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An exploratory cross-sectional study of the impact of farm characteristics and calf management practices on morbidity and passive transfer of immunity in 202 Chianina beef-suckler calves

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ABSTRACT

There are no published data on the risk factors associated with morbidity, mortality and passive transfer failure in Chianina beef-suckler calves. To implement prevention strategies in beef enterprises, gaining management information and identifying risk factors are essential. This cross-sectional study aimed to identify calf-level management practices and farm characteristics associated with disease incidence, mortality and serum IgG concentration in Chianina beef-suckler calves from farms in Umbria, Italy. In total, 202 Chianina beef-suckler calves aged 2–7 days from nine farms were enrolled. For each calf born, blood samples were collected and specific information on management practices and farm characteristics was obtained through farmer interviews. Serum immunoglobulin concentrations were measured using radial immunodiffusion. Mortality and morbidity data were extracted from the farm's cow file six months after the last farm visit. The impact of farm characteristics and calf management practices on the mortality rate could not be assessed due to low case fatality in our enrolled calves (10/202). A multivariable logistic regression model indicated that prepartum vaccination against *Escherichia coli*, rotavirus and coronavirus, and bottle-fed colostrum were associated with serum IgG concentration. Birth season and serum IgG concentration were associated with the development of neonatal calf diarrhoea and the development of both neonatal calf diarrhoea and respiratory disease, respectively. Furthermore, family-owned farms represent an important factor related to respiratory disease episodes. The possible influence of these factors on passive immunity and neonatal calf diarrhoea and respiratory disease appearance should be considered when advising farmers.

HIGHLIGHTS

- Effects of farm characteristics and management practices on health were investigated in 202 Chianina calves.
- Dam vaccination against *Escherichia coli*, Rotavirus and Coronavirus, and colostrum feeding assistance affect calf passive immunity.
- Calves with low serum IgG concentrations became sick; diarrhoea was common during cold months; respiratory disease was more common in family-run farms.

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Introduction

Due to a syndesmochorial type of placentation, calves are born almost agammaglobulinemic with an immature immune system (Godden et al. 2019). Therefore, colostrum transfer of passive immunity provides calves with protection against infections during their first weeks of life (Weaver et al. 2000). Depending on how

the failure of passive transfer (FPT) and livestock systems are defined, the prevalence is reported to reach 16–29% in new-born beef calves (Filteau et al. 2003; Waldner and Rosengren 2009; O'Shaughnessy et al. 2015). The key role of colostrum-derived passive immunity influencing mortality, morbidity and growth of new-born beef calves is internationally recognised

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(Raboisson et al. 2016; Todd et al. 2018). Calf morbidity and mortality result in significant economic losses for the beef industry and represent an indicator of herd health and welfare status (Murray et al. 2016; Mötus et al. 2017). Neonatal calf diarrhoea (NCD) and bovine respiratory disease (BRD) are the most common causes of morbidity and mortality in beef calves worldwide (Schumann et al. 1990; Busato et al. 1997; Lievaart et al. 2013; Santos et al. 2019) and are often directly correlated with FPT (Todd et al. 2018). Previous studies have established that winter calving (Murray et al. 2016), high livestock density (Mötus et al. 2017), dystocia (Ring et al. 2018), unassisted calving (Bragg et al. 2020), male sex (Mötus et al. 2017; Ring et al. 2018), multiple breeds within the herd (Hanzlicek et al. 2013), a higher proportion of cows with mismothering problems (Lievaart et al. 2013) and poor colostrum management strategies (Bragg et al. 2020) correlate with an increased rate of FPT, mortality and morbidity in beef calves. Several management practices and farm characteristics that can increase these pathological conditions may be susceptible to manipulation to reduce their impact on herd health status, especially since these disease events are often difficult to treat or have effects that persist for a long time (Thompson et al. 2006; Boccardo et al. 2016). Therefore, knowledge of these issues could help practitioners improve or re-evaluate farm management decisions to prevent neonatal diseases and ensure better profitability and enhanced animal welfare conditions.

