Austral J Vet Sci **54, 103-114 (2022)**

ORIGINAL ARTICLE

Characterisation of dairy female calf management practices in southern Chile

Paula Toro-Mujica[a], Ricardo Gebauer[b], Karen Tajonar[c], Juan P. Keim[d], Einar Vargas-Bello-Pérez[e,b]*

ABSTRACT. The objective of this study was to characterise husbandry and technical-productive practices at the calf rearing stage in dairy farms in Los Lagos Region, southern Chile. A face-to-face survey was applied to 22 dairy farms in Los Lagos Region in 2017. All farms performed artificial calf rearing under either of two systems: total barn confinement (48%) or a mixed system that considers the first stage with confinement and the second stage in open-air paddocks (52%). More than half (52%) of the farms supplied fresh colostrum to the calf from its dam and the rest of the farms used bottle or oesophageal tube. Only 30% of the farms evaluated colostrum quality using colostrometer (densimeter) or refractometer. After the colostrum supply, milk replacers, waste milk, or a mixture of both were used for calf feeding. Most of the farms (66.7%) did not have automated milk-feeding systems and used bottles (88.9%) and buckets (11.1%) instead. On average, calves were handled by 1.5 caretakers (SD: 0.63) of which 63.4% (SD: 40.2) were men. The average age for caretakers was 43.9 years (SD: 12.7), with 23.8% being less than 35 years old. Overall, results from this study can be used to identify key managements that could improve calves' rearing productive traits.

Keywords: calves, dairy, health, nutrition, production.

INTRODUCTION

Currently, the demands of high production dairy farms have increased the incidence of reproductive, locomotion and metabolic-health problems (Riberio *et al.*, 2017; Carvalho *et al.*, 2019). These problems can lead to poor welfare (Calderón-Amor & Gallo, 2020), a decrease in milk production, economic revenues, all of which could be prevented by improving the rearing of replacement heifers (Probo *et al.*, 2018; Machado *et al.*, 2020). Heifer rearing influences the productivity and profitability of dairy herds (Mohd *et al.*, 2015), which represents between 15 to 20% of the total costs in dairy production systems (Heinrichs *et al.*, 1993).

When rearing replacement heifers, it is pivotal to consider production management such as practices during parturition (for both, the dam and the offspring), supply of colostrum, post-weaning feeding, grouping, health control, and housing infrastructure that guarantees a well-being environment (Murray *et al.*, 2015; Bach *et al.*, 2006; Raboisson *et al.*, 2014; Staněk *et al.*, 2014; Diao *et al.*, 2017). Despite the economic importance of rearing replacement heifers, aspects related to feeding and general management are usually overlooked (Dobos *et al.*, 2001). According to Abuelo *et al.* (2019), in Australian dairy farms, this disinterest is reflected in high pre-weaning morbidity and mortality rates, reaching values close to 35% and 7%, respectively.

In Chile, milk production reached 2,275 million litres in 2020, of which 85% is produced in the southern part of the country (La Araucanía, Los Ríos, and Los Lagos regions with 6.7%, 31.4% and 46.3% of the total milk produced, respectively), which highlights the importance of dairy farms from this area (ODEPA, 2021). Here, dairy production, as indicated by Toro-Mujica *et al.* (2020) is performed under extensive and semi-extensive production systems, which are based on natural grasslands, improved natural grasslands, sown grasslands, and supplementary crops. In these systems, rearing replacement calves is commonly done in two stages. The first stage is carried out in roofed sheds in which individual and/or collective pens are kept. The second stage, called mixed, includes a mixture of an open-air patio and collective pens with a shed. Notwithstanding the above, given the natural variability of dairy production systems in southern Chile, Toro-Mujica *et al.* (2020) suggested that it would be possible to find heterogeneity in productive management performed during the calf rearing stage. Eventually, knowing these productive managements could lead to identifying improvements to reduce mortality rates, morbidity, and increase growth parameters and rumen development (Silper *et al.*, 2014). Furthermore, it has been observed that growth rate during the calf rearing period affects mammary gland development due to a reduced peripubertal allometric mammary growth phase and altered responses to mammogenic stimuli (Geiger *et al.*, 2016). Subsequent lactations are also compromised as a result of trying to get calves to their pubertal body

Received: 19.07.2021.

Accepted: 13.04.2022.

[a]Instituto de Ciencias Agroalimentarias, Animales y Ambientales (ICA3), Universidad de O'Higgins, San Fernando, Chile.

[b]Departamento de Ciencias Animales, Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica de Chile, Santiago, Chile.

[c]Departamento de Medicina y Zootecnia de Rumiantes, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Ciudad de México, México.

[d]Facultad de Ciencias Agrarias y Alimentarias, Instituto de Producción Animal, Universidad Austral de Chile, Chile.

[e]Department of Veterinary and Animal Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark.

Corresponding author: E. Vargas-Bello-Pérez; e.vargasbelloperez@reading.ac.uk

weight earlier due to epigenetic programming (Soberon *et al.*, 2012; Margerison *et al.*, 2013). Until now, there is scarce scientific data on calf management practices in Chile. Thus, the objective of this study was to characterise female dairy calf husbandry and technical-productive practices at the calf rearing stage in dairy farms in Los Lagos Region, southern Chile.

MATERIAL AND METHODS

The study was conducted according to the guidelines of the Committee of Ethics in Research in Social Sciences and Humanities of Pontificia Universidad Católica de Chile (protocol code 151216004 approved in 2016).

DESCRIPTION OF THE STUDIED REGION

The study was performed in Los Lagos Region, latitude 39°17'14" to 40°40'51" and longitude 71°35'33" to 73°43'29". This region has an area of 48,584 km^2 distributed in four provinces (Chiloé, Llanquihue, Osorno and Palena). Around 87% of the Chilean bovine production for both milk and beef is concentrated in the provinces of Llanquihue and Osorno (INE, 2007). Annual rainfall ranges from 865 to 1071 mm, with monthly average temperatures ranging from 6.6 to 16.2 ° C (DMC, 2020). In most of the provinces, the prevailing climate is temperate (Cfb) (figure 1).

FARM SELECTION AND DATA COLLECTION

A survey was designed to characterise productive management practices commonly used at the rearing stage in dairy farms in Los Lagos Region, as it concentrates the greater milk production from the country. The survey was applied to 22 dairy farms that belong to the Chilean Federation of Dairy Producers from Los Lagos Region in February 2017. This trade association had approximately 500 active members in Los Lagos Region. We chose farms that were representative of the range of a milk production greater than 1,500,000 L/year. In Chile, these types of farms produce 90% of the total milk production (Consorcio Lechero, 2019; ODEPA, 2021).

