al., 1994; Santman-Berends et al., 2018). The fact that TI and mortality did not rise in winter and spring in IF suggests that calves can cope well with cold in all year round outdoor fattening facilities, while housing in closed barns to provide shelter from cold weather may rather create conditions favoring the development and transmission of diseases, especially BRD which was confirmed as the most common indication for antimicrobial treatment in CF. This is in agreement with findings that describe an association between closed barns offering access to an outside pen with increased treatment incidence (Schnyder et al., 2019a) and increased mortality (Bähler et al., 2012; Lava et al., 2016a).

An association of ADG with season was not observed, which is in contrast to reports of lower growing rates in fall/winter (compared to spring) (Svensson and Liberg, 2006) or of higher ADG in winter (compared to other seasons), respectively (Renaud et al., 2018b). The effort of maintaining a stable body temperature in winter appeared to have a negligible effect on ADG both in the 'outdoor veal calf' system and CF.

In the present study, a selection bias must be assumed as farmers of both groups had to be motivated above average to accept monthly farm visits and provide detailed farm data during one year, with or without implementing the 'outdoor veal calf' concept. In IF, a majority of the farmers was likely rather innovative as the impact of the concept on antimicrobial use was unknown at the start of the project, and IF farmers may potentially have opted for participation in the study because they were discontent with conventional systems. At least one group of calves was fattened on each IF before the beginning of the actual study period in order to allow the farmers to get used to the new system. The uneventful implementation of the new system on all IF demonstrated that no above-average skills are necessary to implement the concept. As a consequence, every farmer has good prospects of lowering TI_{DDD} and mortality by correctly implementing the 'outdoor veal calf' concept. A limitation to the implementation of the new system is that a sufficient flat surface must be available, which is not given in all farms in certain regions of Switzerland. Less mountainous regions or countries are less likely to be confronted with this limitation and could increase the farm's veal production by adding multiple individual hutches and group hutches. As far as the concept's central requirements such as direct purchase, quarantine and vaccination, and limited group size are fulfilled, comparable results should be achievable with higher numbers of calves per operation.

5. Conclusions

The implementation of relatively simple measures targeted at well-known risk factors for impaired animal health allowed for a drastic reduction of TI and mortality in veal operations without jeopardizing animal health and growth rates. Purchase and transport are currently integral parts of the veal industry and cannot be circumvented, however their negative effects on calf health can be compensated by the positive effects of the new system. This system is easy to realize and can be used in different settings and geographical regions. The observed five-fold reduction in antimicrobial treatments observed in IF compared to CF provides an important contribution to the limitation of the selection pressure for resistant bacteria in veal calf operations.

Conflict of interest

The authors declare no conflict of interest.

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