Most studies have focussed on intensively managed beef cattle systems or extensive calf-cow operations evaluated in several European countries, North America and Australia. However, the factors that can affect neonatal pathological conditions in autochthonous beef breeds, often raised in marginal areas using peculiar management systems, are not well understood (Sbarra 2011).

Chianina is one of the most important Italian autochthonous beef breeds and has been raised for over 20 centuries on the central Appennini Mountains (D'Alessandro et al. 2012). It is a long-lived giant breed selected for its high-quality meat produced with breeding techniques that have low environmental impact (Bongiorni et al. 2016; Torquati et al. 2018). Ninety percent of Chianina farms are located in three regions of central Italy (Tuscany, Lazio and Umbria) (ANABIC 2020). Registered heads increased from 32,246 in 1998 to 46,023 in 2019, followed by a concurrent increase in herds from 1,141 to 1,496 in the same period (Anabic 2020). According to the

European Union, which recognises meat produced from Chianina cattle as agro-food excellence (European Commission 1992), the breeding practices follow strict criteria codified by the "Vitellone Bianco dell'Appennino Centrale" consortium (<https://www.vitellonebianco.it/download/disciplinari>). It is mandatory that calves are fed spontaneously from the dams until weaning and are fattened in multiple pens on permanent litter or tied in closed stalls up to 18–24 months of age fed according to a moderate feeding plan (Cozzi 2007). Although the contribution of Chianina breeding to increasing the sustainability and efficiency of breeding systems in mountainous areas has been known for a long time (Saccomandi and van der Ploeg 1995), no studies have investigated specific management practices in Chianina farms and their influence on neonatal pathological conditions. Thus, this study aimed to investigate current calf management practices and farm characteristics in Chianina farms in Umbria and to determine their association with morbidity, mortality and serum immunoglobulin G (IgG) concentration in Chianina beef-suckler calves.

Materials and methods

Study design and inclusion criteria

This cross-sectional study was approved by the University of Perugia Bioethics Committee (Perugia, Italy; Protocol no. 2019-49). Participants were enrolled using a convenience sample of Chianina beef farms regularly monitored by the ambulatory clinic of the Veterinary Teaching Hospital (OVUD) of the Department of Veterinary Medicine, University of Perugia. Enrolled farms were identified based on three selection criteria: (1) willingness to perform blood samples and collect specific information on calf management practices and farm characteristics through a face-to-face interview; (2) compliance with the breeding methods of the "Vitellone Bianco dell'Appennino Centrale" consortium; (3) location of the farms (≤ 2 h drive from the OVUD).

From 1 November 2018 to 31 October 2019, one experienced veterinarian (LP) visited the enrolled farms once a week. Healthy male and female Chianina calves aged 2–7 days were eligible for inclusion in this study. All calves born at the previous visit were systematically enrolled during weekly farm visits. Calves were identified with the ear tag having the national registry code number at each farm and were excluded if they had signs of congenital malformations, laboured breathing, or were born before the expected term. For each calf born, specific information on

Table 1. General farm characteristics and calf management practices used to investigate their association with morbidity, mortality, and serum IgG concentration in 202 Chianina beef farms located in Umbria.

<i>Variables associated with general farm characteristics</i>	
Animal caretaker	Farmer and family; full-time employees; part-time employees
Herd size	Number of cows
Type of cow barn	Free-range; stanchion barn; loose housing barn
<i>Variables associated with calf management practices</i>	
Gender	Male, female
Age at blood sample	Day
Twin birth	Yes, no
Time of birth	7 am/7 pm (day); 7 pm/7 am (night)
Birth season	Spring (1 March to 31 May); summer (1 June to 31 August); autumn (1 September to 20 November); winter (1 December to 28 February)
Type of calving	Eutocic (unassisted); mild traction; mechanical calf puller; C-section
Dam age	In years
Parity	N
Body condition score at calving ^a	<2.75; 2.75–3.25; >3.25
Dam pre-partum vaccination against vaccinated against <i>Escherichia coli</i> , Rotavirus, and Coronavirus	Yes; no
First colostrum feeding route	Suckle dam; nipple bottle; oesophageal feeder
Colostrum quantity within first 12 h postpartum	Unknown; quantity of colostrum feeding (L)
Type of first colostrum fed	Maternal; frozen