Before applying surveys, selected farms were randomly contacted by phone for collaboration, and only 22 farmers volunteered to participate in the study. A similar recruitment method was previously reported by Vasseur *et al.* (2010) and Santman-Berends *et al.* (2014). In-person surveys were conducted with farm managers using a printed hard copy. The questionnaire had 54 questions, which allowed the

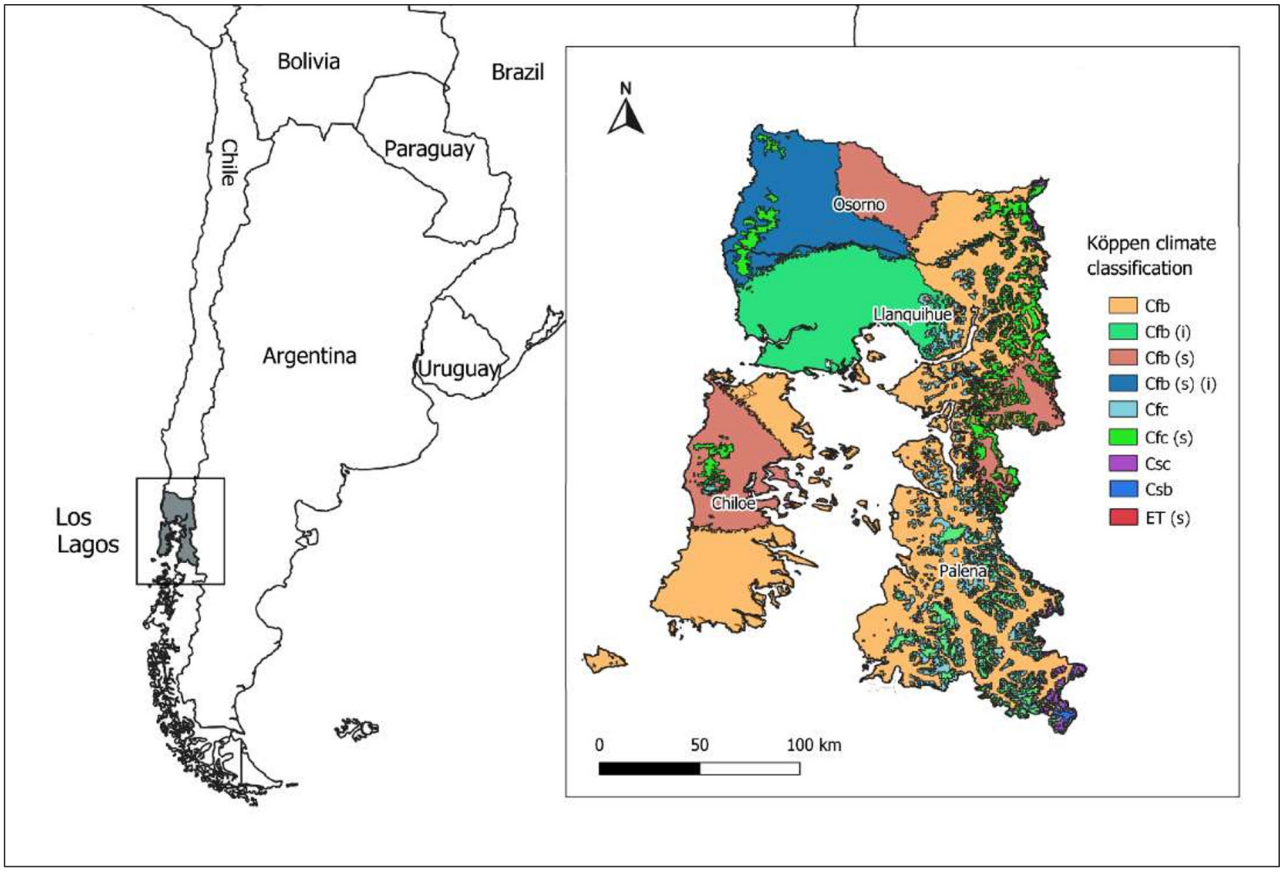

Figure 1. The study zone at Los Lagos Region in southern Chile.

identification of 95 variables. The full survey can be found as supplementary material. Before statistical analysis, the data were reviewed and then, for continuous variables, the outliers were identified using box plot graphics for their subsequent removal from the data set. In the categorical variables, the classification levels used in the survey were kept.

SURVEY DEVELOPMENT

Two professionals (E.V.-B.-P. and P.T.-M.) with PhD in animal production and an agronomist (R.G.) developed the questions for the survey. The survey included general farm data (i.e., production system, size, and location) and specific questions related to the rearing stage, which included information on housing space, feeding, mortality, weaning and health parameters. The survey was divided into three sections: I. Farm data that included 13 general questions regarding farm characteristics (size, production system, and location); II. Calf management that included 33 questions and III. Staff data that included 8 questions. Before using the final survey, a pilot survey was performed on 2 dairy producers from Los Lagos Region to evaluate clarity, the accuracy of response options, use of technical language and overall flow.

STATISTICAL ANALYSIS

The information collected in each survey was coded and stored in an Excel database (Microsoft Excel, Microsoft Corp., Redmond, WA). Firstly, data were used to describe the farms through quantitative descriptive statistics (mean, variances, minimums, and maximums) and qualitatively (percentage frequency). Secondly, paired relationships between calves' mortality and all other variables were searched through regression analysis (quantitative variables), contingency tables, and X^2 test (qualitative variables). The statistical software SPSS 11.5 was used for all statistical analyses.

RESULTS

PRODUCTION SYSTEMS CHARACTERISATION

The average surface of the farms was 448 ha. Around 48% of this area was used for dairy farming, 44% for pasture production and 11% for crop production (table 1). Most (80%) of the surveyed farms had grazing production systems, while the remaining 20% use mixed production systems (grazing animals in spring-summer and confined in winter with feeding based on conserved forages and concentrates). All farms performed milking twice daily and cows had an average lactation length of 307 days.

On average, surveyed farms had 689 females (calves, heifers, and cows); however, wide variability was observed between farms, ranging from 90 to more than 3000 females. Of the total number of cows, on average, 74% were lactating and had a calving interval of 382 days. More than half (59%) of the surveyed farms performed artificial insemination, while 27% combined artificial insemination and herd bull. The most common breed was Holstein (67%), however, 57% of the surveyed farms had more than two breeds.

CALF RAISING HUSBANDRY PRACTICES

Housing. All farms performed artificial calf rearing under either of 2 systems: total barn confinement (47.6%) and mixed system that considers the first stage with confinement and the second stage in open-air paddocks (52.4%). In more than half of the surveyed farms (61.9%), calves management was carried out in groups of 5 to 50 animals ($\bar{x} \pm SD$: 17.5 ± 14.3). This management was performed from day 1 (at birth) in 26% of the farms, while 11% of the farms delayed it until one month of age.