^aBody condition scores were assigned empirically on a 1–5 scale based on the amount of fat reserves at skeletal checkpoints localised in ribs, iliac and ischial bones. This grade criterion was described by Machado et al. (2008) and used in autochthonous sud-American beef cows (Fernandes et al., 2015) and described, using 0.25 increments, in both Italian Piedmont (ANABORAPI– Associazione Nazionale Allevatori della Razza Bovina Piemontese 2021) and Chianina beef cows (ANABIC 2020).

management practices was collected through interviews with farmers (Table 1). During the first visit, the interviewer collected information on farm characteristics and recorded any potential changes during the subsequent weekly interviews.

The sample size was calculated using G*power software. The minimum number of animals required was 160 using an alpha error of 0.05, a power of 0.80 and an effect size f^2 of 0.15, deemed to be associated with the detection of small changes in the dependent variable, according to guidelines reported in Cohen (1988). For sample size calculations, a cautionary number of potential predictors to be included in either linear or logistic regression models was set to 40, accounting for potential categorical predictors with multiple levels, relevant predictors of interest and control factors.

In April 2020, the 6-month mortality and morbidity data of all included calves were extrapolated from the cow file of the farm by the first author (LP). Neonatal calf diarrhoea was defined when $a < 28$ -day-old calf had visibly watery faeces of normal or abnormal colour, with or without blood content, either observed directly or on the perineal region or hind limbs, and treated with antimicrobials or electrolytes. Bovine respiratory disease was defined when $a < 6$ -month-old calf showed cough, nasal/ocular discharge, or laboured breathing was treated with antimicrobials. Mortality (assisted or unassisted) was defined as the involuntary loss of an animal. Mortality and morbidity information was recorded by farm personnel or owners; treatments

and diagnoses were entered after prescription by the farm veterinarian.

Serum IgG evaluation

Each enrolled calf was subjected to blood sampling via jugular venipuncture using a 20-gauge hypodermic needle (BD Vacutainer Precision Glide, Becton Dickinson Co., Franklin Lakes, NJ, USA) and stored in a sterile Vacutainer tube without an anticoagulant (BD Vacutainer, Becton Dickinson and Co. Franklin Lakes, NJ, USA). Blood samples were transported to the OVUD lab in a portable cooler and then centrifuged (NEYA 8, REMI Elektrotechnik LTD Instrument Division, VASAI, India) at 20 °C for 10 min at 900×g within 4 h of collection. The serum obtained was then labelled and frozen into two aliquots at –80 °C before analysis.

Serum IgG concentration was directly evaluated using a commercial RID kit (Bovine Ig Test Kit, Triple J Farms, Bellingham, WA, USA) as the reference method. Serum samples were thawed at room temperature. According to the manufacturer's instructions, 5 µL of undiluted serum samples were pipetted into the plate wells using the manufacturer's reference sera as controls. Plates were incubated for 24 h at 22 ± 2 °C, and the diameter of the precipitin rings was measured using a hand-held calliper. Serum IgG concentrations were determined by comparing the diameter of the samples to a standard straight line of best fit between the three points corresponding to the standard sera. Serum samples with IgG concentrations greater than

the manufacturer's stated performance range for the assay ($>3,000$ mg/dL) were diluted (1:1) with deionised sterile water and retested. All samples were run in duplicates, and the mean value of the results was converted to g/L and used for statistical analysis.

Data analysis

Data were collated in an Excel (Microsoft) spreadsheet and transferred to SPSS 26.0 for Mac (IBM, Armonk, USA) for statistical analysis. The categorical variables considered in the statistical analysis were farm, birth season, type of cow barn, animal caretaker, sex, twin birth, time of birth, type of calving, body condition score at calving, vaccination against rotavirus, coronavirus and *Escherichia coli* (*E. coli*), first colostrum feeding route, colostrum type, development of NCD and BRD, and mortality. These variables were reported as frequencies and percentages with 95% confidence intervals (CIs). The continuous variables were herd size, calf age, age of cow, parity and slgG.

After testing normality with the Shapiro-Wilk test, the only continuous variable normally distributed was slgG concentration and was reported with average and standard deviation (SD). Other continuous variables were expressed as median and interquartile range (IQR) from the 25th percentile to the 75th percentile. The exclusion criteria were as follows: $>30\%$ of the missing data and variables with a percentage of responses assigned to a single category ($>90\%$; mono-level factors). Colostrum quantity within the first 12 h postpartum was deleted from the statistical analysis for $>30\%$ of missing data. Twin calving and type of colostrum fed were omitted from the statistical analysis because they were mono-level factors. Similarly, during the 6 months of study observation, the mortality rate was too low (10 calves [5%]) and therefore not included in the statistical evaluation. Herd size was categorised for multivariable analysis.

Three models were created to explore the association between calf management practices and farm characteristics with slgG concentration, NCD and BRD frequencies used as dependent variables. Univariable analysis was initially created to identify a pool of potential factors (p declared significant at $<.1$) associated with each of the three dependent variables under consideration. Variables identified as potentially useful risk factors in univariate analysis for slgG concentration were then inserted in a multivariable linear regression model using backward stepwise elimination to determine significant ($p <.05$) risk factors associated with slgG concentration in enrolled calves. In contrast,

factors identified as a potentially useful risk for herd-level morbidity were inserted in two multivariable logistic regression models using backward stepwise elimination to determine significant ($p <.05$) risk factors associated with NCD and BRD, respectively.

Results

Twelve Chianina farms were recruited for this study. Three herds were excluded because the owner was unwilling to participate. A total of 212 calves belonging to nine Chianina farms were born during the observational period and were examined for eligibility. However, 10 calves were excluded from the analysis because they did not meet the study eligibility health criterion. Therefore, 202 calves were confirmed eligible for inclusion in the final analyses (see supplementary file). Of these, 103 (51%) were females and 99 (49%) were males.

Enrolled farms had a range of different cattle housing styles: loose housing barn (7 farms), free-range (1 farm) and stanchion barn (1 farm). All farms placed the cows in a free-stall barn at least one week before parturition, excluding the cows housed in stanchion barn farms. Dams that appeared to progress through calving were checked hourly. Delivery assistance was provided after failure to calve within 1–2 h of foetal membranes protruding to the vulva. In loose housing barns and free-range farms, calves feed on colostrum spontaneously from the dams and are housed for up to 15–20 days in a calving pen before entering multiple pens in which they remain with the dams for up to 5–6 months after birth. In stanchion barn farms, calves can spontaneously feed on colostrum from the dams just for the first 6–12 h postpartum. After the first 12 h postpartum, new-born calves are housed in a calf-pen and can nurse from the dam two or three times a day for up to 5–6 months. Calves not seen feeding spontaneously or not standing 3–4 h after birth, were artificially fed with colostrum.

The median age of the calves at the time of blood sampling was 5 days (IQR 25% 3 days; IQR 75% 6 days). Ninety-nine (49%) and 103 (51%) calves were born during the day and night, respectively. Forty-one (20.3%), 40 (19.8%), 49 (24.3%) and 72 (35.6%) calves, were born during winter, autumn, spring and during summer, respectively. Twenty-one calves (10.4%) were born to dystocic calving and resolved with mild traction. None of the calves were born with C-sections or using a mechanical puller.

The median age of the dams was 6 years (IQR 25% 4 years; IQR 75% 9 years) and parity was 3 (IQR 25% 2;

IQR 75% 6). Most dams had a BCS between 2.75 and 3.25 at the time of calving (121; 59.9%), while 43 dams (21.3%) had a BCS lower than 2.75 and 38 dams (18.8%) had a BCS greater than 3.25. Furthermore, most dams were vaccinated against rotavirus, coronavirus and *E. coli* (155; 76.7%). The average slgG concentration was 19.70 ± 11.64 g/L. Concerning colostrum management, most of the calves received colostrum directly by the dam (free suckling 175; 86.6%) and followed by a nipple bottle (27; 13.4%). None of the calves received colostrum via an oesophageal tube feeder.