In all surveyed farms, the bedding material used at calf barns was wood chips. Only 25% of the surveyed farms had calf barns with temperature control. Regarding calf barn capacity, this was related to the number of cows in the herd (X^2 20.98, df. 9, p = 0.013), with a capacity between 101 to 200 animals with a space per animal of 1.5 to 2 m^2. The farm stocking rate was 0.92 cows/ha (standard deviation: 0.37) and the animal stocking rate for dairy production was 1.93 cows/ha (standard deviation: 0.59).

Health. Most farms (85.7%) do vaccination and deworming programs. More than 80% of the farms reported mortality rates below 10%, and there was no relation between calf birth weight and calf mortality rate (X^2 6.22 df.12; P=0.904) (figure 2). With regard to the type of health problems observed at the calf barn, the surveyed caretakers declared that 100% were of respiratory or digestive origin (table 2). In this study, there were not significant relationships between the presence of respiratory and digestive problems and mortality rates (P=0.62).

Calf feeding practices. The results for newborn calf feeding management (table 3) showed that 52.4% of the farms supplied fresh colostrum to the calf from its dam. In the case that fresh colostrum from the dam was not being used, it was obtained from another recently calved cow during the milking routine (78.5%) or from frozen colostrum (21.4%). In both cases, the colostrum was supplied either through a bottle (68.8%) or by using an oesophageal tube (31.4%).

In more than half (52.4%) of the surveyed farms, the evaluation of passive immunity transfer was carried out instead of evaluating colostrum quality, using refractometers or through blood tests. After colostrum supply, milk replacers, waste milk, or a mixture of both was used for calf feeding. Milk replacer was used in 90.5% of the farms, 71.4% of the farms used waste milk, and a mixture

Table 1. Descriptive statistics from 22 surveyed dairy farms from Los Lagos Region.

Quantitative variables	Mean	SE	Minimum	Maximum
Total surface (ha)	448.5	77.0	50	1020
Surface for dairy (total %)	48.8	4.9	18.5	79.2
Grazing surface (%)	44.1	4.2	12.0	70
Cropping surface (%)	11.3	2.4	1.3	42.3
Total number of females	688.5	182.7	90	3152
% of lactating cows	74.1	3.4	31.1	95.0
Calving interval (days)	381.7	7.4	330	424
Lactation length (days)	307.7	13.4	180	380
Qualitative variables	**Category**		**Frequency**	
Production system	Grazing		80.0	
	Partial total mixed ration		20.0	
Milking per day	Two		100	
Breeding type	Artificial insemination (AI)		59.1	
	AI and herd bull		27.3	
	Herd bull		13.6	
Breed[1]	Holstein		66.7	
	Jersey		28.6	
	Red Friesian		33.3	
	Black Friesian		14.3	
	Other		23.8	
Number of breeds used	1		42.9	
	2		47.6	
	3		9.5	
Synchronised calving	Yes		71.4	
	No		28.6	
Calving distribution	All-year-round		19.0	
	Seasonal[2]		81.0	

[1]Percentage of farms with the breed.
[2]Concentration of calving in spring.

of milk replacer and waste milk was used in 33.3% of them. Most of the farms used more than one feed (milk substitute + waste milk or milk replacer + mixture), and only 27% of the farms exclusively used milk replacer. Most of the farms (66.7%) did not have automated milk-feeding systems, and bottle feed (88.9%) and buckets (11.1%) were used. Milk feeding was provided in most of the surveyed farms twice a day (71.4%), however, due to automation, there were farms where a higher number of feedings was provided (*ad libitum*). Weaning time ranged from 1 to 4 months, and then feeding with starter concentrate and forage began from day 1 or at least from week 1, with one or two rations or *ad libitum*. Most farms (95.2%) used forage feeding based mostly on corn silage (78.9%). In most farms (66.7%), forage feeding was used for 2 months. Lastly, no relationship was found between calving time and feeding method. As observed in table 4, the seasonal breeding systems tended to present lower mortalities than non-seasonal breeding systems.

Personnel in charge of the calves. On average, calves were handled by 1.5 caretakers (standard deviation: 0.63) of which 63.4% (standard deviation: 40.2) were men. The number of people in charge of the calves was positively related (P=0.003) to the number of cows on the farm. The average age for caretakers was 43.9 years (standard deviation: 12.7), with 23.8% being less than 35 years old. The educational level of 45% of the personnel responsible for the calves is basic education, while 35% had secondary education (table 5).

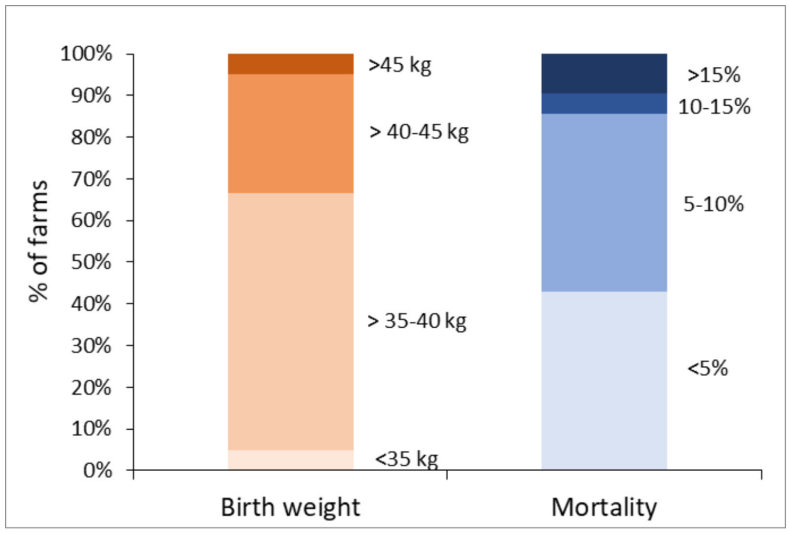

Figure 2. Distribution of calf's birth weights and mortality in 22 surveyed dairy farms from Los Lagos Region.

Weaning criteria parameters. To transfer calves from the calf barn to the next productive stage/housing (after weaning), a combination of weight and age was the most used criterion (52.4% of the surveyed farms) (table 2). Most surveyed farms (71.4%) produce female calves as replacements. Calf weight at weaning ranged between 71 to 120 kg in most farms (76%).

DISCUSSION

PRODUCTION SYSTEMS CHARACTERISATION

As reflected by this survey, grazing systems are predominant in the humid temperate region of southern Chile (Keim *et al.*, 2015). Synchronised calving was a common practice, with the higher (around 70%) concentration of calving taking place during the springtime as a strategy used to reduce feeding costs and calves' survival rate, which is typical of grazing systems in humid temperate regions to match calving with a pasture growth that equals nutritional demands (Roche *et al.*, 2017). In 71% of the surveyed farms, male calves were reared and sold for beef production. Male dairy calves represent 45% of the total animals used for beef production in Chile and Los Lagos region, they account for more than 2/3 of beef animals (INE, 2015).