Concerning the farm type, the median herd size was 120 animals (IQR 25% 90 animals; IQR 75% 190 animals). Most of the calves were born on farms with loose housing barns (172; 85.1%), while free-range (17; 8.4%) and stanchion barn (13; 6.4%) were the least used housing type. Most of the farms in this study had full-time employees (120; 59.4%), while a substantial proportion were family-run (48; 23.8%) and the minority had part-time workers (34; 16.8%).

In one farm, data on NCD and BRD were unavailable. Of the 168 available records, 37 (18.3%) developed NCD and another 37 (18.3%) developed BRD. Univariable linear regression identified birth season, cow barn type, birth time, first colostrum feeding route and dam vaccination against NCD as potential useful risk factors for slgG concentration ($p < .1$). The multivariable linear regression model showed that prepartum vaccination against *E. coli*, rotavirus and coronavirus ($p = .01$) and route of first colostrum feeding ($p = .010$) were the only factors associated with slgG concentration (Table 2).

Table 2. Result from a multivariable linear regression model identifying factors associated with serum IgG concentration evaluated using a commercial RID kit (RID-IgG) in 202 Chianina beef-suckler calves from 9 farms located in Umbria.

Variables	Category (mean RID – IgG ± SD)	p value	Coefficient	CI 95%	
Dam pre-partum vaccination against Rotavirus, Coronavirus and <i>Escherichia coli</i>	Yes (21.4 ± 12)	.01	6.26	2.52	9.99
	No (14.02 ± 7.97)				
Route of first colostrum feeding	Free suckling (20.76 ± 11.47)	.10	–6.16	–10.77	–1.52
	Feeding bottle (12.80 ± 10.48)				

SD: standard deviation; CI 95%: confidence interval.

Table 3. Results from a multivariable logistic regression model identifying factors associated with neonatal calf diarrhoea (NCD) and bovine respiratory disease (BRD) in 202 Chianina beef-suckler calves from 9 farms located in Umbria.

Variables	Category	N	p Value	OR	CI 95%	
NCD						
Season	Winter	41	.010	0.22	0.07	0.70
	Autumn	40	.63	0.32	0.10	1.10
	Spring	49	.37	0.31	0.11	0.93
	Summer ^a	72	–	–	–	–
Serum RID-IgG	–	–	<.01	1.07	1.03	1.12
BRD						
Animal caretaker	Family run	48	<.01	4.56	1.50	13.94
Serum RID-IgG	Fulltime employees ^a	120	.03	1.04	1.01	1.08

OR: odds ratio; CI 95%: confidence interval Data on the NCD and BRD of farm 8 are not available.

^aReference category for each term.

Univariable logistic regression identified the cow barn type, birth season, first colostrum feeding route and slgG concentration as potential risk factors for NCD ($p < .1$). Animal caretaker and slgG concentrations were potential risk factors for BRD development ($p < .1$). The multivariable logistic regression model showed that birth season ($p < .035$) and slgG concentration ($p < .001$) were the only factors associated with the development of both NCD, while animal caretaker ($p = .002$) and slgG concentration ($p = .02$) were associated with the development of BRD (Table 3).

During the study period, none of the enrolled farms exhibited any noteworthy structural changes.

Discussion

This study surveyed management practices and farm characteristics in Chianina beef suckler-calves reared in Umbria to identify factors associated with slgG concentration, mobility and mortality. In contrast to our initial hypothesis, we were unable to assess the impact of farm characteristics and calf management practices on the mortality rate due to low case fatality in our enrolled calves. This finding was also reported by Dewell et al. (2006). According to these authors, this may be explained by the fact that the enrolled calves were maintained by knowledgeable personnel with high-quality regular veterinary care. Moreover, the recorded mortality rate was likely decreased because of the strict selection criteria employed, which excluded some atypical neonatal death episodes. However, in our study, any information about risk factors related to mortality rates would be underpowered

with only 10 calves out of 202 calves in total. Therefore, future studies on risk factors associated with mortality on Chianina farms with a larger number of enrolled subjects are recommended.