CALF RAISING HUSBANDRY PRACTICES

Housing. At the surveyed farms, calf barn capacity was lower than the minimum of 3.3 m^2 per calf recommended by Nordlund and Halbach (2019) and is considered highly determinant for air quality, having a major impact on the quality and moisture of the bedded surface in which the calves lie. Stocking rates are similar to those reported by Toro-Mujica *et al.* (2020) for dairy production systems in southern Chile. In addition, according to Svensson and Liberg (2006), group-housed calves should be maintained in pens of less than 10 calves, however, optimal health and growth performance can be achieved in groups of 20 to 25, as larger groups of calves are associated with an increased risk of respiratory disease (Nordlund & Halbach, 2019). In future studies, it will be of great importance to identify the criteria used for the cleaning and disinfection of pens, as well as the considerations for changing the bedding material, since this has an impact on the health of the animals.

Health. In this study, the lack of relationship between the presence of respiratory and digestive problems and mortality rates would be a consequence of the different recovery capacity of calves between farms, since the most common causes of pre-weaning mortality in dairy calves are neonatal diarrhoea and bovine respiratory disease (Pempek *et al.*, 2017). As reported, the absence of other health problems could be a consequence of vaccination and deworming schedules, a common practice observed in more than 85% of the surveyed farms.

More than 80% of the farms reported mortality rates below 10%. Mortality rates with ranges between 0 to 11% have been reported by different authors (Santman-Berends *et al.*, 2014; Cuttance *et al.*, 2017; Tautenhahn *et al.*, 2020). In this study, mortality was not related to calving time and feeding method. Reiten *et al.* (2018) reported that this would be linked to the incidence and survival rate of season-dependent diseases such as diarrhoea and respiratory diseases. Regarding feeding methods, lower mortalities were observed when automated feeding methods were used. For the use of automatic feeding, it is necessary to handle the calves in groups. Relationships between grouping and calf health are controversial, for example, Svensson *et al.* (2006) associated group management with a higher risk of

Table 2. Characteristics of calf management in 22 surveyed dairy farms from Los Lagos Region.

Variable	Category	Percentage
Female calves' productive purpose	For sale	19.0
	Replacement	71.4
	Other	9.5
Weight at birth (kg)	< 35	4.8
	35-40	61.9
	40-45	28.6
	> 45	4.8
Calves weaning criteria	Weight	38.1
	Age	4.8
	Weight and age	52.4
	Need for space for new calves	4.8
Weaning weight (kg)	51-70	9.5
	71-90	38.1
	91-120	38.1
	More than 121	14.3
Rearing place	Pen	47.6
	Mixed (outdoor + pen)	52.4
Animal capacity (n° head)	Less than 100	23.8
	101 a 200	52.4
	201-300	9.5
	More than 300	14.3
Controlled temperature	Yes	25
	No	75
Space availability (m^2/animal)	Less than 1 m^2 /animal	0.0
	1-1.5 m^2/animal	15.8
	1.5-2 m^2/animal	57.9
	More than 2 m^2/animal	26.3
Diseases	Respiratory	42.9
	Digestive	33.3
	Respiratory and digestive	23.8
Vaccination and deworming program	Yes	85.7
	No	14.3
Mortality (%)	Less than 5	42.9
	5-10	42.9
	10-15	4.8
	15-20	4.8
	20-25	4.8

enteric and respiratory diseases, whereas Hänninen *et al.* (2003) and Babu *et al.* (2009) found that calves housed in groups had lower incidences of diarrhoea and were less likely to have respiratory disease compared with individually housed calves. Medrano-Galarza *et al.* (2017) reported that group size is one of the main contributors to health issues rather than group housing *per se*. However, in the present study, this was not observed. In this regard, Svensson and Liberg (2006) stated that group size is one of several risk factors associated with calf health and therefore many other variables can affect calf health.

In this study, there are few data on the clinical methodology and follow-up of the causes of declared mortality in calves. It must be considered that it is essential to prepare medical records, with data on mortality and morbidity, for the analysis of epidemiological behaviour to make long-term clinical management effective (Vasseur *et al.* 2010). Future studies should investigate further whether there are comprehensive preventive medicine protocols, with staff training on the factors that affect animal health (facilities, biosecurity, cleaning, clinical examinations) and clinical monitoring (laboratory diagnoses and treatments).

Table 3. Calf feeding management in 22 surveyed dairy farms from Los Lagos Region.

Management	Options	%
Colostrum origin	From the dam	52.4
	From stored colostrum	47.6
Colostrum type	Fresh	78.8
	Frozen	21.4
Colostrum supply	Bottle feed	68.8
	Oesophageal tubing	31.4
Colostrum quantity and frequency	4 L/d, in 2 feedings	33.3
	6 L/d, in 2 feedings	66.7
Colostrum check quality*	Yes	30
	No	70
Evaluation of passive transfer of immunity	Yes	52.4
	No	47.6
Milk feeding		
Type of milk	Milk replacer	90.5
	Waste milk	71.4
	Milk replacer and waste milk	38.1
Use of automatic milk feeding (Yes)		33.3
Type of feeding	Bottle feed	88.8
	Buckets	11.1
Lactation length	1 to 2 months	14.3
	2 to 3 months	52.4
	3 to 4 months	33.3
Milk quantity	2-4 L/d	15.0
	4-6 L/d	75.0
	6-8 L/d	10.0
Time of supply	Morning	4.8
	Afternoon	4.8
	Morning and afternoon	71.4
	Other time during the day	19.0
Concentrate feed		
Use of concentrate feed	Yes	100
	No	0
Feeding frequency	Ad libitum	71.4
	One daily ration	9.5
	Two daily rations	19.0
Quantity	Less than 1 kg	25
	1-2 kg	75
Forage feed		
Use of forage feeding	Yes	95.2
	No	4.8
Type of forage	Alfalfa hay	5.3
	Corn silage	78.9
	Meadow silage	10.5
	Other	5.3
Use of forage feeding (months)	1	4.8
	2	66.7
	3	23.8
	4	4.8

*Use of either refractometry or blood tests.

Table 4. Relationship between mortality and breeding time and mortality and type of feeding in 22 surveyed dairy farms from Los Lagos Region.

Mortality	Calving		Feeding	
	Non-seasonal	Seasonal	Manual	Automatic
Less than 5%	22.2%	77.8%	0%*	100%*
Between 5-10%	0%	100%	66.7%	33.3%
More than 10%	66.7%*	33.3%*	33.3%*	66.7%*

*Values that differ from expected values $P<0.05$.

Table 5. Personnel in charge of the calves in 22 surveyed dairy farms from Los Lagos Region.