The results of this observational study showed that calves born to dams vaccinated against *E. coli*, rotavirus and coronavirus had a higher average sIgG concentration. Comparing these findings with those of other studies confirms that colostrum quality is associated with improved sIgG concentration in calves (Godden et al. 2019). Previous studies have established that the vaccination of beef cows for NCD prevention was also associated with increased sIgG concentrations in calves fed with colostrum of vaccinated dams (Kohara et al. 1997). This relationship may be explained by the fact that the cow's vaccination during the final 2–12 weeks preceding calving, results in an increased mass of specific colostrum antibodies (Crouch et al. 2000). However, the protective effect of vaccination is not helpful without proper colostrum management practices (Lora et al. 2018a). This concept can be easily extrapolated from the results of this study. Although vaccination in dams was associated with a higher sIgG concentration in their progeny, sIgG concentration was significantly lower in calves that were not feeding spontaneously after birth and were artificially fed colostrum via nipple bottle. This finding is consistent with that of Bragg et al. (2020), who found that colostrum feeding assistance was associated with low sIgG in 1,131 beef calves of 31 different breeds. This association cannot be easily explained, because it could be related to numerous possible conditions. Beef calves usually suckle their dams and are characterised by a much shorter latency time between birth and first feeding than dairy breeds (McGee and Earley 2019). Therefore, for proper colostrum ingestion, it is necessary to have a good bond with the dam to facilitate standing, walking and finding the teat before consuming colostrum (McGee and Earley 2019). Suckle reflex strength is the most critical factor related to colostrum consumption within the first 4 h after birth in beef calves (Homerovsky et al. 2017a). Therefore, every disturbance that affects the suckle reflex (i.e. pathological conditions or blood acidosis (Boccardo et al. 2017; Homerovsky et al. 2017b) or the dam behaviour (i.e. calves born in stanchion stalls, Filteau et al. 2003) can lead to a reduction in colostrum ingestion. Considering this, it seems disadvantageous to use nipple bottles in these calves because their suckle reflex probably does not allow for an adequate amount of colostrum ingestion. These results suggest that colostrum feeding assistance on

Chianina farms should be substantially improved, focussing on earlier intervention and administration of an adequate volume of colostrum. Although the incorrect use of oral devices can cause pharyngeal or oesophageal lesions (Sala et al. 2019), when correctly used, oesophageal feeding has the advantage that relatively large volumes of colostrum can be administered (McGee and Earley 2019), thus improving and quickening colostrum administration. Contrastingly, it seems necessary to evaluate that most bottle-fed calves were in our enrolled farms' sole stanchion stalls (see supplementary file). Although the cow barn type was identified as a significant factor only in univariable logistic regression analysis, the high percentage of calves with low sIgG concentration could also result from the limited maternal bond that typically occurs in this type of housing (Filteau et al. 2003). In these circumstances, standard postpartum behavioural patterns may be challenging to achieve and, therefore, may delay/impede the normal teat-seeking process of the new-born calf with an increase in the number of bottle-feeding assistances to be performed (Filteau et al. 2003).

In the literature, laborious calving has been identified as one of the major factors influencing suckle reflex and vigour in beef calves (Barrier et al. 2012; Homerovsky et al. 2017a). A higher proportion of low sIgG concentration among calves born from dystocic calving (being a twin or being born to a heifer, foetal malposition, male sex associated with foeto-pelvic disproportion) has been reported (Waldner and Rosengren 2009; Bragg et al. 2020). Interestingly, in the present study, no associations were found between sIgG concentration and calving type. This result can be explained by the fact that dystocia episodes observed in our study sample were all resolved with mild traction. This finding is consistent with that of De Amicis et al. (2018), who found that manual correction of the dystocia accounted for most cases in Italian autochthone beef breeds, and that of Robichaud et al. (2017) who reported that providing early assistance to cows during calving with only human force during traction did not negatively influence vigour at birth and passive immunity transfer.