Variable	Category	Percentage
Educational level	Basic	45
	High school	35
	Technical	15
	University	5
Training at farm	Yes	81
	No	19
Training frequency	Less than a month	17.6
	Monthly	17.6
	Every 6 months	52.9
	Every 12 months	11.8
Personnel who perform handling and / or procedures in calves	Farm staff	52.4
	Veterinarian	28.6
	Both	19.0
Age (years)	18-25	9.5
	26-35	14.3
	36-45	38.1
	46-55	9.5
	More than 55	28.6
Work satisfaction	Yes	85
	No	15

Calf feeding practices. More than half of the surveyed farms used fresh colostrum for the calf from its dam, however, this contrast with Stanek *et al.* (2014), where all farmers supplied colostrum artificially. The latter is a recommended procedure as it ensures the recommended volume of colostrum supply (Moran, 2002).

The use of tubing for colostrum supply was observed in 23% of the farms, a value that exceeds the reported 8% of dairy farms in Canada (Medrano-Galarza *et al.*, 2017) and 5% in the Czech Republic (Staněk *et al.*, 2014). Large quantities of colostrum supplied through oesophageal tubing have been associated with reduced apparent efficiency of IgG absorption (AEA) and slightly lower serum IgG concentration compared with colostrum administered by nipple bottle (Lee *et al.*, 1983). Colostrum administered by oesophageal tubing enters the rumen before moving into the abomasum and intestine (Lateur-Rowet *et al.*, 1983). Thereafter, it takes 2 to 4 h for the colostrum to leave the rumen. This interval may be the reason for lower AEA, because the intestine may mature during this time, thereby reducing the number of actively absorbing cells in the intestine.

In this study, most surveyed farms used colostrum from recently calved cows followed by those using frozen colostrum mostly supplied using bottles. As Costa *et al.* (2017) reported, the colostrum storage method, either by refrigeration, freezing or at room temperature (after fermentation or chemical treatment) for its subsequent use is a frequent practice that does not affect the nutritional composition or its immunoglobulin content. Irrespective of the type of supply, the amount of colostrum delivered was between 4 to 6 litres divided into two feedings. This

amount of colostrum was less than that indicated by Renaud *et al.* (2020) in farms in Ontario, where around 9.6 litres of colostrum were supplied within the first 24 hours of life. The amount of colostrum, along with its cleanliness, quality, and speed of administration, are some of the factors that Godden *et al.* (2019) and Pempek *et al.* (2017) associated with the improvement of serum IgG levels and with the survival rate and health of calves. However, in the present study, a relationship between the amount of colostrum supplied and calf mortality (X^2 1.97, df 4, p = 0.741) was not observed.

Assessing colostrum quality before feeding is recommended as an important productive practice (Godden *et al.*, 2019). Regarding colostrum quality, only 30% of the farms evaluated this parameter, using a colostrometer (densimeter), or refractometer. In a Canadian survey on calf management practices, only 23% of the farms evaluated colostrum quality (Medrano-Galarza *et al.*, 2017), while Barry *et al.* (2019) reported 12.8% in Irish dairy farms. In contrast, a Czech survey reported that 44.1% of farmers measured colostrum quality (Staněk *et al.*, 2014). As noted by Turini *et al.* (2020) the supply of high-quality colostrum ensures the delivery of immunity reducing pre-weaning morbidity and mortality. In this regard, values greater than ≥10 g/L of IgG using radial immunodiffusion (Weaver *et al.*, 2000) or ≥5.2 g/dL of total serum protein (Buczinski *et al.*, 2018) are considered adequate.

The percentage of surveyed farms with automated milk feeders was higher than that described by Medrano-Galarza *et al.* (2017) in Canadian farms, who reported their use in 16% of the surveyed farms and Stanek *et al.* (2014) in Czech dairy farms (2.2%). Among the advantages mentioned by Stanek *et al.* (2014) for the use of automated milk feeders, the most important were to provide greater amounts of milk, facilitate greater number of feedings, and greater social interaction. However, the health of the animals can be compromised if this feeding system is not handled properly (Svensson *et al.*, 2006).

Personnel in charge of the calves. The number of persons working with calves was related to the number of lactating cows (P=0.005) and the size of the rearing place (P<0.001). However, Sischo *et al.* (2019) reported that in smaller dairy farms, it is usually common for a caretaker to be responsible for more than one task and, therefore, there would be an increase in the number of animals handled with the consequent increase in hours dedicated to the activity by the same worker.

On average, personnel in charge of the calves had more than 36 years of age (table 5), which differs from the reports of Sischo *et al.* (2019) in North American dairy farms, where 40% of the calf managers were under 30 years old, however, it should be noted that most the staff corresponded to immigrants or their descendants.

The educational level of the personnel in charge of the calves was consistent with the average years of schooling in the region which reached 10.1 years in 2017 (CASEN, 2018). In this regard, only 5% of the personnel had university education, which contrasts with the reports of Sischo *et al.* (2019) who mentioned percentages of 37, 11 and 24% for calf managers, calf feeders and treaters, respectively. It is important to note that the latter study was done in North America where the caretakers of calves and technical staff can be composed of qualified personnel coming from Latin American countries, which contrasts with the conditions of the present study.

Although the specialisation in animal production of the personnel in charge of the calves is scarce, this has changed at the local level through training courses, thus 82.4% of the farm's staff received at least one training per year. Within the training topics related to calving management, as indicated by Schuenemann *et al.* (2013), those related to newborn-calf care practices (e.g., time and amount of colostrum administered) were fundamental for calves' performance. In Chilean farms, it could be suggested to employ calf-specific personnel that may lead to increasing the specialisations of skills in the staff and the ability of veterinary practices to target training courses. In the United Kingdom (Mahendran *et al.*, 2022) the development and implementation of standard operating procedures in conjunction with veterinary practices is becoming more common and even a requirement for some dairy contracts and this could be applied in Chile in the near future.

Weaning criteria parameters. In this study, the criterion for weaning partly agrees with studies from Europe. In the United Kingdom, farmers use age as the main weaning criteria, with an age ranging from 6 to 12 weeks (Mahendran *et al.*, 2022). In Czech dairy herds, Stanek *et al.* (2014) reported that calving in group pens predominated (67% of farms) and the main weaning criterion was age (61.7%) followed by intake of starter and concentrated feeds. It is noteworthy mentioning that none of the farmers used dry feed intake as a weaning criterion, which is a recommended practice as it is related to rumen development (Moran, 2002). In Switzerland, weaning calves with concentrate-dependent feeding regime has been shown to be an effective strategy to allow a faster physiological development without a negative impact on rumen development, weight gain, or health status (Roth *et al.*, 2009). In line with this, Benetton *et al.* (2019) suggested that weaning based on individual concentrate intakes can lower overall milk consumption and maintain similar postweaning weights compared with calves weaned at a fixed age.

IMPLICATIONS AND LIMITATIONS OF THE STUDY

It is worth mentioning that this survey was performed on a limited number of dairy farms (n = 22) from Los Lagos Region, that according to farm surface, the number of animals and milk production per year represent large scale dairy farms (Consorcio Lechero, 2019). Large-scale dairy farms

represent 10% of total dairy farmers in Chile (Consorcio Lechero, 2019). These farmers are characterised by using more technology and recording more data compared with smallholder dairy farms (Chang'a *et al.*, 2010). Thus, it may be expected that rearing conditions in most of the dairy farms in the country, would be poorest compared with the selected group that we are reporting in this study. Further studies will need to consider increasing sample size, including different types of production systems and farm size levels. In addition, future surveys should include an analysis of medical records from each farm.

Dairy farmers would benefit from the findings in this study since it has been demonstrated that benchmarking motivates them to improve dairy calf management (Summer *et al.*, 2018). The survey showed some management practices that need to be improved and were not completely achieved or performed by a large proportion of the respondents. According to Mee (2008), key features of successful newborn dairy calf management are ensuring heifers and cows are moved in time to calve to suitable maternity housing, with discreet calving supervision and appropriate timing of any necessary calving assistance, immediate parturient evaluation of at-risk newborn calves and prompt movement of the newborn calf to hygienic calf housing. Furthermore, colostrum management is the single most important management factor in determining calf health and survival (Godden *et al.*, 2019), and it is recommended that calves should receive colostrum three times during the first 24h at a dose of 5-6% BW, which was not the selected criteria used by farmers, who let calves to get fresh colostrum from their dams or received 4 - 6 kg artificially divided into two feedings. This may be one of the reasons for the 20% of respondents with mortality rates greater than 10%, as AEA may be not successfully achieved. The results of the study suggest that other practices or managements should be further improved, for example: space per calf (>3 m^2/calf), weaning criteria (based on starter intake, rather than age or weight), and lack of colostrum quality measurements, among others.

In this study, twenty-two dairy farms from southern Chile were characterised by grazing systems where cows are milked twice a day and the use of artificial insemination. In the case of newborn calves, colostrum was supplied directly from the dam or through other approaches such as oesophageal tubing. Evaluation of colostrum quality and passive transfer of immunity, as well as automated feeding, are not predominant in this region but appear to be an upward trend.

Due to the limited sample size, it was not possible to identify that the calving system and feeding method were related to calf mortality. The impossibility of identifying significant relationships between variables arises from the heterogeneity of the dairies, both in dimensional terms and type of production systems as well as in relation to calf management. In this way, and considering the multiple variables that conditioned calf mortality, more research is required, with a greater number of farms, which will provide a suitable data set for multivariate analysis. It is very important to note that 22 dairy farms were surveyed and therefore our data is not a reflection of the Chilean dairy production.

Overall, results from this study can be used to identify key managements that could improve calves' rearing productive traits but caution must be paid as our data does not represent Chilean dairy production systems. For example, farmers should reduce barn-stocking rate, supervise pens disinfection and cleanliness, avoid humidity of bedding, measure colostrum quality, supply colostrum artificially, improve management of automatic feeding systems and implement a clinical protocol to monitor calves' health.

ACKNOWLEDGEMENTS

This research was funded by Comisión Nacional de Ciencia y Tecnología (CONICYT), grant number REDI170084. The authors declare no conflict of interest.

REFERENCES

Abuelo, A., Havrlant, P., Wood, N., & Hernandez-Jover. M. (2019). An investigation of dairy calf management practices, colostrum quality, failure of transfer of passive immunity, and occurrence of enteropathogens among Australian dairy farms. *Journal of Dairy Science, 102*(9), 8352-8366. https://doi.org/10.3168/jds.2019-16578

Babu, L. K., Pandey, H., Patra, R. C., & Sahoo, A. (2009). Hemato-biochemical changes, disease incidence and live weight gain in individual versus group reared calves fed on different levels of milk and skim milk. *Animal Science Journal*, *80*(2), 149-156. https://doi.org/10.1111/j.1740-0929.2008.00620.x

Bach, A., Juaristi, J. L., & Ahedo, J. (2006). Growth effects of regrouping dairy replacement heifers with lighter weight and younger animals. The *Proffesional Animal Scientist*, *22*(4), 358-361. https://doi.org/10.15232/S1080-7446(15)31120-7

Barry, J., Bokkers, E. A. M., Berry, D. P., de Boer, I. J. M., McClure, J., & Kennedy, E. (2019). Associations between colostrum management, passive immunity, calf-related hygiene practices, and rates of mortality in preweaning dairy calves. *Journal of Dairy Science, 102*(11), 10266-10276. https://doi.org/10.3168/jds.2019-16815

Benetton, J. B., Neave, H. W., Costa, J. H. C., von Keyserlingk, M. A. G. & Weary, D. M. (2019). Automatic weaning based on individual solid feed intake: Effects on behavior and performance of dairy calves. *Journal of Dairy Science*, *102*(6), 5475-5491. https://doi.org/10.3168/jds.2018-15830

Buczinski, S., Gicquel, E., Fecteau, G., Takwoingi, Y., Chigerwe, M., & Vandeweerd, J. M. (2018). Systematic review and meta-analysis of diagnostic accuracy of serum refractometry and brix refractometry for the diagnosis of inadequate transfer of passive immunity in calves. *Journal of Veterinary Internal Medicine, 32*(1), 474-483. https://doi.org/10.1111/jvim.14893

Calderón-Amor, J., & Gallo, C. (2020). Dairy calf welfare and factors associated with diarrhea and respiratory disease among Chilean dairy farms. *Animals 10*(7), 1115.

Carvalho, M. R., Peñagaricano, F., Santos, J. E. P., DeVries, T. J., McBride, B. W., & Ribeiro, E. S. (2019). Long-term effects of postpartum clinical disease on milk production, reproduction, and culling of dairy cows. *Journal of Dairy Science*, *102*(12), 11701-11717. https://doi.org/10.3168/jds.2019-17025

CASEN. (2018). *Síntesis de resultados. Educación. Casen 2017*. http://observatorio.ministeriodesarrollosocial.gob.cl/casen-multidimensional/casen/docs/Resultados_educacion_casen_2017.pdf

Chang'a, J. S., Mdegela, R. H., Ryoba, R., Løken, T., & Reksen, O. (2010). Calf health and management in smallholder dairy farms in Tanzania. *Tropical Animal Health and Production*, *42*(8), 1669-1676. https://doi.org/10.1007/s11250-010-9619-x

Consorcio Lechero. (2019). *Sector Lácteo de Chile - Indicadores 2018*. Consorcio Lechero.