The study results showed that calves with a low sIgG concentration were more likely to have pre-weaning morbidity (NCD, odds ratio, OR, 1.07; BRD, OR 1.04). Several studies have suggested an association between passive immunity and negative health episodes in beef and dairy calves (Waldner and Rosengren 2009; Boccardo et al. 2016; Todd et al. 2018; Lora et al. 2018b). More specifically, our results

confirm that sIgG concentration is associated with morbidity based on serum immunoglobulin levels. Dewell et al. (2006) reported that preweaning morbidity events were diagnosed in only 10.1% of calves with sIgG1 concentrations >16 g/L compared with 21.7 and 13.4% for calves with sIgG1 concentrations <8 g/L and between 8 and 16 g/L, respectively. Similarly, Perino and Wittum (1995) showed that the association between sIgG concentration and morbidity events was consistent during the post-weaning period. Although the IgG concentration is universally recognised as the determining factor in assessing the quality of ingested colostrum, it should be noted that a higher sIgG concentration is most likely related to higher ingestion of other molecules and immunoreactive cells directly involved in the neonatal immune system development (Baumrucker et al. 1994; Pakkanen and Aalto 1997). Calves with a lower IgG concentration receive lower amounts of other immunoreactive components, potentially leading to a higher percentage of pathological events during the neonatal period.

Another important finding was that small family-owned farms are an important factor related to BRD episodes in Chianina beef-suckler calves (Table 3). This result may be explained by the fact that the use of sanitary measures on family farms is commonly selective and insufficient (Relić et al. 2020), thus maintaining a constant presence of risk factors (i.e. air quality and ventilation, pathogen exposure and hygienic conditions) that result in increased cases of respiratory disease in calves. Although in cow/calf operations, BRD is sporadic and usually of low prevalence (Stokka 2010), these results suggest that management practices on small family Chianina farms should be substantially improved, for example, by using a timely vaccination protocol to provide more proper protection on these farms. We also noted a seasonal effect on NCD prevalence (Table 3). Diarrhoea incidence in calves is highest during the winter months because a cold and humid environment can support the survival and higher excretion of several infectious agents (such as *Cryptosporidium parvum* and Coronavirus) (Collins et al. 1987; Maddox-Hyttel et al. 2006; Gulliksen et al. 2009). Based on these data, we suggest enhancing the cleaning frequency, the levels of biosecurity practices and reducing the animal numbers in the calving pen during the winter period to reduce the number of NCD cases during the coldest months of the year.

There were some significant limitations to our study. First, this observational study was performed using a convenience sample, which may limit the

generalisability of the results. Farmers who agree to participate in these studies are usually more progressive and more likely to implement better management practices. Therefore, a selection bias could have been introduced due to the absence of farmers who are less willing to participate with lower farm management levels. However, we believe that this limitation can be partly mitigated by the fact that our convenience sample is reasonably typical of all Chianina cattle breeding farms in Central Italy because many calf rearing management factors have been standardised by the "Vitellone Bianco dell' Appennino Centrale" consortium criteria. Second, although the sample size used was satisfactory, the recruited farm number was restricted due to time and budget constraints. This may underpower the strength of the correlations between the factors under examination. Third, although calf-level studies are necessary to understand the relationships between factors affecting FPT, morbidity and mortality, the resulting associations are not automatically real at the herd level, with the possibility of creating an atomistic bias that could invalidate the results obtained (Morin et al. 2021). To our knowledge, this is the first report on factors related to sIgG and morbidity in Italian Chianina herds. Future work as a herd-level study on the association between management practices and Chianina beef-suckler calves' health status should be designed with a considerably larger number of enrolled farms.

Conclusions

This study identified that dam prepartum vaccination against NCD aetiological agents and the first colostrum feeding route were the major management practices associated with sIgG concentration in Chianina beef-suckler calves. Logistic regression analysis showed that sIgG concentration and birth in family owned farms or during winter months affected morbidity rate. We believe that these results will have clinical applications. Routine vaccination against rotavirus, coronavirus and *E. coli* must be implemented in Chianina farms. In calves unable to suckle from the dam after birth, colostrum feeding assistance should be substantially improved by reducing the time of the first administration using devices such as the oesophageal tube feeder, which can bypass voluntary colostrum intake, allowing the administration of high amounts of good quality colostrum. Improving sIgG concentration is of economic importance as it may lead to a decrease in NCD and BRD episodes, thereby reducing calf morbidity and mortality. Additional attention

should be exercised during the winter months to reduce NCD prevalence, and more attention should be paid to BRD prophylaxis in small farms. These findings could help practitioners improve or re-evaluate farm decision management in Chianina beef farms.










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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its [supplementary materials](#).

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