Costa, J. F. D. R., Novo, S. M. F., Baccili, C. C., Sobreira, N. M., Hurley, D. J., & Gomes, V. (2017). Innate immune response in neonate Holstein heifer calves fed fresh or frozen colostrum. *Research in Veterinary Science* 115, 54-60. https://doi.org/10.1016/j.rvsc.2017.01.008

Cuttance, E. L., Mason, W. A., McDermott, J., Laven, R. A., McDougall, S., & Phyn, C. V. C. (2017). Calf and replacement heifer mortality from birth until weaning in pasture-based dairy herds in New Zealand. *Journal of Dairy Science*, *100*(10), 8347-8357. https://doi.org/10.3168/jds.2017-12793

Diao, Qy., Zhang, R., & Tu, Y. (2017). Current research progresses on calf rearing and nutrition in China. *Journal of Integrative Agriculture*, *16*(12), 2805-2814. https://doi.org/10.1016/S2095-3119(17)61767-2

DMC (2020). *Anuario climatológico 2019*. Dirección General de Aeronáutica Civil, Dirección Meteorológica de Chile, Subdepartamento Climatología y Meteorología Aplicada .

Dobos, R., McPhee, M., Ashwood, A., & Alford, A. (2001). A decision support tool for the feeding and management of dairy replacement heifers. *Environmental Modelling and Software*, *16*(4), 331-338. https://doi.org/10.1016/S1364-8152(01)00009-3

Geiger, A. J., Parsons, C. L. M. & Akers, R .M. (2016). Feeding a higher plane of nutrition and providing exogenous estrogen increases mammary gland development in Holstein heifer calves. *Journal of Dairy Science*, *99*(9), 7642-7653. https://doi.org/110.3168/jds.2016-11283

Godden, S. M., Lombard, J. E. & Woolums, A. R. (2019). Colostrum management for dairy calves. *Veterinary Clinics of North America - Food Animal Practice 35*(3), 535-556. https://doi.org/10.1016/j.cvfa.2019.07.005

Heinrichs, A. J. (1993). Raising dairy replacements to meet the needs of the 21st century. *Journal of Dairy Science*, *76*(10), 3179-3187. https://doi.org/10.3168/jds.S0022-0302(93)77656-0

Hänninen, L., Hepola, H., Rushen, J., de Passillé, A. M., Pursiainen, P., Tuure, V. M, & Saloniemi, H. (2003). Resting behaviour, growth and diarrhoea incidence rate of young dairy calves housed individually or in groups in warm or cold buildings. *Acta Agriculturae Scandinavica Section A - Animal Science, 53*(1), 21-28. https://doi.org/10.1080/09064700310002008

Instituto Nacional de Estadísticas (INE). (2007). *Censo Agropecuario 2007, Base de microdatos*. Instituto Nacional de Estadísticas.

Instituto Nacional de Estadísticas (INE). (2015). *Encuesta de Ganado Bovino 2015*. Departamento de Estadísticas Económicas Subdepartamento de Estadísticas Agropecuarias. Instituto Nacional de Estadísticas.

Keim, J. P., López, I. F., & Balocchi, O. A. (2015). Sward herbage accumulation and nutritive value as affected by pasture renovation strategy. *Grass and Forage Science 70*(2), 283-295. https://doi.org/10.1111/gfs.12115

Lateur-Rowet, H. J., & Breukink, H. J. (1983). The failure of the oesophageal groove reflex, when fluids are given with an oesophageal feeder to newborn and young calves. *Veterinary Quaterly 5*(2), 68-74. https://doi.org/10.1080/01652176.1983.9693874

Lee, R. B., Besser, T. E., Gay, C. C., & McGuire, T. C. (1983). The influence of feeding colostrum on IgG concentrations acquired by calves. *Proceedings of the 4th International Symposium on Neonatal Diarrhea,* VIDO, Saskatoon, Saskatchewan, Canada.

Machado, V. S., Celestino, M. L., Oliveira, E. B., Lima, F. S., Ballou, M. A., & Galvão, K. N. (2020). The association of cow-related factors assessed at metritis diagnosis with metritis cure risk, reproductive performance, milk yield, and culling for untreated and ceftiofur-treated dairy cows. *Journal of Dairy Science, 103*(10), 9261-9276. https://doi.org/10.3168/jds.2020-18643

Mahendran, S.A., Wathes, D.C., Booth, R.E., & Blackie, N. (2022). A survey of calf management practices and farmer perceptions of calf housing in UK dairy herds, *Journal of Dairy Science*, *105*(1), 409-423. https://doi.org/10.3168/jds.2021-20638

Margerison, J. K., Robarts, A. D. J., & Reynolds, G. W. (2013). The effect of increasing the nutrient and amino acid concentration of milk diets on dairy heifer individual feed intake, growth, development, and lactation performance. *Journal of Dairy Science*, *96*(10), 6539-6549. https://doi.org/10.3168/jds.2012-6489

Medrano-Galarza, C., LeBlanc, S. J., DeVries, T. J., Jones-Bitton, A., Rushen, J., Passillé, A. M., & Haley, D. B. (2017). A survey of dairy calf management practices among farms using manual and automated milk feeding systems in Canada. *Journal of Dairy Science*, *100*(8), 6872-6884. https://doi.org/10.3168/jds.2016-12273

Mee, J. F. (2008). Newborn Dairy Calf Management. *Veterinary Clinics of North America - Food Animal Practice*, *24*(1), 1-17. https://doi.org/10.1016/j.cvfa.2007.10.002

Mohd Nor, N., Steeneveld, W., Mourits, M. C. M., & Hogeveen, H. (2015). The optimal number of heifer calves to be reared as dairy replacements. *J Dairy Sci* 98, 861-871.

Moran, J. (2002). *Calf rearing: a practical guide*. Landlinks Press.

Murray, C. F, Fick, L. J., Pajor, E. A., Barkema, H. W., Jelinski, M. D., & Windeyer, M. C. (2015). Calf management practices and associations with herd-level morbidity and mortality on beef cow-calf operations. *Animal, 10*(3), 468-477. https://doi.org/10.1017/S1751731115002062

Nordlund, K. V., & Halbach, C. E. (2019). Calf barn design to optimize health and ease of management. *Veterinary Clinics of North America - Food Animal Practice*, *35*(1), 29-45. https://doi.org/10.1016/j.cvfa.2018.10.002

Odepa (2021). *Boletín de la leche: avance de recepción y elaboración de la industria láctea.* https://www.odepa.gob.cl/publicaciones/boletin-de-la-leche-avance-de-recepcion-y-elaboracion-de-la-industria-lactea

Pempek, J. A., Schuenemann, G. M., Holder, E., & Habing, G. G. (2017). Dairy calf management - A comparison of practices and producer attitudes among conventional and organic herds. *Journal of Dairy Science*, *100*(10), 8310-8321. https://doi.org/10.3168/jds.2017-12565

Probo, M., Pascottini, O. B., LeBlanc, S., Opsomer, G., & Hostens, M. (2018). Association between metabolic diseases and the culling risk of high-yielding dairy cows in a transition management facility using survival and decision tree analysis. *Journal of Dairy Science*, *101*(10), 9419-9429. https://doi.org/10.3168/jds.2018-14422

Raboisson, D., Mounié, M., & Maigné, E. (2014). Diseases, reproductive performance, and changes in milk production associated with subclinical ketosis in dairy cows: A meta-analysis and review. *Journal of Dairy Science*, *97*(12), 7547-7563. https://doi.org/10.3168/jds.2014-8237

Reiten, M., Rousing, T., Thomsen, P. T., Otten, N. D., Forkman, B., Houe, H., Sørensen, J. T., & Kirchner, M. K. (2018). Mortality, diarrhea and respiratory disease in Danish dairy heifer calves: Effect of production system and season. *Preventive Veterinary Medicine* 155, 21-26. https://doi.org/10.1016/j.prevetmed.2018.04.007

Renaud, D. L., Steele, M. A., Genore, R., Roche, S. M., & Winder, C. B. (2020). Passive immunity and colostrum management practices on Ontario dairy farms and auction facilities: A cross-sectional study. *Journal of Dairy Science*, *103*(9), 8369-8377. https://doi.org/10.3168/jds.2020-18572

Ribeiro, E. S., & Carvalho, M. R. (2017). Impact and mechanisms of inflammatory diseases on embryonic development and fertility in cattle. *Animal Reproduction*, *14*(3), 589-600. http://dx.doi.org/10.21451/1984-3143-AR1002

Roche, J. R., Berry, D. P., Bryant, A. M., Burke, C. R., Butler, S. T., Dillon, P. G., Donaghy, D. J., Horan, B., Macdonald, K. A., & Macmillan, K. L. (2017). A 100-year review: A century of change in temperate grazing dairy systems. *Journal of Dairy Science*, *100*(12), 10189-10233. https://doi.org/10.3168/jds.2017-13182

Roth, B. A., Keil, N. M., Gygax, L., & Hillmann, E. (2009). Influence of weaning method on health status and rumen development in dairy calves. *Journal of Dairy Science*, *92*(2), 645-656. https://doi.org/10.3168/jds.2008-1153

SAG (2019). Crea el sistema de control oficial de comercialización y uso de anabólicos con fines de promoción del crecimiento en bovinos. Resolución 4254 EXENTA. Servicio Agrícola y Ganadero. http://normativa.sag.gob.cl/Publico/Normas/DetalleNorma.aspx?id=1105737

Santman-Berends, I. M. G. A., Buddiger, M., Smolenaars, A. J. G., Steuten, C. D. M., Roos, C. A., Van Erp, A. J., & Van Schaik, G. (2014). A multidisciplinary approach to determine factors associated with calf rearing practices and calf mortality in dairy herds. *Preventive Veterinary Medicine*, *117*(2), 375-387. https://doi.org/10.1016/j.prevetmed.2014.07.011

Schuenemann, G. M., Bas, S., Gordon, E., & Workman, J. D. (2013). Dairy calving management: Description and assessment of a training program for dairy personnel. *Journal of Dairy Science*, *96*(4), 2671-2680. https://doi.org/10.3168/jds.2012-5976

Silper, B. F., Lana, A. M. Q., Carvalho, A. U., Ferreira, C. S., Franzoni, A. P. S., Lima, J. A. M., Saturnino, H. M., Reis, R. B., & Coelhom, S. G. (2014). Effects of milk replacer feeding strategies on performance, ruminal development, and metabolism of dairy calves. *Journal of Dairy Science, 97*(2), 1016-1025. https://doi.org/10.3168/jds.2013-7201

Sischo, W. M., Moore, D. A., Pereira, R., Warnick, L., Moore, D. L., Vanegas, J., Kurtz, S., Heaton, K., Kinder, D., Siler, J., & Davis, M. A. (2019). Calf care personnel on dairy farms and their educational opportunities. *Journal of Dairy Science*, *102*(4), 3501-3511.

Soberon, F., Raffrenato, E., Everett, R. W., & Van Amburgh, M. E. (2012). Preweaning milk replacer intake and effects on long-term productivity of dairy calves. *Journal of Dairy Science 95*(2), 783-793. https://doi.org/10.3168/jds.2011-4391

Staněk, S., Zink, V., Doležal, O., & Štolc, L. (2014). Survey of preweaning dairy calf-rearing practices in Czech dairy herds. *Journal of Dairy Science*, *97*(6), 3973-3981. https://doi.org/10.3168/jds.2013-7325

Sumner, C. L., von Keyserlingk, M. A. G., & Weary, D. M. (2018). How benchmarking motivates farmers to improve dairy calf management. *Journal of Dairy Science*, *101*(4), 3323-3333. https://doi.org/10.3168/jds.2017-13596

Svensson, C., & Liberg, P. (2006). The effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. *Preventive Veterinary Medicine 73*(1), 43-53. https://doi.org/10.1016/j.prevetmed.2005.08.021

Svensson, C., Linder, A., & Olsson, S. O. 2006. Mortality in swedish dairy calves and replacement heifers. *Journal of Dairy Science*, *89*(12), 4769-4777. https://doi.org/10.3168/jds.S0022-0302(06)72526-7

Tautenhahn, A., Merle, R., & Müller, K. E. (2020). Factors associated with calf mortality and poor growth of dairy heifer calves in northeast Germany. *Preventive Veterinary Medicine* 184, 105154. https://doi.org/10.1016/j.prevetmed.2020.105154

Toro-Mujica, P., Vera, R., Pinedo, P., Bas, F., Enríquez-Hidalgo, D., & Vargas-Bello-Perez, E. (2020). Adaptation strategies based on the historical evolution for dairy production systems in temperate areas: A case study approach. *Agricultural Systems, 182*, 102841. https://doi.org/10.1016/j.agsy.2020.102841

Turini, L., Conte, G., Bonelli, F., Sgorbini, M., Madrigali, A., & Mele, M. (2020). The relationship between colostrum quality, passive transfer of immunity and birth and weaning weight in neonatal calves. *Livestock Science, 238*, 104033. https://doi.org/10.1016/j.livsci.2020.104033

Vasseur, E., Rushen, J., de Passillé, A.M., Lefebvre, D., & Pellerin, D. (2010). An advisory tool to improve management practices affecting calf and heifer welfare in dairy farms. *Journal of Dairy Science*, *93*(9), 4414-4426. https://doi.org/10.3168/jds.2009-2586

Weaver, D. M., Tyler, J. W., VanMetre, D. C., Hostetler, D. E., & Barrington, G. M. (2020). Passive transfer of colostral immunoglobulins in calves. *Journal of Veterinary Internal Medicine*, *14*(6), 569-577. https://doi.org/10.1111/j.1939-1676.2000.tb02278.x